FRAMING IN THE WILD:
EXPRESSIONS OF DECISIONS IN REAL-WORLD SITUATIONS

by

Lelyn Duane Saner

Bachelor of Science, Eastern Mennonite University, 1995

Master of Arts, George Mason University, 2001

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This dissertation was presented

by

Lelyn Duane Saner

It was defended on

March 18, 2008

and approved by

Kevin D. Ashley, Professor, Intelligent Systems

William M. P. Klein, Associate Professor, Psychology

John M. Levine, Professor, Psychology

Dissertation Advisor: Christian D. Schunn, Associate Professor, Psychology

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Lelyn Duane Saner, Ph.D.

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An important phenomenon in the study of behavioral decision-making is the surprising finding that people who are given choices framed in positive vs. negative terms exhibit different preferences. This study focused on a newer question: what factors influence the selection of frames by decision-makers? The development of a decision frame that has positive or negative overall value is a process that can be influenced by a number of factors. Several theoretical approaches to decision-making were examined with respect to making predictions regarding factors that would influence frame selection: mental accounting, task complexity, mental workload, expertise, regulatory focus, and message formulation goals. Predictions were extrapolated from each of these approaches and tested with data from a real-world decision-making situation - planning conversations from a set of NASA mission control meetings. The planning statements were transcribed and coded for frame selection and other behavioral/situational elements that were predicted to be related to frame selection. Mental accounting was not found to be related to frame selection. A predominance of positive framing, along with minimal use of negations, provided some support for the influence of positive expression bias. There was also evidence for aspiration mode impacting the selection of frame. The strongest predictor of frame selection, however, was an increase in expertise that occurred over the course of the mission. Between early and late mission phases, there was a significant decrease in positive framing, and this decrease interacted with task complexity. Based on these

results, the hypothesis was proposed that decision-makers use opportunities for action as a means to frame decisions.

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1.0 INTRODUCTION

People use representations for many aspects of decision-making. They look at photographs to make judgments about what really happened in a situation. They study graphs to determine what the trends in their capital returns have been, and to predict the future direction of their investments. They gather opinions from several people about which brand is the best before purchasing a product, and sometimes their decision hangs on a single turn of phrase that happens to strike a chord. One major area of psychological research is directed toward understanding the different ways people use representations and what the effects of using one representation as opposed to another will be. For this study, the question of interest is that of how representations are generated in the first place.

There are different classes of representations. The examples referred to above (i.e. photographs and graphs) are visual representations of information that are presented in the decision maker's environment, and there has been much research on how those types of representations are utilized (Pinker, 1981; Kleinmuntz & Schkade, 1993; Tufte, 1997; Trickett, Fu, Schunn, & Trafton, 2000; Schunn, Saner, Kirschenbaum, Trafton, & Littleton, 2007). Verbal descriptions (e.g. having people describe their opinion of something) are another class of external representations that provide information in a different format. This investigation will focus on mental representations, the information structures that reside in people's minds when they make decisions. These internal representations are referred to as *decision frames*, and the influence of decision frame on choice is well documented.

1.1 DECISION FRAME AS REPRESENTATION

In general, a *framing effect* occurs when a significant shift of preference results from a change in the way a choice is expressed. The effect of framing on choice is an important phenomenon in behavioral decision making theory. It has motivated a great deal of research and serves as a prime example of how human behavior violates the assumptions of normative rational theory (Von Neumann & Morgenstern, 1947; Savage, 1954). In the traditional laboratory demonstrations, participants are presented with a decision situation and the outcomes of two alternatives. They then choose which of the alternatives they prefer. The most common example is the "Asian disease problem," where participants are told that there will be an outbreak of an unusual disease and that it is expected to kill 600 people (Tversky & Kahneman, 1981; Kahneman & Tversky, 2000). In one condition, participants are asked to decide between Program A, which says that "200 people will be saved", and Program B, where "there is a one-third probability of saving all 600 people and a two-thirds probability that no one will be saved." In another condition, participants are asked to decide between Program C, which says that "400 people will die," and Program D, where "there is a one-third probability that no one will die and a two-thirds probability that 600 people will die."

By expected utility theory, the programs in each pair are mathematically equivalent to each other. Because of this equivalence, the observation of systematic preferences among participants between these programs is a surprising finding. It suggests that people are unaware that there is no effective difference between the programs and that the utilities of each of the two programs are evaluated differently. That result led to the emergence of subjective expected utility theory. Even more unexpected is that in the first condition, where outcomes are framed positively (lives saved), the majority of participants selected Program A (the sure thing), while in the second condition, where negative framing (lives lost) is used, the majority preference is for the "risky" Program D. This response pattern suggests that something in the way the alternatives are described leads to a reversal in preference from risk-aversion to risk-seeking attitudes. More importantly, because the description is independent of the values of outcomes, normative accounts are insufficient to explain the effect. There would appear to be something more psychological going on.

Much of the research that has been done on framing has focused on tracking the impact of particular frames on particular choices or expressed preferences. The pattern of risk aversive preferences under positive framing and risk seeking preferences under negative framing has been supported under a number of methods, such as within-subjects designs (Maule, 1989) and elicitations of rationales for choices (Miller & Fagley, 1991). The results of these studies provide strong support for the hypothesis that the way decision problems are expressed does indeed impact choice, and the evidence they provide serves as a starting point for considering other related questions.

Rather than continuing to study the framing effect (the effect of a given frame on decision making), the primary focus of this investigation is on the psychological process of <u>framing</u>; how is a *frame itself* selected (Fischhoff, 1983; Payne, Bettman, & Johnson, 1992) and how can we predict the selection of a particular frame (McKenzie, 2004)? If there is a large effect of framing on decision-making and the real world involves problem solvers selecting their own frames, then the question of how decision makers select frames becomes pragmatically and theoretically important. The pragmatic importance is obvious. But the theoretical importance is subtler. First, if the mental constructs that people use for decision-making are derived differently when people do it themselves than they are when people are presented with externally manipulated frames, then research that manipulates only external constructs may have misrepresented phenomena. The manipulated objects and the theoretically intended resulting frames may not correspond well with the objects people naturally operate on and the resulting "real" frames. Second, the ways in which people choose frames may be related to the factors that cause the framing in the first place (as shall be shown in detail below), and thus phenomena related to frame choice may further inform theories of the framing effect.

1.2 THEORETICAL APPROACHES TO DECISION FRAMING AND REPRESENTATION

In order to address the question of which influences are most significant, this analysis drew upon research from several connected, but relatively distinct aspects of psychological activity. It is important to note that no formal theories have directly been developed for predicting frame choice in the past. Strong theories should be generative, making useful predictions in new situations. There are a variety of decision-making theories that have logical implications for frame choice, however extrapolation in the social sciences is a risky affair. The assumptions and predictions of the theoretical approaches that will be reviewed are being pushed some to see how they manifest in a real-world decision situation. It should not be surprising if many of the theories make initial predictions for frame choice that are not upheld empirically.

The first section of this review will examine some of the definitions of framing that have been suggested and specify the definition that will be important in this particular analysis. A conceptual structure will be proposed for how the elements that are suggested by each theory can be integrated into an overall decision frame. Subsequent sections examine different groups of theories that will make different predictions for how frames are chosen. The second section will focus on behavioral economics approaches to decision framing, represented by prospect and mental accounting theories. This level of psychological inquiry places a particular emphasis on how people code decision problems and on how positively and negatively valued aspects of the decision are grouped or distributed as a result. The third section will look at several general theoretical approaches to the study of reasoning and the factors that influence it; in particular theories of cognitive workload and biases toward positive information. The primary emphasis with respect to reasoning will be on how information about positive and negative aspects of alternatives is formulated. The fourth section will consider the motivational level of behavior, in terms of regulatory focus theory. The emphasis at this level of behavior is on how people derive positive and negative value in the decision based on how possible actions are related to expected outcomes. The last section, then, will connect the different theoretical approaches examined in sections two, three, and four, providing several examples to illustrate how the framing process is being conceptualized for this research.

1.2.1 Defining the Decision Frame

This research deliberately goes beyond existing theories of decision-making, but in order to ensure that it is relevant, existing theories have been consulted for guidance on what elements to look for in the natural framing process. Two key assumptions drove this analysis. First, it was assumed that the decision representation and the decision frame are one and the same. The terms representation and frame will be used interchangeably from this point forth. Second, it was assumed that the primary purpose of the decision frame is to inform the decision maker about possible actions and what the consequences of each action are likely to be. As such, an effective representation from the decision maker's standpoint is one that increases the contrast between alternatives so that one clearly dominates over all the others.

The concept of decision frame was originally introduced by Tversky and Kahneman (1981), who pointed out that a decision frame is influenced partly by the way the decision problem is formulated, but it is also subject to the "norms, habits, and personal characteristics of the decision-maker." These influences span multiple levels of psychology (e.g. cognitive, affective, personality, etc.), and different studies of framing invariably focus on different components of the decision representation (Tversky & Kahneman, 1981; Kuhberger, 1998; Levin, Schneider, & Gaeth, 1998).

The original definition of "decision frame" was "the decision-maker's conception of the acts, outcomes, or contingencies associated with a particular choice" (Tversky & Kahneman, 1981). This definition notes directly that several elements can be part of the frame. The definition also implies that the frame can vary in its scope (i.e. how comprehensive it is). An example of an open-ended conception of the framing process is found in the work of Goldin, Ashley, & Pinkus (2006a, 2006b), who examined framing in the context of professional ethics decision-making. They observed that a case or problem is framed by first introducing a set of labeled concepts that pertain to the situation, which may be defined or applied in some way, and then by adding constraints to the problem description to show how the concepts apply to the issue at hand. The ways that frames are manipulated in many studies of framing effects, however, reveals that most manipulations are reducible to changing the positive or negative valence of the information given. That was the conclusion of Levin, et al. (1998) after reviewing a large number of framing studies. They note that, although different aspects of the decision may be framed, in most studies when framing is manipulated, the changes that are made between given formulations are designed to induce either positive or negative semantic associations in the mind of the decision-maker. They refer to these manipulations as “valence” framing.

One thing that is common to all studies of framing effects is that, regardless of how the description of the problem is manipulated, an effect of framing can only be measured when the *choice* is the same in all of the different expressions. In other words, it has to be the same problem: the expected payoff value of each alternative must be maintained, even when the terminology for describing it is altered. This research, however, is not designed to measure framing effects. The goal here is only to determine whether people prefer positive or negative valence for expressing their options and to determine what predicts their selection of expression. Therefore, my definition of decision framing, and the one upon which this research rests, is that framing to *express one or more elements of a decision problem in terms of either positive or negative information such that congruent semantic associations are created with related alternatives*.

1.2.2 The Decision Thought Schema

Because the general objective here is to predict the representations that decision makers will use, the definition of framing just stated suggests the information level (i.e. data structures used for cognition) as a possible starting point. Positive and negative valence can be manipulated at multiple places on the data structure, and as such, it is necessary to posit a structure in which multiple sources of valence can be integrated and shaped into a representation. The mechanism proposed here is the *decision thought*. In this schema, any action that can possibly be taken in the situation is viewed as an alternative to choose from, and the decision process is one of posing arguments for and against different alternatives until such time as an action is chosen for implementation. Any form of a decision-making process, whether it is cost-benefit analysis, deliberation, argumentation, or negotiation, will be influenced by both the unspoken thoughts of individuals and by verbalized forms of those thoughts that emerge in the statements that individuals make, regardless of whether the decision process is an individual or a group endeavor. As such, a *decision statement* is any decision-relevant statement made in the deliberation or dialogue surrounding a particular decision.

The verbal instantiation of a decision thought consists of a simple compound statement that connects a choice action with a consequence. Thoughts themselves are not always complete, however, especially when they are verbalized. Therefore, what is outlined here is a model of the ideal decision thought. It is a schema for a thought, with the major slots representing value-carrying elements that were derived from different theories of decision-making. The schema provides a basis for dissecting the verbal statements of decision makers into individually framed components (see Figure 1).

For a statement to be identified as a decision thought, at least two slots will need to be filled in a verbalized thought, such that there is some complete proposition made. The thought may be about a possible action by itself (e.g. We ought to do X.) or it may be about a general outcome or state of affairs (e.g. We might be able to avoid problem Y.) Outcomes can be further dissected into the attribute, which is some asset that can be gained or lost (Levin, et al., 1998) and the domain", which is the direction of change (positive or negative) in the attribute that is experienced (Kuhburger, 1995).

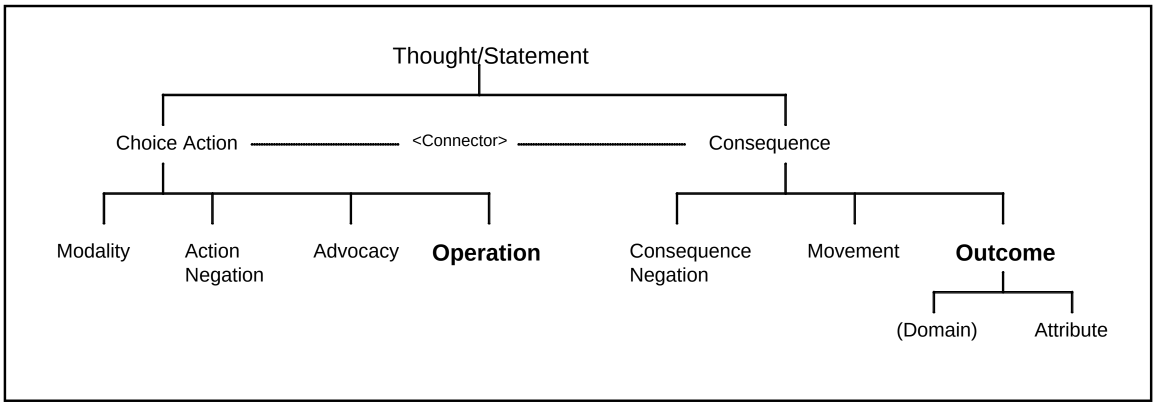

Figure 1. Hierarchical Diagram of Valence-Carrying Elements in a Decision Thought

Ideally the thought will be one that expresses a connection, or contingency (Tversky & Kahneman, 1981), between a considered action and what is likely to result from it (e.g. We ought to do X because we might be able to avoid problem Y.). For example, getting to work on time when driving yourself depends on what route you choose take, how fast you drive, etc. But getting there on time while taking the bus depends on you catching the right bus, how fast the bus driver drives, etc. Some variables may overlap between the options, but the contingencies between them will be different.

An instantiation of how this example decision, in terms of decision statements, would be diagrammed using the schema is presented on Table 1. A person may think or speak out loud the monologue, "If I wait for the bus, I will not get to my 10:00 AM meeting on time. I cannot drive, because then I have to pay for parking. I think I should bike to avoid traffic." Each statement is in a column where the words corresponding to different elements are aligned in the same row and some implied words are in parentheses. The connector is italicized because it really spans the whole statement. Often its words are placed between the action and consequence being connected, but in the case of "If/then" statements, part of the connector is included in both parts.

Table 1. Hypothetical Examples of Decision Statements

Element	Statement 1	Statement 2	Statement 3
Modality		I can	I should
Action Negation		not	
Advocacy			I think
Operation	I wait for the bus	drive	bike
<Connector>	*If (then)*	*because then*	*(in order) to*
Consequence Negation	not		
Movement	I will	I have to	avoid
Domain	get	pay	
Attribute	to my 10:00 AM appointment on time	for parking	traffic

Words and phrases are individual pieces of information, and when they are put together, statements are expressed on the computational level (i.e. processing of information) where plans for implementation of action are conceived. Statements also carry information back from the implementation level (i.e. feedback from the world: new constraints, prior outcomes, etc.) to be used for further computation. Decision frames evolve through this continuous exchange of information.

Kuhberger (1995) also provides a simple example of how information-level elements in combination can affect overall frame value. In his conception, the outcome can occur in either the ***domain*** of gains or the *domain* of losses, and a frame is set by asserting or negating a domain, such that the negation of a domain yields the opposite frame. As such, a positive frame can be set by either saying that a gain will occur (e.g. 200 people will live) or that a loss will not occur (e.g. 200 will not die). This distinction illustrates how the frame is an integrative assessment of the net gain or loss associated with the decision. The frame may be derived directly from given information or indirectly from transformations of information. A positive frame is directly apprehended from the "200 people will live." To see the positive frame of "200 people will not die," however, it is necessary to infer that 'will not die' *is equivalent to* 'will live.' In the example above, this inference must also be made to translate "will not get to (appointment)" into "will miss (appointment)." Another example of a transformation inference that might influence the frame is to recognize the complementary information that is not given directly (e.g. inferring that '200 people will live' *implies* that '400 will die/not live'). In other words, framing is not just a matter of how given information is expressed, but of whether complete information is given. Kuhberger (1995) found that modifying these aspects of formulation affected people's choice behavior, but he made no predictions about what formulations people would select to use on their own.

The elements in Figure 1 can be understood better by referring to some theories that have already used them. The elements were not pulled from a vacuum and the next three sections will therefore review several theoretical approaches with respect to what value-carrying elements are thought to influence the decision frame and when information is likely to be positive or negative. The decision thought schema will then be revisited to define the elements specifically and to situate them in the theories that first suggested them.

1.2.3 The Behavioral Economics Approach

One general aspect of selecting decision frames is choosing an appropriate level of specification for the representation. Any decision-making situation is going to require the decision maker to discern important from unimportant information and to integrate the important information in some way so that the decision can be made. The key question here is, how do people sort out and organize available information? Prospect theory appears to assume that what decision makers ultimately operate on at the point of choice is the information as it is presented. According to Thaler, Tversky, Kahneman, & Schwartz (1997) "… prospect theory does assume that people are passive in accepting the 'frames' or problem descriptions offered to them."

There are two aspects of the Thaler, et al. (1997) assumption that appear to be problematic. One problem is that the bulk of evidence that supports prospect theory has been derived from laboratory studies where the decision tasks involve very specific, systematic manipulations of the framing information. In these settings, the "offered" decision frame is part of the experimental control and thus easy to identify. In more natural settings where there is no experimental manipulation being done, however, the decision maker may be presented with any number of information sources to assist with making a choice, each of which will be framed in some way. Whether one views a product advertisement, or studies a "Consumer Reports" data table, or simply gets the opinion or advice of a friend, each of these will be framed a certain way, and each might be considered an "offered" frame for the decision in the situation. In other words, the first question that I raise here is whether people are "offered" frames in real-world situations in the same way that frames are offered in controlled laboratory studies.

The other problematic aspect of the Thaler, et al. (1997) assumption is the idea that "people are passive in accepting the frames offered to them." Research in cognitive psychology has repeatedly shown that mental representations mediate between stimuli and behavioral response, and more importantly, that mental representations are not equivalent to the information displayed at stimulus (Hayes & Simon, 1977). Mental representations are constructed using given information, but are also thought to include information drawn from the individual's semantic memory. He or she may ignore parts of presented information and potentially add other information that wasn't presented but which is judged to be relevant and important. There is also evidence that different representations carry different processing demands (Larkin & Simon, 1987) and that changing representations can lead to changed problem solving performance (Kaplan & Simon, 1990), just as changing a decision frame can change preference. The implication of these effects is that the construction of mental representations requires people to engage very actively in gathering and processing information before they can make a choice. A person's response to offered information is not passive and the *original presentation of information is* ***not*** *equal to the final representation*.

As it turns out, the passive reception assumption seems to conflict somewhat with the original conception of prospect theory as well, since Kahneman & Tversky (1979) actually did distinguish between two phases of decision making, editing and evaluation, that decision makers engage in. During the editing phase, a preliminary analysis of the alternatives is done in order to derive simpler representations of them, after which the edited alternatives are evaluated for value dominance in the second phase. In their exposition, Kahneman and Tversky identified six distinct editing operations (e.g. coding outcomes, simplifying probabilities, etc.) which they assumed would be "performed whenever possible." A theory of framing would have to be able to predict how decision makers use these operations to organize valence information.

In one of the few studies of framing itself, Fischhoff (1983) attempted to predict "three frames that reasonable individuals might impose on or derive from the decision problem." The framings that he compared were defined by the editing operations that produced them, but his results showed that all three frames were equally likely to be judged as "most natural" way of "thinking about" the problem. In other words, none of the editing operations that he used appeared to be preferable for deriving frames. Despite his mixed results, however, Fischoff's approach was one of the first attempts to predict selection of a decision *formulation*. The most critical limitation of the study was that the frames that were presented to participants were still pre-constructed, so that there was ultimately no measure of which formulations participants would have generated on their own.

Another approach to predicting framing in the context of prospect theory emerged in the work of Thaler (1985, 1999) on what he called "mental accounting." Thaler interpreted the prospect theory value function to make several predictions about when people perform certain coding operations. Thaler's general prediction was that people will attempt to compensate for loss aversion by "segregating gains" and "integrating losses." Since gains diminish in value as one moves away from the reference point, there is some compensation to be had from individually itemizing as many gains as possible. Focusing on the number of individual gains is one strategy for increasing the apparent amount of *overall* gain. For instance, one way to help make the "bike" alternative dominant in the earlier example is to explicitly note that you will save money on gas, save time by avoiding traffic, and have more route options to choose from (since the bike can go where the car cannot). Similarly, people are expected to "integrate smaller losses with larger gains," since a large gain on one attribute will overshadow the loss on another (e.g. "If I take the bike, I can't go as fast, but I will more than make up for it in being able to zip between stopped cars.”). The upshot of these predictions is that even though people will not be able to eliminate negative values from their representations completely, their goal will be to focus on the positives and they will use whatever strategies are available to maintain that focus.

Thaler’s predictions are applicable to predicting the number and valences of ***outcomes*** that people will naturally identify. Mental accounting theory, and other recent research (Harinck, Van Dijk, Van Beest, & Mersmann, 2007), indicates that positive information is more compelling than negative information. It is likely, therefore, that there will be a higher proportion of positively framed statements than negatively framed statements as a natural result of gain segregation.

Kahneman and Tversky (2000) presented another conception of decision representations in terms of accounts in which the psychological account refers to the scope of information included in the representation. Their prediction was that people are most likely to spontaneously use *topical accounts* to represent decisions. In contrast to comprehensive accounts, which include considerations beyond the immediate context, and minimal accounts, which involve only the individual features that differ between alternatives, a topical account is a relatively complete representation of just the immediate decision context. Kahneman and Tversky drew a parallel between topical accounts and basic-level cognitive categorization, noting that, just as basic-level categories are the default level of specification for characterizing elements of everyday experience, the topical account is the default level of detail for distinguishing individual acts and outcomes.

The mental accounts defined by Kahneman and Tversky actually provide a useful way to distinguish different levels of ***operations*** in choice actions. On a given day, a person is most likely to consider the actions that he or she can take to accomplish immediate goals, and this level of thinking is consistent with the topical account scope of consideration. Referring again to the example used earlier, describing one's alternatives as being to "take the bus", or to "drive", or to "bike" is to characterize these activities on a *basic level*. A person could also describe the goal at by saying, "I can go to work, and then I can pay my bills." However the truth of this statement does little to help the person decide on a mode of transportation. Instead, it serves better to contextualize the person's goal more comprehensively in considerations that go beyond the immediate task of getting to work, and thus refers to a *super-ordinate* representation of the activity. Similarily, to distinguish the component sub-steps of a basic-activity in order to specify the consequences of each step would be minimal account thinking. Driving to work will cost gas, time to find a parking spot, and money for parking. Biking will cost physical energy and more time, but allow more flexibility in where you can go. This shift to consideration of more detail corresponds to moving down to a *sub-ordinate* level of categorization in everyday activity. It is important to note that different decision making situations will inevitably have different possible operations available for generating and comparing alternatives, such that definitions of operation levels depend on the task at hand.

In sum, research in behavioral economics is generally concerned with the scope of information that people will include in their frame and how the outcomes that they decide to focus on will be encoded. With respect to outcomes, the motivation to minimize a sense of loss implies that people are most likely to identify and attend to positively framed outcomes. For characterizing operations, people are likely to focus on the actions that are most relevant to their immediate goals. The key question, however, is whether the level of characterization of operations is at all related to whether people refer more to positive outcomes or more negative outcomes.

1.2.4 The Reasoning Approach

A second general aspect of selecting decision frames is choosing an appropriate expression for the information in the representation. In standard laboratory practices, the pre-defined framings that are offered to participants almost always describe outcomes in terms of either gains or losses. One is presented with either gain-framed outcomes or loss-framed outcomes (depending on the condition one is in) and the frame is the same for all of the alternatives. In natural settings, though, the decision maker is free to select a mode of expression for evaluating outcomes that is not limited to one or the other exclusively. One may use positive, neutral, or negative terms as appropriate to one's construal of the situation. When there are multiple dimensions of the choice, and thus multiple outcomes, one may choose to evaluate some attributes of alternatives in terms of gains and others in terms of losses, using valences in combination. One may also choose to assess both the gains and the losses of a single attribute.

This ability to mix positive and negative information has at least two clear advantages. First, it permits the expression of trade-offs, wherein a greater gain on one attribute may compensate for a greater loss on a different attribute (Simonson & Tversky, 1992). A person's willingness to consider trade-offs depends on the situation and on the individual (Payne, Bettman, & Johnson, 1993), but when framing is pre-set and the participant is only allowed to express preference for one option, there is no opportunity for the decision-maker to verbalize any additional considerations that he or she may be entertaining with respect to the decision.

The second advantage of having multiple frames available is that it is easier for a decision-maker to maintain the coherence of a representation over the course of the decision process. The re-evaluation of elements based on new information, and potentially the changing of their framing, appears to be a natural tendency for people. Holyoak and Simon (1999, Simon

& Holyoak 2002) had undergraduate students do an initial evaluation of a set of legal arguments followed by a second evaluation after the facts of the case were presented. They found that the assessments shifted in relation to the verdict that participants generated throughout successive additions of information. This result suggests that editing of a representation is bidirectional, rather than linear, so that evaluations done and operations performed at one point in the process may lead one to modify evaluations done at an earlier point.

The flexibility in evaluating information positively or negatively is offset, however, by a high level of complexity in the natural world. In the natural world there is more information available for the decision maker to sift through. There are often more attributes to be considered and multiple strategies that one might use for evaluating and integrating dimensions of decisions. In laboratory studies the decision maker is presented with a finite set of available (consistently framed) alternatives, but rarely is the complete alternative set presented in the natural world. In addition, the outcomes of given alternatives along with the exact probabilities of their occurrence are presented in the laboratory and this information is not always fully available in the world either, such that the uncertainty associated with the decision may be increased.

These observations suggest that there may be positive or negative value associated with the *amount* of information available. On one hand, the larger amount of possibly relevant information is higher, which means that the processing workload placed on the decision maker is higher (Sweller & Chandler, 1994). On the other hand, the decision-maker is always faced with the possibility that the set of information that he or she chooses to consider is incomplete or partially incorrect. Assessments of value and risk could be wrong or a particular alternative may not yield all of the outcomes one would hope for.

With these possibilities added to the equation, decision-makers in natural settings also need strategies for testing hypotheses about what outcomes will result from each available course of action, since these will impact the frame as well (Trope & Bassok, 1982, 1983; Klayman & Ha, 1987, 1989). These dynamics illustrate the open-endedness of framing in the natural world and illustrate how the omnibus framing of a decision is not of singular origin, but rather more likely to be derived from multiple sources.

Cognitive Load: Cognitive load theory (Chandler & Sweller, 1991; Sweller & Chandler, 1994; Sweller, van Merrienboer, & Paas, 1998) makes several specific assumptions about how the complexity of a representation relates to workload and performance. Starting with demonstrated limitations on working memory capacity (Just & Carpenter, 1992; MacDonald, Just, & Carpenter, 1992), the theory predicts that the higher the number of elements that are relevant to a task, and the higher the degree of interactivity between these elements, the more taxed working memory will be on that task. The *intrinsic cognitive load* is the minimum necessary processing that is unavoidably associated with a task. In laboratory manipulations of frame, the level of intrinsic load varies with the complexity of the presented description of the decision. In the natural world, there is intrinsic load associated with the complexity of the task one is attempting to accomplish. In both cases, the intrinsic load is not something that the decision maker can change with any amount of framing, but the intrinsic load associated with the task complexity or an existing description may affect the framing of alternatives that are based on them.

At the same time, the decision maker can find ways to manage and adapt to the intrinsic load. Two methods that Sweller, et al. (1998) describe are to present either fully completed examples or partially completed problems to scaffold the process of solving a problem at hand.

Using these strategies requires consideration of the concrete particulars of the decision situation, but they are another approach to reaching a frame. The commuter might make the observation, "The bus always takes me 25 minutes to get to work, but the last time I biked, it only took me 20 minutes," such that recalling the outcome of the last episode of biking eliminates the need to estimate the outcome again for the framing of the current decision.

At the same time, whether or not there is a benefit to using existing data structures depends on a person's ability to apply them appropriately to specific cases. Such ability often comes only with training and expertise, and the advantages of expertise have been shown in many studies (Chase & Simon, 1973; Chi, Feltovich, & Glaser, 1981; Chi & Glaser, 1985). In a study conducted by Schunn, McGregor, and Saner (2005), expert and novice military officers were compared with respect to their application of leadership strategies. The officers were given scenarios describing situations that they might face in real command contexts and asked to describe how they would respond in the situation. Schunn, et al. found that the more experienced officers possessed a larger repertoire of strategies than novices did, that they selected the best strategies more frequently than novices did, and that they used those strategies more effectively (i.e. applied them more appropriately) than novices did. These results provide evidence from a natural world task that, when the intrinsic complexity of the task is high, it can be compensated for with increased experience.

Intrinsic cognitive load is unlikely to predict framing of any particular element because it is a product of overall complexity itself. However, intrinsic cognitive load must also be distinguished from *extraneous cognitive load,* which is what results from a sub-optimal representation of the task. In the laboratory, the decision maker has no more control over extraneous load than over the intrinsic load, but in the natural world extraneous load can be reduced when the decision maker selects decision frames with the appropriate formulation and level of detail.

<u>*Cognitive Economy*</u>: Because decision framing is primarily about the formulation of the representation for activating particular semantic associations, the cognitive economy of a frame is determined mainly by the relative simplicity of the expression and by the connotations of the ***attributes*** that are included (Galotti, 2007). As integral as they are to defining outcomes, there are so many factors that might affect the selection of attributes in a given situation that attempting to predict them is almost intractable. Sometimes key attributes will be dictated by the task, such as in the Asian disease problem. The decision-maker cannot ignore human life as an attribute because it is a common denominator to all of the alternatives.

It has also been shown that the selection and labeling of the attribute being framed (Goldin, Ashley, & Pinkus, 2006a, 2006b; Trope & Neter, 1994; Trope & Pomerantz, 1998) may be influenced by recent memories that are still active. For example, seeing a cup that was empty now filled to the halfway mark increases the likelihood that people will describe it as "half full" (McKenzie & Nelson, 2003). In addition, attribute labels themselves may be constraining (Paradis, 2000, 2001). Adjectives that are specifically used to denote valence opposition (e.g. good/bad vs. excellent/terrible) vary in what information is conveyed (absolute vs. relative valence, respectively). In any event, the selection and description of attributes is an important cognitive economic consideration. The commuter in the example could just as well consider taking a boat or a plane to work, especially since a plane is likely to be the *fastest* mode of transportation (on the speed attribute), however the values of these options on other attributes are likely to rule them out of consideration. Some semantic links are more natural and plausible than others, and the goal of the person doing the framing is to use the most useful and accessible meanings as possible.

Selecting appropriate attributes can help simplify the frame overall, but there are some more basic factors that help. One factor is that negative information is more difficult for people to cognitively process than positive information (Clark & Chase, 1972; Sherman, 1976). The more ***negations*** there are the more cognitive resources will be required to comprehend and utilize the representation. As such, it makes sense for decision-makers to choose representations that minimize negations, and when negations are necessary, to ensure that they will not be redundant. To take an example, it is easier to immediately comprehend the sentence, "I should NOT take the bus because I will NOT get to my appointment" than it is to immediately comprehend, "I should drive because otherwise it is NOT true that I will NOT be late." Both sentences involve two negations, but the second sentence involves a clearly redundant double negation that makes reading it awkward. Negations are also difficult to process because simply canceling two negatives will not necessarily yield an equivalent or true statement (i.e. "I should drive because I will be late."). Even individual terms, when negated, are not always interpreted as equivalently opposite (e.g. "*not wide*" does not equal "*narrow*", Paradis & Willners, 2006). As such, despite the theoretical plausibility of Kuhberger's (1995) hypothesis that negating a domain will yield the opposite frame, based on cognitive economy considerations, it seems more likely that people will assert actions and outcomes directly whenever possible.

One other way to simplify the frame is to limit the information one will consider. Research on hypothesis testing has shown that people generally focus mostly on positive information, despite other evidence that people are also interested in the diagnosticity of information when generating hypotheses (Trope & Bassok, 1982, 1983; McKenzie, 2004). In a general sense, it takes more effort to ensure that information is accurate, and this is even truer in conditions involving high cognitive load (Trope & Alfieri, 1997). In any case, although it may simplify cognition, limiting one's range of consideration to only positive cases reduces the likelihood of accuracy.

There are many theories in the literature on reasoning about what motivates peoples' bias for positive information, most of which are not directly relevant to this study (Wason, 1960; Evans, Barston, & Pollard, 1983; Klayman & Ha, 1987 & 1989; Oaksford & Chater, 1995; Evans, Clibbens, & Rood, 1996; Evans & Handley, 1999; Evans, 2002). However, in natural world settings where the outcomes of actions are not always known beforehand, every proposal of an alternative is essentially a proposal of a hypothesis about the link between action and outcome. The positive-test strategy involves a bias toward target events (Klayman & Ha, 1987 & 1989), but in this investigation the goal is to predict what people see as target formulations, not necessarily target alternatives. It may be that people will frame alternatives using courses of action that they believe will yield desired (target) outcomes (e.g. only consider the options that will definitely get one to work on time). Furthermore, if an optimal data selection bias is involved in framing (Oaksford & Chater, 1995), where information is sampled from prior experience, people may sample target outcomes from those already experienced to motivate the proposals, drawing them out of long-term memory if they are not already activated (a factor discussed earlier in this section). Because previously encountered outcomes already have a memory trace, it requires less search cost to draw upon them than to draw from the space of other hypothetically possible outcomes.

In sum, two major considerations are continuously traded off with each other in the reasoning process; effort and accuracy. Decision-makers have a need to know that their information is accurate, which they can get by testing hypothetical relations between acts and outcomes. Decision-makers also have a need for efficient cognitive processing, which is improved by keeping frames simple and by compensating for cognitive load.

1.2.5 The Motivations Approach

A third general aspect of selecting decision frames is ensuring that one's goals are appropriately addressed by the representation. An important feature of decision-making in natural world contexts is that the decision-maker generally holds stake in the decision. He or she is personally interested in both the outcome and the process by which the decision is made (Shah & Higgins 1997, 2001). Personal involvement can be increased to some degree in laboratory procedures by manipulating task factors or context factors as they are described by Payne, Bettman, and Johnson (1992), but the natural world typically offers decision-makers more freedom to fully express their assessment of each alternative and to explicate the motivation associated with their preferences (Frisch, 1993).

One limitation of laboratory studies is that they generally only measure *preference* for presented alternatives. Regardless of what response mode is offered for participants to express their preference with, it is assumed that the option that is chosen corresponds to what the decision maker would actually advocate if the situation were really encountered. However, because he or she is forced to respond in a certain way, the actual level of advocacy associated with an alternative is not measured.

Expressed preference does not always match behavioral action. In the natural world, decision-making is more than identifying which course of action one would prefer to take; it is about taking actions or not taking them, and then experiencing consequences (Rothman &

Salovey, 1997; Detweiler, Bedell, Salovey, Pronin, & Rothman, 1999). Hypothetical tasks often keep motivations, goals, and reasons hidden under the umbrella of stated preference. In the natural world, one is free to explain what one intends to do and defend a past action with a line of reasoning. It may be that one supports both or all of the available options to different degrees or that a single option is supported for one reason and discounted for another. In that case, demanding categorical preference for only one option fails to capture the full mental representation.

Message Framing: There is much evidence that motivational factors affect the evaluation of information as positive or negative. One means by which motivation is created and represented is through the use of rhetorical messages (Rothman, Salovey, Antone, Keough, & Martin,1993; Rothman & Salovey, 1997; Detweiler, Bedell, Salovey, Pronin, & Rothman, 1999). Framing informative messages motivates particular behavioral responses. According to Salovey and Williams-Piehota (2004), the framing of a message is determined by whether its emphasis is on the positive or negative consequences that will result from adopting or failing to adopt a particular behavior. The standard definitions describe a message as positively framed if it identifies the benefits associated with adopting a behavior and negatively framed if it points out the costs that will be incurred if the behavior is *not* adopted.

It is important to note, however, that these definitions assume the behavior in question to be a healthful one (i.e. that the action itself would naturally be evaluated as a *positive* action, such as using sunscreen, performing breast self-exams, etc.) Although it is not clearly addressed in the message framing literature, message framing can just as easily be done with unhealthy behaviors (e.g. smoking, engaging in unprotected sex, etc.). A message would still be positively framed if it points out the benefits of adopting a healthy behavior (e.g. using protection during sex decreases risk of STDs), but it would also be positively framed if it identifies the benefits of avoiding an unhealthy behavior (e.g. abstaining from unprotected sex reduces the risk of STDs). Similarly, negative framing would be accomplished by explicating the costs of either not adopting a healthy behavior or of adopting an unhealthy behavior (e.g. increased risk of STDs). The important point of this approach, however, is the observation that actions or behaviors themselves often have inherent value associated with them naturally.

It is also important to observe that messages that merely connect behaviors and consequences are not necessarily associated with particular ***advocacy***. Even if one intends for a message to persuade someone else to adopt a particular behavior, and even if the message does induce a behavior change, its effectiveness in this respect does not depend on explicit advocacy of the particular behavior. To say, “If you diet, you will lose weight” is, in itself, merely a statement of fact. When a person hears this message and forms their personal representation of the consequences, something within the representation motivates them to adopt or not to adopt the dieting behavior. It is only when the message is formulated in a form similar to “I suggest that you diet…” that there is advocacy included with the message. In a general sense, advocacy is more likely to be used when framing a statement for someone else (e.g. “I think you should take the bus.”). When an one frames an alternative for oneself, it will probably be implicit, if it is distinguishable from preference at all (e.g. “I think I should take the bus.”)

Advocacy of an action is also separable from the ***modality*** of the statement. Using the same example, “If you diet, you will lose weight” is an asserted possibility, but there are other modalities with which to frame the message. Actions can be presented as obligations (e.g. “I must take the bus if I want to ensure that I get there on time.”) or as aspirations (e.g. “Ideally I would walk in order to enjoy the beautiful day.”). In any event, the purpose of making these distinctions is to illustrate that, even if simply identifying the consequence itself motivates a person to pursue it, explicit advocacy and modality are additional levels of motivation that may be associated with the behaviors being suggested. It has also been shown that messages are even more persuasive when they are presented “in the field” (Salovey & Williams-Piehota; 2004). In other words, messages appear to have more power when they are presented in the same settings where decision-makers engage in the behaviors and have personal involvement with attitude objects.

Regulatory Focus: Another theory that focuses on the relationship between motivation and value is regulatory focus theory (Levine, Higgins, and Choi, 2000; Shah and Higgins, 2001; Higgins, Idson, Freitas, Spiegel, & Molden, 2003). As described by Brockner and Higgins (2001), regulatory focus theory posits two general foci of self-regulation processing that individuals can operate under. A person who is "promotion-focused" is motivated by growth and development tendencies. He or she is likely to exhibit strong desire to reach an ideal self and to pay attention to positive outcomes. By contrast, one who is "prevention-focused" is driven by a need for security. One is likely to make attempts at being who one thinks one ought to be and will likely pay greater attention to negative outcomes. These orientations may be chronic, such that they are persistent within individuals over long periods of time. They may also be temporarily induced by manipulation for purposes of performing a particular task, or more naturally, by environmental factors within a situation.

Shah and Higgins (1997) noted that goals are construed differently under different regulatory foci. Under a promotion focus, goals are construed as accomplishment or aspiration, but under a prevention focus, they are construed as duty or responsibility. They added that prevention focus is not just suppression of negative outcomes, but also an active pursuit of the positive outcome of security. As such, the two regulatory foci coincide with two different strategies for attaining desirable end states; either approach matches to them (accomplishment; promotion focus) or avoid mismatches to them (security; prevention focus). Higgins, et al. (2003) further clarified the features of these strategies, distinguishing between an “eager strategy” (ensuring “hits” and ensuring against “misses”) associated with promotion focus and a “vigilant strategy” (ensuring “correct rejections” and ensuring against “false alarms”) associated with prevention focus. The eager strategy involves a concern for what *will be gained by choosing* an alternative. In contrast, someone using a vigilant strategy is more concerned with *what will be lost by not choosing* an alternative.

There is a natural link between regulatory focus and peoples’ preferences for frames. But the biggest obstacle to using regulatory focus in this analysis is that it does not readily translate into verbal expression. The best measure of actual motivation related to regulatory focus is in the motivation mode that can be derived from the elements of modality and advocacy.

One remaining element in the decision statement schema, however, is referred to by both the message framing paradigm and regulatory focus theory; the ***movement*** toward or away from a particular outcome. Some outcomes are to be approached (e.g. getting to the appointment on time) and some outcomes are to be avoided (e.g. being late), but both can be used for framing alternatives. Neither theory sets out to predict when people will refer to approaching or avoiding in the framing of alternatives. The theories identify these tendencies as being important and were designed to predict when people actually would exhibit approach and avoidance behaviors.

1.2.6 The Rational Choice Approach

A final theoretical paradigm to consider, one that straddles the boundary between reasoning and motivational approaches, is that of rational choice (Selton, 2001; Kahneman, 2003). Although it is not a singular theory per se, the paradigm assumes that the probability of taking some action is a function of the payoff of the action minus the cost of taking it. Just as Oaksford and Chater (1995) applied this principle to information search, it can also be applied to representation selection because the choice of representation will affect the choice of action to be taken. With respect to having rhetorical goals when framing alternatives, the "payoff" for selecting one representation over another is if it leads to the action being implemented, especially in the context of group decision-making. As a result, regardless of what action is used to achieve the outcome, if using one frame (e.g. “I will be late”) increases the probability that an action will be taken more than the opposite frame (“I will be on time”) does, it is expected that that frame will be used more frequently. The next section will focus on integrating these theoretical approaches with each other. It will also revisit the decision-thought schema with respect to how the component elements of decision frames are connected between the theoretical approaches.

1.3 INTEGRATION OF THEORETICAL APPROACHES WITH RESPECT TO FRAME SELECTION

The boundaries between theories are often ill-defined and the preceding literature review was structured so as to address several theoretical approaches in three segments. The behavioral economics paradigm focused on the mental accounting of actions and outcomes. The reasoning literature addressed cognitive workload, complexity, and cognitive economy considerations in the formulation of frames. The motivation approach was concerned with the representation of actions and consequences. Each set of theories provided grounds for some of the elements in the decision-thought schema and it is now possible to formally define these component elements.

First, based on the earlier observation that framing as a process can have both broad and narrow conceptions, it seems reasonable to view framing as hierarchical in nature. The message-framing paradigm suggests the highest level of a decision thought. In order for a person to distinguish one alternative from another, a *choice action* must be connected in some way to a proposed *consequence*.

The hierarchy of valence emerges with the observation that neither the choice action nor the consequence is unitary. Each of these elements is comprised of several other more elementary value-carrying elements. Tversky and Kahneman's (1981) original definition of a decision frame ("the decision-maker's conception of the acts, outcomes, or contingencies associated with a particular choice") illustrates the core elements within both the choice action and the consequence. The "act" refers to the particular behavior or *operation* that will be implemented if the choice action is taken. The "*outcome*" refers to the objective event that will result from implementing the operation and the connectors used to denote the nature of the relationship between operations and their outcomes establish the "contingencies". Most importantly, however, is that operations and outcomes alone cannot be equated with choice actions and consequences. Each of these core elements must be combined with other elements.

First, with respect to the consequence, the identification of the "*domain*" as the valence of the change relative to a reference point was already discussed earlier (Kuhberger, 1995). The change is only observable with respect to some *attribute* of which a person can experience gaining, having, or losing some amount. Both of these elements (domain and resource) are components of the "outcome." For the sake of clarity and simplicity, however, the *outcome* will from this point forth be equivalent to the direction of change (i.e. domain).

Three value-carrying elements were introduced by the motivations paradigm. Two of them, the *modality* of the statement and the *advocacy* apply motivations specifically to the choice action. The modality indicates whether one is merely making a suggestion, identifying an imperative, etc. The advocacy indicates whether the person referring to the operation is personally in favor of implementing it or opposed to doing so. The third element, the *movement*, was suggested specifically in the message framing literature and is key to transforming the outcome into a consequence. The framing of the outcome describes an objective change in a resource, but whether that particular change will be a positive or a negative experience for the decision maker is dependent on the situation. The movement captures the fact that some outcomes are to be avoided (i.e. "moved" away from) and some are to be pursued (i.e. "moved" toward). When a movement is not specified, it is implied that the outcome will be experienced directly.

The remaining value-carrying element serves as a modifier of valence across multiple other elements in the decision thought, and that is *negation*. Performing a general logical function, negations reverse the valence of the elements next to them. In the decision-thought schema, there is a slot for negations in the action and a separate slot for negations in the consequence. The presence or absence of negations also affects the overall cognitive economy of the decision thought, as described earlier.

It is also important to note here that some of the factors discussed above as affecting the valence of the decision frame actually function on a higher level than the decision thought.

Cognitive load is not on the information level, nor is expertise. Load is a function of both the complexity of the decision thought expression and the general task complexity, and expertise is a function of practice with the task. Both factors are expected to affect the formulation of decision thoughts, but not in a way that is traceable to particular elements.

The diagram of the decision thought schema is reproduced here in Figure 2, and it illustrates the hierarchical breakdown of the elements just described. The criteria by which the elements can be recognized in spoken dialogue will be explained in the methods section. In a general sense, the process of framing is such that valences and evaluations combine into concepts and thoughts, which combine into messages and arguments, which are then combined again to construct mental models of the overall problem. The major advantage of this mechanism is that it shows how individual elements are integrated into local frames for propositions. As a result, the mechanism permits coding of representation on multiple levels of resolution, based on how much detail is available in verbalized decision-making speech.

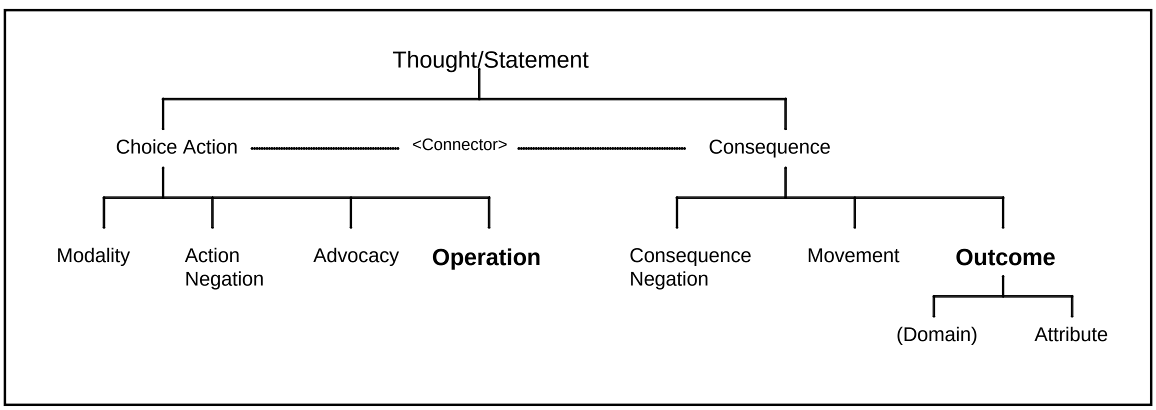

Figure 2. Hierarchical Diagram of Valence-Carrying Elements in a Decision Thought (Copied)

1.4 SUMMARY

Before describing the methods, a few more hypothetical examples may help to illustrate the interactivity between elements for creating positive and negative value. In the long run, value is ultimately relative to the goals of the decision maker. In the statement, "The terrain is likely to get more rough as we approach the crater's edge," the domain of the *outcome* is positively framed (i.e. "more"), but the *attribute* (i.e. "rough") carries with it a negative semantic association. This example also illustrates how real human speech must sometimes be reorganized to fit into the schema structure. The consequence was referred to before the choice action (i.e. "approach the crater's edge"), but the overall meaning of the statement was unchanged. The example also shows how positive and negative valences can be closely linked (e.g. "more rough") and need to be sorted out when using the representation.

In another example statement, the value of the outcome to the decision-maker is even more ambiguous; "If we wait until midday when the surface temperature rises, there will be a jump in wind speed." This statement refers to a consequence (i.e. increased wind speed) resulting from a change in the general situation status (i.e. increased surface temperature). Here, a naturally occurring event, outside of the decision makers' control, leads to a positively framed *outcome*, but the implied valence of the consequence cannot be determined directly from the statement. It may be positive if the situational goal is to observe a variety of atmospheric phenomena, in which case a unique shift in wind speed would be of scientific interest. If the goal in the situation is to avoid danger (e.g. of high winds), however, this outcome has negative associations for the decision-maker.

Both of these examples were presented to illustrate a key point. The decision thought does provide an externalized diagram of otherwise internal cognitive manipulations of valence.

What it does not specify, however, is the psychological function by which individual positives and negatives are integrated into an overall decision frame of positive or negative value. The decision thought schema serves as a grid upon which the values pertaining to a decision can be laid out. When this is done, the values of each decision thought element can be aggregated within and across decision thoughts. However, since aggregation is not the same as synthesis, the actual mechanism of integrating values cannot be captured in the decision thought construct. The integration may be as simple as a mental majority rule. By this mechanism, if there are more positively framed elements than negatively framed elements, the decision frame will be positive, and vice versa. It may also be that one framing has to dominate the other by some criterion ratio, or perhaps it is a more complex function. There may not even be a general integration algorithm, since values and preferences appear to be quite fluid in the human mind (Fischhoff, 2000).

In spite of this, support for the predictions made above can be derived from the patterns with which the key elements are used. Furthermore, although the scope of all of these specific predictions is limited to the formulation of individual decision thoughts, the construct also allows for analysis across multiple decision thoughts. Sequences of decision thoughts that are associated with a single choice permit the modeling of the omnibus global value (i.e. the overall decision frame) as it emerges over the time-course of the deliberation process. Every constraint that applies to the situation and needs to be considered can be itemized in its own statement. A single trade-off can be described using at least two statements. And while isolated reasons may require nothing more than specification of a consequence, a line of reasoning can be traced by following a contiguous set of individual thoughts that together form the arguments surrounding the decision.

2.0 METHODS

The approach of this research was to perform an analysis of an actual strategic planning process conducted in a real-world environment. In the context of this planning process, the stakes were real and high, and the courses of action decided upon were actually implemented. In addition, naturalistic settings are complex and peoples' selection of representations may be influenced from many directions.

The general methodology that was used for this research is one that Dunbar has termed "in-vivo," by way of analogy to methods used in life sciences (Dunbar & Blanchette, 2001). Dunbar and his colleagues observed that our canon of biology knowledge is the result of a combination of research methods. There are highly controlled laboratory experiments, referred to as "in-vitro" methods. In addition, a great deal has also been gained from doing ethnographic analyses of the natural activities of living organisms; methods which Dunbar terms "in-vivo." The in-vitro procedures allow for strong inferences to be made about the specific mechanisms of life processes. Using in-vivo methods in addition to them allows for an understanding of how those processes play out in the natural environments in which organisms live, thus keeping the theory grounded in the real world. A given study may only use one method or it may use both concurrently, but it is undeniable that our understanding of biology would be lower if both methods were not being used.

Much of Dunbar's work has involved a combination of in-vivo and in-vitro methods for studying human cognition in a similar way (Dunbar, 1995, 1997, 1999; Dunbar & Blanchette, 2001). His primary applications have been to the dynamics of scientific reasoning and more general reasoning by analogy. After making direct observations of reasoning mechanisms used by biologists in laboratory groups, follow-up experiments were conducted in the psychology laboratory to examine reasoning strategies in more detail. The goal was to see if scientists and science students performing simulated research design tasks would exhibit the same reasoning patterns that were observed in the field. Dunbar has cited several findings that were surprising relative to prior psychological theories in order to support his methodology choice. For example, based on in-vivo observations, certain types of analogies have been found to play a different role in scientific discovery than was previously thought (Dunbar, 1997).

Other researchers have employed in-vivo techniques as well. It has been applied to the reasoning of scientists in other topic areas, including neuroscience and astronomy (Trickett, Fu, Schunn, & Trafton, 2000). Another supporter of this approach is Hutchins, who has pointed out the value of in-vivo methods for understanding cultural influences on cognition (Hutchins, 1995; Hutchins & Hazlehurst, 1995, 2002) and who has applied it to human factors research as well (Hutchins, 2000). Hall and colleagues have studied theory-related discourse and the establishment of representation infrastructure among interdisciplinary collaborators (Hall, 1999; Hall, Stevens, & Torralba, 2002).

The literature on decision framing appears to be dominated by in-vitro studies of the framing effect. The intention of this research to provide the in-vivo counterpoint to them and to add to an increasing literature on the psychological processes involved in decision framing (Fischhoff, 1996).

2.1 THE SAMPLE

2.1.1 Overview of Mars Exploration Rover Mission

In the summer of 2003, the National Aeronautics and Space Administration (NASA) launched two vessels, each carrying a robot probe toward the planet Mars to begin a major planet surface exploration mission. These "Mars Exploration Rovers" (hereafter referred to as MERs) landed on the surface in February of 2004. The first to land was dubbed "Spirit," and it was followed twenty days later by "Opportunity," which landed on the other side of the planet. Each rover was intended to be fully operational for at least 90 Mars days, which were called "sols." That time frame, referred to as the nominal mission, has been far exceeded, however, since the rovers continued to run without fatal malfunction for over 1400 sols.

The goal of the mission was to collect as much data as possible about the surface conditions on the planet. The aspects that were of most interest were the weather patterns, the characteristics of the terrain, and the geological composition of surface material. The rovers are identical in construction. To accomplish the mission goals, each was equipped with solar panels for recharging power cells, six specialized scientific instruments, and several antennae with which to communicate with Earth.

The planning was done by teams of scientists from five areas of science who stayed onsite at the NASA Jet Propulsion Lab at the California Institute of Technology during the nominal mission. There were geologists, geochemists, mineralogists, atmospheric scientists, and NASA's long-term planning researchers. Every science group was represented by 8-10 scientists who ranged in experience from being graduate students in training to being tenured professors who were leaders in their fields. Many scientists worked on both MERs over the course of the mission. On any given sol, however, the scientists in each area were divided into sub-groups and exclusive interdisciplinary teams ran operations for each MER. Despite coming from very different domains of specialization, the scientists who participated in this exploration mission rapidly adopted a very successful planning process. It was the planning process that served as a sample of in-progress decision making for this research.

During the nominal mission, all rover operations, including driving, scientific analysis, communications, and maintenance were orchestrated through a daily sequence of three planning meetings and breakout planning sessions. The general sequence of events was fixed and repeated each day in keeping with a Mars sol schedule (Local Sol Time, LST). A large group meeting, where all of the science groups were represented, was held first thing in the morning to provide everyone with information on the status of the mission. Afterward, the members of the science groups met individually to develop their individual goals, which were then presented in the second large group meeting held in the early afternoon. The proposed activities were prioritized during a second period of breakout group discussion and then compiled into a conceptually sequenced plan in a third large group meeting. More detailed descriptions of the rover equipment and the sequence of meetings are presented in Appendix A.

2.1.2 MER Planning as a Decision Making Process

Research on decision-making involves a wide range of decision tasks and situations. It is therefore important to situate the Mars exploration mission within the spectrum of decision tasks. First, the Mars exploration mission was not a situation of simple choices between given alternatives. The primary task, in fact, was to generate the alternatives and outline the contingencies associated with them. There was an end-of-day deadline each sol for the scientists and engineers to have a plan as developed as possible; one comprised of a sequence of prioritized operations that filled the available time in the following sol. Final decisions were not often reached within the coded meetings on the courses of action to be taken because the specific choices that led to the plan were distributed across all of the scientists' interactions throughout the day. As such, the focus of analysis in this case was more on the reasoning about alternatives than on the choice between them.

Second, there was also a relatively well-defined set of resources (i.e. attributes) that could be gained or lost in the course of conducting operations that had to be considered when making decisions. Some of the resources were limited in quantity, which necessitated careful monitoring of their levels at all times. As an example, time was one critical resource and the meeting of scheduling constraints was an especially important part of the decision task. Some general engineering operations, as well as activities that were repeated every day (e.g. communication passes), could only occur during specific windows of time. Proposed scientific operations therefore had to fit neatly between those blocks which were determined a priori. As such, the task was in large part one of constraint satisfaction (Holyoak & Simon, 1999).

The third important feature of this decision task is that the reasoning process was not just that of a single individual and decisions were not made by individuals. In this context, the decision-making entity was a group of individuals, each of whom had their own preferences based on the information at hand. Decisions were reached by way of a consensus building process instead of a singular choice (Regenwetter, Kim, Kantor, & Ho, 2007), and the effects of framing were dispersed among the members of the group. All framed statements were generated by individual group members and were thus presented to the rest of the group. Therefore decision frames were never presented exactly the same to everyone from the outside, and the ability to reach consensus on decisions depended on imperfectly shared situation awareness of the group members.

Finally, inasmuch as this was a consensus building process, it was one that had to be accomplished by people who had very diverse knowledge backgrounds and different levels of experience within them. All of them shared the goal of wanting to collect as much data as possible on Mars. At the same time, it is possible that much of that desire was motivated by self-interest, that is, the motivation to advance their own sciences first. Consequently, the level of investment that individual science groups contributed to the collective planning may have been somewhat limited by the degree to which their discipline gained from the day's plan. Furthermore, the level of investment may have varied among individual members of groups. Those who had higher expertise would be more aware of the stakes; of what could be gained or lost with each component choice of activity.

In sum, this decision situation involved individual people participating in a group decision-making process. The participants came from different disciplinary backgrounds and even varied some in their level of expertise within their fields. Alternatives had to be generated before they could be decided on, but they were developed on the basis of a well-defined and well-understood set of relevant attributes. And in the context of these factors, a number of complicated individual decisions were made in order to produce a basic plan of operations for the rovers to complete.

2.2 DESIGN

On both MER missions (MER-A and MER-B), the large group meetings were video-recorded for a subset of the 90 sols of the nominal mission. There were recordings from 29 MER-A sols and from 25 MER-B sols. Some of these sols had two video records taken from different vantage points in the meeting room. The recordings were obtained by a team of human factors researchers whose visits to the site were spaced throughout the life span of the missions. Each visit lasted for several sols, such that recordings were obtained for consecutive planning cycles.

A sample of Science Downlink Assessment meetings was selected from this set of recordings to be analyzed in this study. The first criterion for selection was the audibility of the dialogue in the meeting, because that was the primary data for this research. The video cameras were placed in fixed locations around the meeting room, and occasional variations in microphone settings made some meetings too difficult to hear accurately.

The second criterion was contiguity of sols. Since the decision-making was a continuous process, it was possible for the actions and considerations of one sol to have an influence on the next sol. Scientists naturally used the findings from one sol to ground operations in the next sol. The goal was to find sets of three consecutive sols where the meetings were of sufficient quality. This would allow for analysis of such contingency between meetings. It would also make it easier to connect the actions that were considered with the actions that were actually implemented in the plan.

The third criterion for selection of meetings was their distribution across the mission lifetime (see Figure 6). As with any other activity done repeatedly, it was expected that the members of the planning staff would get better at their jobs over time. Such improvement would be evident in their ability to streamline the planning process logistics as well as in their knowledge of what they wanted to accomplish in a sol's activities. Decision making processes might change with experience in the mission or other contextual factors (e.g. urgency or uncertainty) that may vary over time. Therefore, meeting sets were specifically chosen so as to span between early stages and late stages of the nominal mission.

Finally, to control for effects of incidental differences between the missions, roughly half of the meetings were sampled from MER-A and half were sampled from MER-B. For each mission, some meetings were from early stages and some from later stages. It must be noted, however, that since the mission time lines were offset by approximately 20 sols, by the time the MER-B mission began, the staff already had 20 sols of experience with MER-A. To account for this, the early/late boundary was assessed relative to the total 110 sols of nominal mission activity (i.e. 90 + 20).

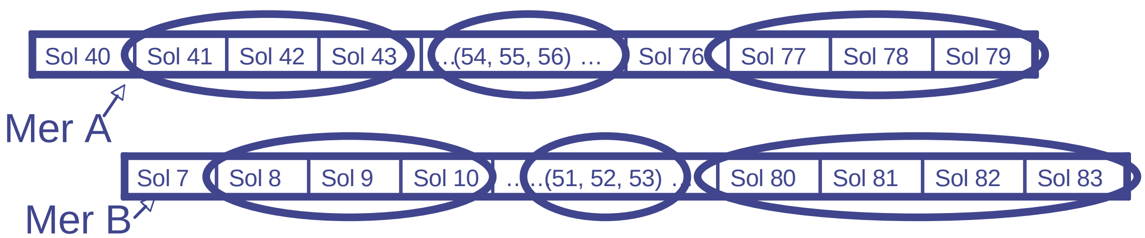

Figure 3. Sets of Sols for which Planning Meetings were Analyzed

2.3 PROCEDURE AND CODING

The selected planning meetings were transcribed from the video data. Small cameras had been placed around the edges of the large room where rover operations were conducted. At the beginning of the mission, each individual science group was given a planning station with an electronic whiteboard and a monitor for accessing the long-term plan outline. A camera was inconspicuously placed above the monitor in each group's area and was not salient to the scientists while they worked. The cameras remained fixed in those locations, and as a consequence, they did not move to follow who was speaking in the large group meetings. Because of this, it was not possible to do detailed analyses of speaker demographics. However, recurring voices within the audio stream did allow for some measure of continuity in the input of particular people.

As in many in-vivo studies, the analysis is essentially a verbal protocol analysis of the transcripts (Ericsson & Simon, 1993). There were 86,116 words across all of the transcripts. The transcripts were segmented into meaningful individual utterances and each utterance was given a code for each of the dimensions. This technique is commonly used for analyzing reasoning and problem-solving behavior. It is distinct from retrospective description of one's own mental behavior, which is often subject to distortion caused by people reflecting on their own thoughts. Instead, a recording of the thoughts that are verbalized while the cognitive task is being performed represents an external trace of the internal process, one that is relatively free of meta-cognitive editing. In this context, it is a group that completed the task, not an individual. As such, the transcripts reflected the working process of the group, a process that included both cognitive and social elements.

All of the data was independently coded by two trained coders. Several transcripts that were not included in the data set (also of science downlink assessment meetings) were used for training. Each coder used the pre-defined scheme to code a dimension in the transcript alone. When both coders were finished with a portion of the data, the codes of each were copied side by side in one file and reliability was assessed based on the raw codes. At that point, the coders met together to address disagreements. When a criterion level of reliability was achieved on the training material, the transcripts selected for analysis were coded with exactly the same process.

The meaning of a statement is not always immediately evident from the words themselves, especially when voice intonations and pauses are lost in transcription. For example, in the following statement it is difficult to know if the person is simply informing the group of something that is being done or whether the person is suggesting the italicized portion as an option, "So the other thing we're generally trying to leave the option open to do is *to not have the afternoon X-band orient rover well for the UHF so that we can get more time to collect more data at the end of the day* if that's what you guys wanna do." Comparisons of two interpretations were sufficient to highlight the sources of ambiguity and all disagreements were reconciled easily through face-to-face discussion.

2.3.1 Protocol Segmentation and Isolation of Planning Statements

Coding of data was conducted in several successive stages. The first step was to segment the protocols appropriately for the decision statement level of analysis that was the goal of the study. Initial segmenting was done by the author, reading through the raw transcripts in the word processing documents and using carriage returns to place individual thoughts on separate lines. For all of the dialogue in the transcripts, a new segment division was made whenever an individual speaker expressed a new thought. Because sentence punctuation is arbitrary in transcribed speech (i.e. cued by voice intonations and pauses), the primary cue for dividing segments was the end of a natural phrase (e.g. "We should drive today"). At the same time, common connector words (e.g. if, then, because, so, etc.) were the primary cues for more complete decision statements. If two phrases were connected by these words, they were kept together as one decision statement segment. Typically, the segment size was limited to a single sentence. However, because the dialogue was transcribed from real conversations, sentence divisions were somewhat arbitrary and. Some segments, therefore, included more individual phrases; enough so that the "thought" was clear when read in a written transcript.

Two other segmenting cues were data driven. One cue was identification of a new outcome (e.g. "it will cost us some time" would be separated from "but it will give us a picture of something we haven't already got"). The other cue was a references to a new operation (e.g. "we can RAT first" would be separated from "and then we can do the MI"). The latter cue was more difficult to apply, however, without confounding the coding of planning level (discussed in the next section). In some cases the judgment had to be made whether the next operation mentioned was the proposal of a new alternative or a particular detail of the alternative being described just prior to the mention of the operation.

- "Um we also got, ah, we don't have the navcams but we're putting in place holders for, ah, multiple-filter pancams of targets of rocks in the area
- and also pre-drive, we are, ah, um, have, um, mini-TES at the tracks also, ah,
- and a pancam of the tracks, a-, at lower priority.
- The other things we're doing is the pen-ultimate mini-TES to get the IDD work volume at the end of the drive
- and then also our systematic surveys, our recon raster which will hopefully provide the mineralogy looking out, um, the future."

The bulleted list above shows a set of proposed actions described by one participant. The last two statements were easier to separate because each referred to the expected outcome of the activity. Because the first three statements do not have outcomes related to each unique operation, it could be that all of the operations (multiple-filter pancams, mini-TES, and pancam) are all part of a mini-plan being proposed as a single alternative. Other cues, however helped justify the decision to separate them. The first set of pancams are noted to be "multiple-filter," but the setting for the pancam in the third line is unstated. The mini-TES was specified as pre-drive, which added a time separator between it and the other operations.

There is no escaping that some segmenting judgments were more difficult than others, but this process was checked with double coding as well. After initial segmentation, the lines were copied into a spreadsheet for coding the dimensions, and as coders were doing their coding of planning, they were instructed to highlight the cells of segments that appeared to be either too inclusive or incomplete relative to prior and succeeding lines. As planning coding was being reconciled, decisions were finalized about what material to include in each segment.

The second step was to identify the segments of meeting dialogue that pertained specifically to action planning. Because meetings included references to logistics and other off-topic dialogue, such material had to be separated from the statements pertaining to proposals and arguments about possible activities. A *planning* statement was defined as any comment related to future operations. All of the segments in the list above are good examples. A reference to the previous sol's plan was only counted as planning if it was part of a reason or justification for an operation being proposed for the next sol's plan. References to any other data at hand were treated the same way. Even if it was clearly something that the decision makers might be interested in knowing, if the information was not being explicitly used to determine what would and would not be in the plan it was coded as merely an *informational aside*.

One example of an information aside is the general progress comment, "OK, mission success, um, this is, ah, we are now 32 sols of operation, 21 for opportunity, so that of course increments everyday, we have good sols." Instrument status reports were included in this category (e.g. "Ah, MI is doing just fine. Ah, the temperatures are colder than I've seen before, but that's because we started early in the morning; minus 17 degrees."). Statements of scientific hypotheses and explanations were also information asides (e.g. “Ah, I’m sure there’re ones that are larger but I’m also some what suspecting that maybe these things are ah fine particles that are just a, some kind of accumulation.”). Finally, all questions were included in this category, with only one exception. A question was only counted as a planning statement if it was the only reference to a possible action (e.g. “Well, could we maybe drive up to it and then see what it looks like?”).

Within meetings, different alternatives were often distinguished only by the differences in details for a general type of operation. Initially, all references to the same operation were marked as planning. This was the only way to insure that possible alternatives were not missed. Redundant multiple references were removed in a second pass, after all the different combinations mentioned within each meeting could be assessed side-by-side. In the following exchange, for example, the issue is the length of the drive and where it will put the rover relative to the “dark material.” Speaker 1 initially says 50 meters, and is interrupted by Speaker 2 with an estimate of 70-80 meters, and then Speaker one finishes the full action-outcome thought. In this case, the first statement was not counted, since the fuller thought followed the suggestion of Speaker 2. However both the second and the third statements were counted separately in the final analysis because they are two different alternatives (70-80 meters to edge vs. 100 meters to middle).

- Speaker 1: “At 50meters are we going to be into this darker material? We’re, we're pretty close to it, I think…”
- Speaker 2: “Yeah, in about 70 to 80 meters, we'll be on the edge of the dark streak.”
- Speaker 1: “…the dark streak so if we do two mega-drives, that puts us uh, if we do go 50meters, a 100 meters, that puts us in the middle of that dark streak”

Part of the coding for planning was identifying the action and consequence portions of each statement. For each planning statement, the portion of the statement that described the specific rover operation or operations under consideration (e.g. Drive 100 meters) was highlighted in one text color designating "action." The portion of the statement describing anything that was expected to result from the action was highlighted in a different color that designated "consequence" (e.g. get to middle of dark streak). This color coding served two functions. First, it made the key parts of the statements visually salient to the coders. And second, it clearly delineated what was included in each part. Any uncolored parts of the statement were left as informational asides.

As implied in the segmenting discussion, it was also possible for a segment to be just an action or just a consequence. An action could be proposed without a consequence being identified, in which case there would be no consequence portion (e.g. "I think we should do the drive."). It was also possible, however, for multiple consequences to be associated with a single proposed action ("If we drive today, we will be that much closer to meeting the mileage milestone and we'll have more time for science tomorrow."). In these cases, the first consequence of a proposed action was always kept in the same segment with the action. Each additional consequence was then segmented separately, so that it could be coded individually.

When all of the other coding was done, such that each planning statement had been fully characterized, the codes for the action were copied once for each consequence of that action as part of the redundancy clean-up process. As long as any given planning statement was comprised of one unique action and consequence pairing, there was no redundancy in the data. This process is exemplified in the following statements, where three consequences are identified for the one action. The action is stated explicitly and the first statement is segmented to include the first consequence. The two other consequences of the action are separated from it on two additional lines. Then when the coding is all done, the action codes from the first statement are copied into the empty slots on the other lines so that all of the statements are effectively counted as complete decision thoughts. Each statement could technically be a unique alternative to be implemented in the plan (or rejected from it).

- "so if we're just going straight to the limit of our world, it's about 15 minutes of actual driving time/
- (*if we're just going straight to the limit of our world*) ~~and~~ there's like some set up stuff in the beginning
- (*if we're just going straight to the limit of our world*) ~~and~~ (there's) some clearing up of stuff at the end…"

It should also be noted that when it comes to generating possible courses of action, the ability to take an action is itself a resource that can be framed. As such, if a person observed in one statement that taking one action would affect their ability to perform some other operation, it was coded as an action-consequence statement (e.g. "We need to delete some old data products or else we won't be able to do the integration tomorrow.")

If a statement that clearly pertained to action planning (i.e. referred to operations or resources) was started but not completed, it was coded as *indeterminate* (e.g. "Now the, the gotcha…"). Phrases where the thoughts were fragmented and did not form a coherent proposition were also coded as indeterminate. References to current meeting logistics (e.g. "OK, let's hear from the geochemistry group."), as well as references to planning tasks that would take place in later meetings (e.g. "Tomorrow we will finalize that sequence.") were coded as *meta-planning*. These were important for regulating the decision-making process, but they were not part of the decisions being made. These statement types, along with all informational asides and any other speech segments that did not fall into one of these categories, were counted as *non-planning* (NP).

2.3.2 Coding of Mental Accounting Part 1: Level of Operations Planning

Once the planning statements were identified, the second stage of coding was determining what *level* of planning was represented by the proposed action, which was primarily based on the level of detail that was explicitly discussed. It could be as general as what type of sol was being planned or as specific as the settings that would be used to conduct an operation. Level of planning was also partly determined by the scope of the goal that would be accomplished by doing the operation. For example, there was a standing set of mission milestones that were imposed by NASA to measure overall mission success and which served as large umbrella goals. The milestones included a minimum distance to be driven by each rover, a minimum number of distinct locations to be investigated by each rover, the successful use of each instrument at least once, and a set of seven specific data products to be obtained. At the other end of the goal spectrum were immediate scientific goals that arose in those cases where opportunities to accomplish them arose (e.g. “We’ve been wanting to do some analysis of that material and who knows when we’ll get another chance.”).

It must be noted that these criteria are defined by the Mars exploration mission context. They were determined with input from researchers at the NASA Ames research laboratory who were involved in the observation of the Rover science teams and in the design of planning software for the Rover mission. In particular, proposed actions were classified into three general levels of planning; superordinate-level, basic-level, and subordinate-level. Details about the criteria used for making these classifications can be found in Appendix B.

The *operation* proposed in each statement was the core of the action portion. Every action was coded as being on one level of planning (SUPER, BASIC, SUB). The highest and most general level of planning was labeled *superordinate-level*. The label refers to the fact that these considerations were generally a step above the set of issues that the planners had to work with on a sol-to-sol basis. This category included statements about mission-level goals; that is the accomplishment of the mission success criteria (e.g. "We need to drive another 250 meters to reach that milestone"). It also included references to particular long-range scientific goals (e.g. "We should go to Victoria crater") and things that the planners knew to be true in general. These considerations were applied to planning throughout the mission and brought to bear when applicable. Also in this category were explicitly mentioned multi-sol plans. For example, the plan for the following week may have been to do a four-day exploration of a large rock formation or a three-day super-drive that included several stops along the way. If the discussion did not get to the point of detailing the next single sol or two, it was coded as super-ordinate level planning.

The level of detail that the planners were most concerned with was the sequencing of an activity plan for the following sol. Operations that were proposed and debated with respect to this process represented *basic-level* planning in this context. Some operations, such as driving a longer distance or grinding away the surface of a rock, could consume nearly all of the rover's daily active period. As a result, labels were often used to characterize particular sol-types (e.g. Drive sol or RAT sol). The main determinant of basic-level planning was expressing a concern that was limited to within one sol's worth of time. Mentioning the sol-type of a future sol while detailing the current sol's plan was coded as basic-level. In contrast, listing the sequence of sol-types for the next four sols was coded as a multi-sol plan, because the thought was clearly extending beyond the scope of one sol.

Basic-level planning was often a matter of referring to a category of activity. For example, because there were several instruments mounted on the IDD arm, planners often referred to “IDDing” as an activity. In those cases, it was understood that one or more of the instruments would be used for an operation, but that the particular combination would be specified later. Another example is what the planners referred to as “touch and go,” which was a general term for driving up to a target, doing some operation on it, and then driving off. References to specific instruments, either singly or as a set, were classified as basic-level, but only if the targets of those instruments were left unspecified.

Planners often implied what instruments would be used by referring to the data product that they wanted to obtain (e.g. “panorama” implied using the Pancam, “full spectroscopy” implied using APXS or Mossbauer or both). By the same token, references to specific targets were basic-level if the planners did not specify what instruments would be used on them. Any routine scientific or maintenance operation task fell into this category. Perhaps most importantly, it was considered basic-level planning whenever a statement identified multiple specific operations as distinct options, thereby implying a choice to be made (e.g. “… so we’re either going to do MI or Mini-TES on it.”)

The most detailed level of planning was to discuss specific instruments being used on specific targets with specific parameters set. This *subordinate-level* planning was coded if an instrument-target pairing was identified or if a setting was proposed for a specific operation (e.g. what target to take a picture of and what filter settings to use, what resolution to do spectroscopy at, how deep to scratch a rock, etc.). Here again the instrument could be implied by reference to the product. In addition, since not all targets were given proper names, references made with definite articles were counted (e.g. "I would rather brush *this* rock than than *that* one."). This was especially important when the debate was about what portion of a larger target to do the operation on (e.g. "this smooth part would be easier, but that rough area might be more interesting."). For the operation of driving, a specific period of driving, a drive length, and/or a particular destination had to be identified. For communications, the specific antenna could be identified, as well as the length of the communication pass. This category included any non-routine operations, as well as new types of observations. Finally, any discussion that was devoted to the specific ordering, timing, and prioritization of operations was classified as subordinate-level.

If the statement included a consequence only, it was temporarily coded as "NONE" on this dimension. When the remaining action dimensions had been coded and all isolated consequences were being connected to their actions, this temporary code was replaced with the codes of the action that corresponded to the consequence according to the process described above.

2.3.3 Coding of Mental Accounting Part 2: Framing of Outcomes

The third stage of coding focused on the consequences of the actions. Just as the operation was the core of the action, the objective *outcome* was the core of the consequence. The main determinant of positive or negative frame is the gain or loss in some resource. Decision-making in the MER context appeared to hinge on changes in seven key *attributes*. The resource is part and parcel with the outcome, because the outcome cannot be recognized as such without a change that is experienced in the real world. One of these outcomes is the ability to conduct some activity. As long as a rover has full original functionality, the general ability to do something is always there. This resource, however, refers to gains and losses of opportunities to perform operations, the availability of which fluctuated relative to changing situations. Two other resources that were also measured with respect to gains and losses of opportunities were scientific data and distance driven. In a cumulative sense, these could only increase as the mission progressed, but from moment to moment, the chances to gain them were either gained or lost.

Other resources were electric power, time, and data volume (i.e. flash drive memory storage). One more resource that was related both to activity and time was timing. Timing refers to shifts in the ability to fit activities into the overall plan. The goal was of course to pack as much in as possible, and putting some things into the plan would inevitably make it impossible to do others. Aside from these seven primary resources, there was an "Other" category for any other specific resources that may have been mentioned. If there was no resource explicitly identified, but the tone of the outcome was clearly positive or negative, resource was coded as NONE (What I'm putting up here is a sort of dummy sol plan and I think it has a lot of good news.").

An outcome was framed *positive* when a statement referred to gaining or saving some amount of a resource (e.g. "we'll get a picture of that type of soil" or "we'll save 20 minutes by going in that direction"). If taking an action would resolve an existing problem, it was framed positively. It was also positive framing if taking an action would make the overall situation more advantageous (e.g. "It will probably be a smoother drive if we go that route."). *Negative* framing was attributed to consequences when the opposites of these types changes were identified. If there was a loss of some resource, or some cost measured by it, the framing was negative. It was also negative if it was suggested that an operation might lead to a new problem or make the situation less advantageous (e.g. "taking the picture at that resolution might lead to a flash issue."). In cases where an outcome clearly resulted from the action, but the frame of the outcome was neither clearly positive nor clearly negative, it was framed as *Neutral*. This code was only used if there was no clear reference point to indicate whether that outcome would be seen as positive or negative within the context of the discussion.

2.3.4 Coding of Cognitive Economy: Use of Negations

For the remaining stage of coding, there were several other dimensions that were related to operations and outcomes, but distinguishable from them. They characterized the planning statements in more detail, situating operations within actions and situating outcomes within consequences. One of these dimensions was whether or not negations were used. As Kuhberger (1995) observed, the framing of an outcome can be changed by negating the domain, such that a negated loss is equivalent to a gain (e.g. "…that will not cost us any more time…"). Because of this, the original framing of the outcome was coded first, as described above, and negations were coded independently.

The use of negations was the primary measure of the cognitive economy of statements because attributes were used to define outcomes. Negations were coded in both actions and consequences (*action negation* and *consequence negation*). In both components of the statement, the role of negations was always the same. *One* negation would reverse whatever was being asserted. For example, negations in the action might occur like, "We will not be driving today" or "It is simply not possible to fit that into the plan." Consequence negations could be applied to positively framed outcomes (e.g. "We can do that, but it won't solve our problem") or to negatively framed outcomes (e.g. "If we take a nap, we will not run out of power any time soon."). It was also possible for *two* negations to be used within the same segment of the thought. In these cases, the double negations would cancel each other and leave the main assertion intact (e.g. "We can't not have that in the plan." = "We must have that in the plan."). The absence of negations was coded as NONE.

2.3.5 Coding of Cognitive Load: Task Complexity and Expertise

Cognitive load is closely related to cognitive economy. If the expression of information is not kept as simple as possible, it will result in increased cognitive load. In this context, planners could control how they expressed their suggestions, but some tasks were inherently more complex than other tasks. Task complexity was something that they could not control that affected their experience of cognitive load. The only way to compensate for it was acquire experience and increase their level of expertise with respect to planning activities in the Mars exploration domain. Aside from baseline training in the general procedures, the scientists themselves had to learn how to use the procedures most efficiently. This involved a combination of practice and trial-and-error. Their understanding of what would and would not work improved through increased familiarity with Mars and the rover capabilities.

The primary measure of cognitive workload was the level of *task complexity*. Data on this dimension was available in terms of the sol-types that were mentioned earlier. Some operations were harder to coordinate than others, and when sols were focused mainly on one activity in particular, the sol-types themselves could be classified as easy or hard. Easy sol types included those in which panoramas and spectroscopy data were collected. For these operations, it was basically a matter of choosing a target, pointing, and shooting.

One hard type of sol was a drive sol, where the plan was to spend most of the day driving. A great deal of monitoring, and possibly adjusting, had to be done as the rover encountered obstacles or just hazardous terrain along its route. Another difficult sol-type was given the label "Scratch & Sniff" because it generally involved several hours of RAT brushing or grinding followed by some detailed analysis of the exposed area. The latter process might take several hours itself. Since there was only one meeting used from a given sol, each meeting was coded as having *low complexity* (i.e. easy sol) or *high complexity* (i.e. hard sol).

The *expertise* of the planners was not measured directly, but rather as a function of mission progress. The meetings that occurred *early* in the mission (prior to MER-A Sol 52) were compared to those that occurred *later* in the mission (after MER-A Sol 52), with the assumption that expertise was lower early on and higher later on. Another measure of experience was the relative *novelty* of plans. As sequences of operations were constructed and proven to be effective, it was expected that those sequences might be re-used in later plans where the situations were similar. A decrease in plan novelty, therefore, would be an indicator of increased expertise. The highest proportion of novelty observed in any meeting was 90%, so a split-half division was performed on the sample of meetings. Based on the proportion of novel planning within it, each meeting was coded as having *low novelty* (i.e. less than 45% novel planning) or *high novelty* (i.e. more than 45% novel planning).

2.3.6 Coding of Motivation

Regulatory focus is about how congruent the decision-maker's goal orientation is with respect to the decision. The motivation may be to promote a certain ideal aspiration level or to prevent undesirable events from occurring. Message framing is about motivating behavior by identifying its relationship to outcomes. Evidence of the planners' motivations was coded in both the action and the consequence using three additional dimensions. In the action, motivation was manifested in both the statement *modality* and in *advocacy*. In the consequence, it was captured by the *movement* dimension.

The *modality* was coded as having four possible values. One modality for an action is actuality. If it was stated that an operation definitely was in the plan, and was therefore going to be performed, it was coded as *actual* (e.g. "We will brush and then do a short grind."). Statements about what could be done were coded as *possible*. Possibilities may have been identified directly as options by themselves (e.g. "We can drive today."). They could also be contained within conditional statements where a suggested consequence was being connected to a possible action (e.g. "If we drive here, we could make good time."). In addition, possible actions were evident in statements about possible targets of analysis (e.g. "Well, this rock is already in the work volume."). The "work volume" was the space surrounding the rover that was within reach of the instruments. As such, to identify a target as being accessible to an instrument was to assert the possibility of conducting the operation.

Some operations, whether or not they were possible, may have been desirable to do if circumstances allowed, and these were coded as *ideal*. References to mission success criteria, for example, were often coded as having the modality of ideal (e.g. "They would really like us to get that if we can."). It may also have emerged in the course of exploration, as the scientists became more familiar with both the rover's capabilities and with what there was to explore further (e.g. "It would really be good to get a picture of that while we are here."). Explicit judgments about which target was the best one fell into this category as well.

Finally, the most forceful modality was that of necessity. This was coded when the motivation to conduct an activity was imposed in some way (e.g. "This has to happen before we move on."). In other words, if the action was being taken in order to satisfy a constraint or meet an obligation, it was coded as *necessary*.

The other action dimension that was indicative of motivation was *advocacy* and it was coded whenever the speaker expressed explicit personal preference with respect to the action proposed. A statement was coded as having *positive* advocacy when there was indication that the individual was actively in support of an action and pushing to have it implemented (e.g. "I recommend that we grind first, so that the brushing will blow away the dust." or "I think the second rock is better."). If it was clear that the speaker was actively against an action it was coded as having *negative* advocacy (e.g. "I think we should avoid doing it at this point."). In statements where subjective preferences about the action were not explicitly evident, the modality was coded as described above and advocacy was coded as NONE. It is important to note that advocacy was coded independently of modality.

Finally, as indicated earlier, the movement captures the fact that some outcomes are to be avoided and some are to be pursued. Positive outcomes are generally pursued (e.g. "If we do the drive, we will be that much closer to our 600 meter benchmark."). Similarly, negative outcomes are often avoided when possible (e.g. "If we go toward this target, we will miss that rough patch."). Though perhaps unusual, the situation may be such that these general tendencies are reversed. Therefore in a theoretical sense this motivation must be treated as independent of the outcome frame. The *movement* was coded *positive* if it implied that an outcome, positive or negative, would be pursued or approached. Movement was coded as *negative* if it referred to the avoidance of an outcome, again regardless of the frame. If no such motivation was explicit, it was coded as NONE.

2.3.7 Coding of Rational Choice in terms of Activity Implementation

Finally, in order to test whether the selection of frame type (positive or negative) was related to the likelihood of the framed actions actually being carried out, an additional code was applied to statements. An archived set of spreadsheets that supported this coding were the daily summaries of which activities were actually put into the plan. These records included a number of pieces of information about each operation performed on a given sol, however only a few were helpful for this coding. The "activity-name" was the specific description of the individual operation. For example, "Elevation -20 degrees" described the setting for a mini-TES analysis of the sky. The "observation-name," which was the larger activity that the operation contributed to helped distinguish particular references when the same operation was used multiple times. For example, the observation, "Anytime_Mini-TES_Sky_Stare_AND_Ground (atm)" included several operation settings, including the one just mentioned. Other observations may have used the exact same activity-name, so the observation name distinguished them. If there was still ambiguity in the reference, the "duration" (in seconds) could be used to clarify, assuming that the duration of the operation was actually discussed in the meetings that were coded. The considered actions in the transcripts were compared with the lists of implemented actions in the summaries. A binary marker was used for each statement, such that the statement was coded as "1" if the action was in and "0" if it was left out.

2.3.8 Reliability of Coding

The general coding process was described earlier. All data was double coded independently. To measure the reliability of the coding, Cohen's Kappa analyses were conducted for each coded dimension. Kappa is a widely used method of performing chance-correction to raw agreement rates. Kappa of 0.60 is generally considered high reliability. For Kappa values ranging between 0.40 and 0.60, the reliability is often considered to be minimally acceptable and it was in this process as well. Dimensions with values below 0.40 were judged to be unreliable.

For the first stage of coding, the identification of planning material, the reliability was exactly at full criterion (k=0.60). The coding of planning level, however, was more complicated, due to the hierarchy of detail in characterizing operations. That dimension reached a ceiling at k=0.52, which was judged acceptable for further analyses. The coding of outcome framing, however, was quite straightforward (k=0.79). The other consequence dimensions were highly reliable as well; k(consequence negation)=0.91 and k(resource)=0.79.

The other dimensions related to actions, however, had very mixed reliability. Action negation was also relatively straightforward (k=0.61) and advocacy was just under the bar (k=0.56). Modality was right in the middle of the scale (k=0.49) and was considered to be on the borderline of adequate.

Table 2. Outline of Coded Variables

Variable	Codes (Possible Values)
Modality	Actual / Possible / Ideal / Necessary
Action Negation	One / Two / NONE
Advocacy	Positive / Negative / NONE
Operation	Superordinate-Level / Basic-Level / Subordinate-Level

Consequence Negation	One / Two / NONE
Movement	Positive / Negative / NONE
Outcome	Positive / Negative / Neutral / NONE
Attribute	Activity, Data, Mileage, Power, Time, Memory, Timing

A summary of the variables coded and their possible values is provided on Table 2. On the table, the variables are arranged from top to bottom in congruence with the ordering of elements in the ideal decision thought.

2.3.9 Test for Data Dependency

The goal of this research was not to study group decision-making, but instead to measure individuals' decision statement framing in a context where people would naturally express such statements aloud and without needing to be probed. The MER planning meetings represented a readily available convenience sample of such a context, one that provided the kind of data needed for this inquiry. Using this sample, however, requires that the possible sources of data dependency be addressed. Dependency does add difficulty to the interpretation of the data. However, the characteristics of this particular group setting make testing for dependency difficult as well.

It is important to observe that, although some types of dependency among statements may threaten the validity of the analyses, other types were expected by design. For example, groups of consecutive sol meetings were specifically selected so that it would be possible to look at continuity of planning between sols. Dependency between sets of meetings is less likely because they were generally separated by 10 to 20 sols.

There are two key sources of dependency in this study. One source of dependency derives from the fact that every statement is part of a continuous sequence of speech. Because independence of statements in a dialogue context would lead to incoherency in the conversation, it is expected that statements will be linked to those that preceded and followed them. At the same time, the segments that were coded as planning segments and used in the analyses were not always contiguous within meetings. There were blocks of on-task discussion, but these blocks were also unevenly distributed among blocks of non-planning segments. This intermittency in planning adds to the difficulty of doing a general analysis of segment-to-segment dependency. Nevertheless, this source of dependency could be and was addressed by applying tests for auto-correlation among the codes: the data for each dimension was correlated with itself offset by one sequential position.

The other source of dependency derives from the fact that this was a group context. There are many examples of how being in a group changes individual behavior (e.g. increase in base-rate neglect, falsifying actual perception in response to pressure to conform, etc.). In this study, however, group influences are more difficult to examine. Sadler and Judd (2001) reviewed a number of statistical methods for assessing the impact of groups on individual behavior measures. Unfortunately, there are two main reasons why these methods could not be appropriately applied in this situation.

The first obstacle to using the methods outlined by Sadler and Judd is that they require at least two comparison groups across which to assess relative group influence. In the MER context, there are no clear comparison groups with which to measure effects of groups because none of the possible sub-groupings were completely orthogonal to each other. The Mer-A/Mer-B distinction cannot be used because individual people rotated between them. Even successive, contiguous sol meetings had only partial overlap of participants, so that the method of repeated measures comparisons between successive meetings was also not appropriate. Because of the fluidity of group membership throughout the mission, the set of Mars planning data must be considered as a whole.

The other problem with using traditional statistical methods (e.g. intra-class correlation) to assess the degree of dependency here is that they apply only to data on a continuous scale measured on manipulated and randomly assigned predictor variables. In this study, however, levels of the predictors were categorical distinctions imposed on the data, such that the scale of measurement would violate the assumptions of the tests.

Furthermore, because the variables were not manipulated a priori, levels of the predictors could not be used as comparison groups either. Indeed, the levels of the independent variables were the subgroups needed for testing influences on framing. If the distribution of participants across these groups was known beforehand, there would have been no need to do this study.

In any case, it is likely that the group setting in which it was produced influenced individual framing. Without an appropriate comparison group, however, the extent of this dependency cannot be accurately estimated. Moreover, the existence of group level effects does not invalidate the potential existence of individual level effects.

3.0 RESULTS

The dimensions that were described above were each coded in order to test different hypotheses about what predicts the selection of positive or negative frame. The results related to each of the hypotheses are reported in the following sections. The first set of results characterize the data overall. These are followed by tests of predictions from mental accounting theory, and then effects of cognitive economy and cognitive load are reported. The influence of motivational factors will be addressed, and finally a test of whether rational choice is applicable to frame selection.

Across the 18 meetings that were sampled, there were 4992 individual speech segments. The largest proportion of speech segments (53%) were devoted to providing general information about the rover and situation status, as well as to describing matters of scientific interest. There were 1330 speech segments (27%) specifically devoted to rover activity planning and these were the focus of analyses. Statements regarding meeting logistics and assignment of planning tasks to meeting participants comprised 13% of the speech. And the remaining 7% of segments were off-task or incomplete statements. The diagram in Figure 4 shows the breakdown of segments graphically.

All statements that referred to actions were coded as planning statements. Of the 1330 planning statements, 597 (45%) had consequences explicitly associated with them. Because the primary framing is applied to the outcome, most of the analyses focus on this subset of 597 speech segments. There were some analyses, however, that were only done with respect to the actions. In those cases, all 1330 of the planning statements were used.

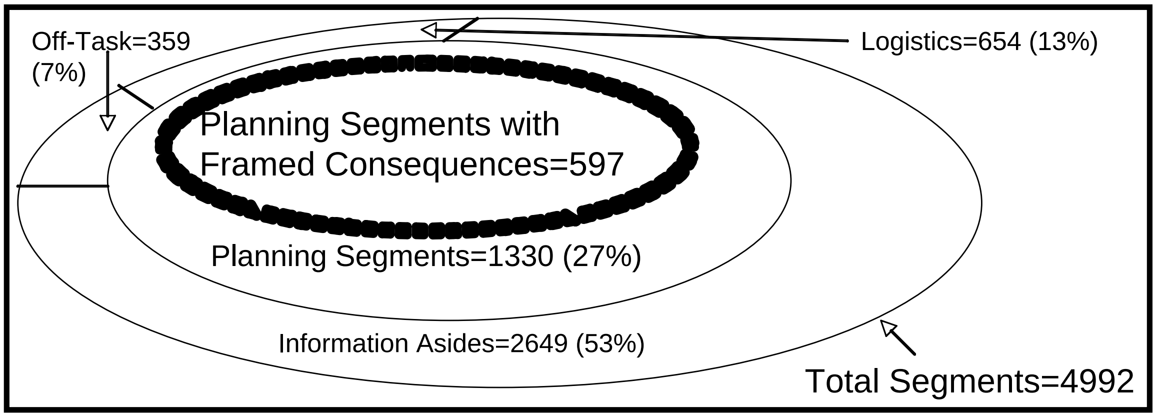

Figure 4. Composition of Data Set by Statement Types

In addition to the statement type, it must be noted that there are three other ways of dividing the speech segments. One way of dividing them is by the mission from which the speech was sampled (i.e. MER-A vs. MER-B). A difference between the missions in the distribution of planning was not expected, and would in fact be a potential confound in the analysis, requiring that planning segments from one mission be analyzed separately from those of the other mission.

The second way of distinguishing statement types, one that is important with respect to assessing changes in scientists' expertise, is the distinction between early mission and late mission dialogue. The third division is between early meeting and late meeting speech and it can be used to determine changes in planning within meetings. The frequencies of speech segments within each of these divisions are shown on Table 3.

Table 3. Major Divisions of Speech Segments

	Early Mission	Late Mission	TOTAL
MER-A	2190	1021	3211
MER-B	442	1339	1781
TOTAL	2632	2360	4992
	Early Meeting	Late Meeting	TOTAL
MER-A	1609	1602	3211
MER-B	893	888	1781
TOTAL	2502	2490	4992

Analyses were conducted to ascertain whether planning occurred more often in particular contexts. Such differences in planning density might produce spurious differences in later analyses by way of third variable correlations, and would have to be addressed in follow-up analyses. A higher proportion of the total number of planning statements (66%, S.E.=1%, n=1330) were found within MER-A meetings. In terms of the proportion of planning within each mission, however, there was no difference between the missions. In MER-A 27% (S.E.= 1%, n=3211) of the overall number of statements were planning statements and in MER-B the proportion was 25% (S.E.= 1%, n=1781).

Across both missions, a significantly higher proportion of discussion was devoted to planning during the late stages of meetings (33%, S.E.= 1%, n=2490) than during the early stages of meetings (21%, S.E.= 1%, n=2502), (X^2(1, n=4992)=98.18, p<0.005). In contrast, the proportion of general information statements was higher in early meeting stages (60%, S.E.= 1%, n=2502) than it was in later meeting stages (44%, S.E.= 1%, n=2490), (X^2(1, n=4992)=122.21, p<0.005). This shift in the pattern of planning was expected, since status and situation reports were made at the beginning of the meetings, and after that the floor was opened up for activity proposals.

The level of planning also differed between meeting stages. There was a higher proportion of superordinate-level planning in early meeting stages (7%, S.E.= 1%) than in late meeting stages (3%, S.E.= 1%), $X^2(1, 1330)=10.92$, $p<0.01$. There was also a higher proportion of basic-level planning during the late stages of meetings (57%, S.E.=0.02) than during the early stages of meetings (52%, S.E.= 2%), $X^2(1, n=1330)=4.01$, $p<0.05$. This shift in planning level is also congruent with what would be expected in a typical meeting. The higher-level, more general superordinate goals were reviewed up front, such that subsequent planning at a more detailed level would be able to address how to achieve those goals. There was no difference between early and late stages of meetings in the proportion of subordinate-level planning.

3.1 MENTAL ACCOUNTING

The hypotheses regarding mental accounting were tested to determine whether the distribution of selected frame is related to the level of planning under consideration. First it is important to note that over half of the planning statements (55%, S.E.= 1%, n=1330) were proposed actions that had no consequences associated with them, which essentially meant that they were "unframed." The proportion of action-only statements was also not affected by the level of planning, (SUPER=48%, BASIC=59%, and SUB=50%; S.E.= 1%).

Because neutral framing of outcomes occurred so infrequently (5%), and also because the distribution of neutral framing among planning levels was proportionally the same as the distribution of negative framing across planning levels, the neutral frame category was collapsed with the negative frame category. All analyses of frame distribution were therefore done with respect to a distinction between *positive* and *non-positive* framing.

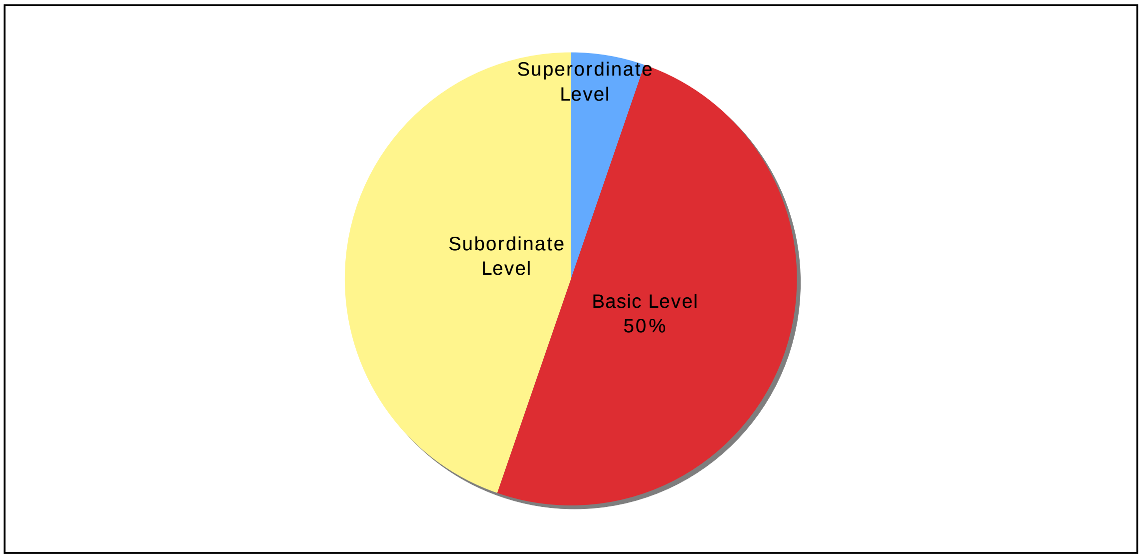

Figure 5. Overall Distribution of Planning Level Among Framed Statements

Most planning (55%, S.E.= 1%, n=1330) occurred at the basic-level. As shown on Figure 5, even within the smaller set of statements that were framed, the proportion of basic-level planning was equal to the other levels combined (Basic=50%, S.E.= 2%, n=597), with subordinate level planning picking up the difference (Subordinate=45%, S.E.= 2%, n=597). Basic level planning statements accounted for a significantly higher proportion of framed planning than both of the other two categories combined, X^2 (1, N=597)= 73.88, p<.005.

In terms of the relationship between mental accounts and framing, preference for positive framing decreased as planning became more detailed. The superordinate-level level of planning exhibited the highest proportion of positive framing, 81% (S.E.= 7%, n=26). This was followed by basic level planning, of which 69% (S.E.= 3%, n=205) were framed positively. And at a slightly lower rate subordinate-level planning was framed positively 64% (S.E.= 3%, n=172) of the time (see Figure 6). None of the pair-wise differences between these proportions were significant.

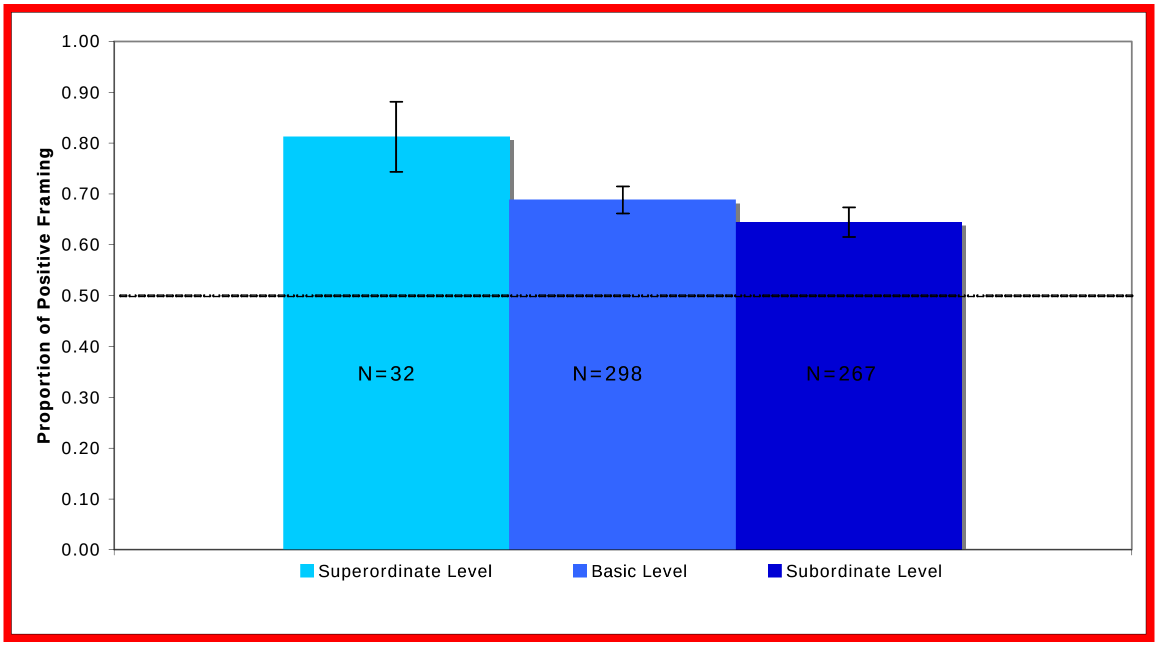

Figure 6. Framing by Planning Level

One possible explanation for the trend shown on this graph is that perhaps people were equating the scope of consideration (or the size of the account) with the magnitude of the gain or loss that would be associated with it. In other words, based on the fact that superordinate-level goals were the broadest and most inclusive, people may have assumed that the impact of a loss on such actions would be proportionally high. In contrast, for subordinate-level goals, which were smallest in scale, the associated smaller losses here and there would have been seen as having less impact and would therefore be easier to consider.

In any event, the general expectation based on mental accounting theory was rooted in the gain segregation tendency. That is, if people tend to segregate gains, then positive framing should be the preferred frame overall. This was supported by the fact that the overall proportion of positive framing across planning levels was 68% (S.E.=0.02, n=403). The null hypothesis confidence interval for this proportion was (54% > p > 45%). Because 68% was outside of that interval, positive framing carried a significantly higher proportion than non-positive framing. This result, along with the others, indicates a general pattern of positive framing being preferred regardless of what level of detail is being used for decision-making.

3.2 COGNITIVE ECONOMY

Expectations about cognitive economy were supported with respect to the use, or perhaps more accurately the non-use, of negations in the decision statements. As expected, negations were generally avoided. Only 17% (S.E.= 2%, n=597) of the planning statements had any negations in them at all. When there was negation, it was almost always limited to one. This was true for both actions (98%, S.E.= 2%, n=41) and for consequences (99%, S.E.= 1%, n=74).

There were only two instances of double negation (one among actions and one among consequences), which was well below the probability of double negations (9%) that is expected by chance with this number of planning statements (n=597). There were also no cases of more than two negations total. In the instances of double negation, they were the only two in the statement. There were very few instances of there being a negation in both the action and the consequence as well (2%, S.E.= 1%, n=597). However, the probability of the consequence being negated was proportionally higher when the action was also negated than it was when the action was not negated, X^2 (1, N=595)= 20.59, p<.005. The direction of causation in this pattern is not clear. It may be that actions were negated when planners thought that desired consequences would “not” occur. Alternatively, actions may have been negated, or decided against, because it was hoped that certain consequences would not occur. In any case, negations cannot be avoided completely in speaking about alternatives. It may be that matching action negations with consequence negations was a strategy for psychologically canceling negations and improving cognitive economy somewhat as a result.

Perhaps most importantly, there was no relation between the rate of negation and the framing of outcomes. The rate of negating non-positive outcomes (14%, S.E.= 3%, n=596) was not significantly higher than the rate of negating positive outcomes (11%, S.E.= 2%, n=596). These results indicate that, even though negations are used on occasion, they are not used to compensate for loss aversion any more than they are used for gain maximization. As such, one strategy for framing may be to negate the opposite frame (Kuhberger, 1995), but it does not appear to be a dominant strategy. Furthermore, a nearly equal proportion of positive and non-positive outcomes were negated. As such, when the valences of the original outcome frames were negated in order to derive integrated overall consequence frames, where appropriate, there was no change in the mental accounting results pattern described earlier.

The observed rates of negation in this data do support the hypotheses about cognitive economy. Negations are generally avoided and are almost never used adjacently to each other. There was no interaction between negation use and framing, however, which may mean that these two ways of manipulating valence are independent of each other. Or put another way, cognitive economy may explain the avoidance of negations, but it likely does not explain the preference for positive outcomes.

3.3 COGNITIVE LOAD

The effects of expertise, task complexity, and cognitive workload on representation selection were measured at the meeting and mission level, as opposed to the statement level. With respect to expertise, there were several indicators that an increase had occurred over the course of the mission. Meetings in the early stages of the mission were longer (M=5795 words, SD=2053) than meetings in the late stages (M=3975, SD=1417), $t(16)=2.13$, $p<0.05$; an effect size difference greater than 1. This effect suggests that, as the mission progressed, the scientists were able to complete their planning with much less discussion than when the mission first began. There was also evidence that they were able to begin the actual planning earlier in the meetings. As noted earlier, there was a significant difference between early meeting and late meeting phases in the amount of planning done during those periods. More planning occurred in the later phases of the meetings. This difference was significantly bigger for early mission meetings than it was for late mission meetings, $X^2(1, n=1330)=4.21$, $p<0.05$. During early mission, the average proportion of early meeting planning was 36% (S.E.=2%, n=690), but during late mission, the proportion was 42% (S.E.=2%, n=640).

A change in the level of planning over the course of the mission was observed as well. There was a significant decrease in the amount of basic-level planning between early mission (58%, S.E.=2%, n=690) and late mission phases (52%, S.E.= 2%, n=640), $X^2(1, n=1330)=5.73$, $p<0.05$. This coincided with a rise in subordinate-level planning which comprised 37% (S.E.= 2%, n=690) of the total planning in early mission and 44% (S.E.= 2%, n=640) of the total in late mission, $X^2(1, n=1330)=7.86$, $p<0.01$.

The shift toward subordinate-level planning could be the result of two possibilities related to the scientists' level of experience. On the one hand, an increase in expertise leads to increased confidence with respect to the task. After having mastered the basic operations of the rover and successfully obtained some data products, the scientists may have felt surer of themselves in experimenting with parameter differences to push the limits of the rovers and to obtain more unique and innovative data products. On the other hand, if they had already achieved many of the required milestones by the latter half of the mission, they may have objectively been more at liberty to attempt untried settings for operational procedures.

In any case, with these behavioral differences providing evidence for increased expertise, the key purpose of this research is to determine what factors are related to the selection of decision frames. As such, the most critical difference between early and late mission phases was a significant decrease in the level of positive framing. During early mission, the framing of outcomes was 71% positive (S.E.= 3%, n=322). In late mission, however, only 63% (S.E.= 3%, n=275) of the outcomes were framed positively, $X^2(1, n=597)=4.91$, $p<0.05$ (See Figure 7).

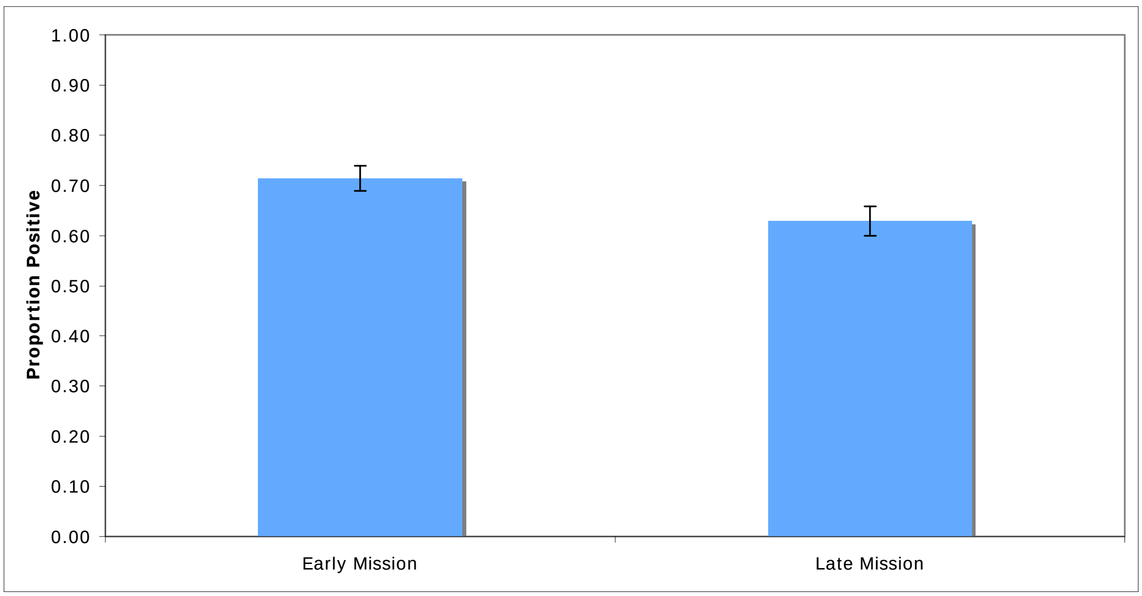

Figure 7. Overall Proportion of Positive Framing Relative to Expertise

In order account for this drop in positive framing, the rate of positive framing between expertise levels (i.e. mission phases) was compared relative to task complexity. The level of cognitive workload experienced by a decision-maker is actually a function of both task complexity and expertise. A novice who is faced with a highly complex task will experience the *highest* level of workload because a higher number of task details will need to be processed by someone with the least amount of task experience. Similarly, an expert who is faced with a less complex task will experience the *lowest* level of workload. There are fewer details, and someone with more experience can easily handle those details. The other two combinations, low complexity with low expertise and high complexity with high expertise, represent the *intermediate* range of workload. Practice is required to master tasks no matter how simple they are. At the same time, having had more practice within a domain does not reduce the number of details that are inherent to the task.

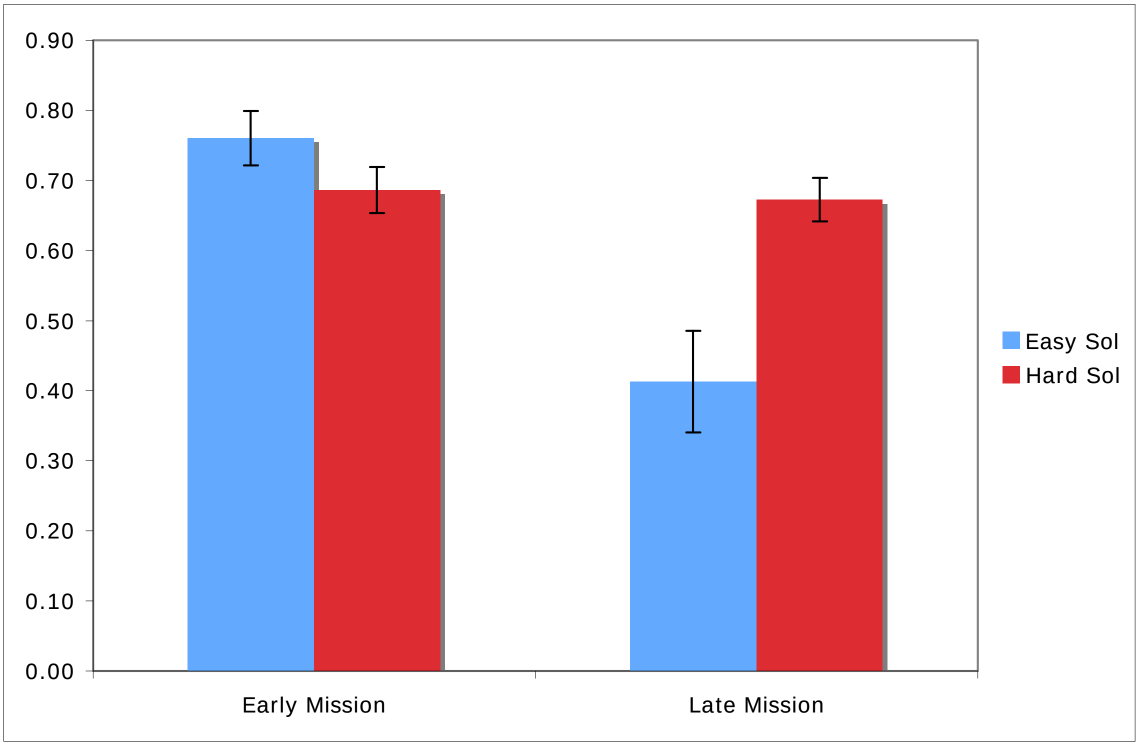

Figure 8. Proportion of Positive Framing by Expertise (Mission Phase) and Task Complexity

Task complexity compared across expertise levels (i.e. mission phases) led to an interesting interaction. Figure 8 illustrates how, between early and late mission, there was no difference in the rate of positive framing within the hard planning (high complexity) sols, (69% and 67%, respectively, S.E.= 3%, n=597). In contrast, the proportion of positive framing for easy planning (low complexity) sols was higher than that of the hard planning sols (76%, S.E.=

4%, n=597) during early mission, but then the rate dropped below that of the hard sols during late mission, (41%, S.E.= 7%, n=597). There was a main effect of mission phase, $F(1, 593)=7.48$, $p=0.01$, but no main effect of task complexity. The interaction between expertise and task complexity was significant, $F(1, 593)=13.19$, $p<0.001$.

Based on this pattern, the reduction in preference for positive framing appears to be driven not by workload, but by expertise. When the planners were at novice level, they tended to focus on positive outcomes in general. This focus was strongest when the tasks were simpler. It may be because gains were more salient in those situations. It may be also be the result of a confirmation or a positive-test bias trumping a critical assessment of the contingencies. In contrast, when the planners achieved significant expertise with the planning process, they were more likely to focus on non-positive outcomes in simpler planning tasks. The shift may reflect a higher level of situation awareness, as well as increased willingness to engage in cost/benefit evaluation, both of which are congruent with increased expertise. Expertise did not appear to alter the preference for positive framing in high complexity conditions.

Another interesting pattern emerged when framing across mission phases was compared with the other coded measure of expertise, which was the novelty of the planning within sols. The proportion of positive framing was compared between high novelty and low novelty sols across the mission phases using a 2*2 ANOVA. As shown on Figure 9, there was a main effect of mission phase, such that the drop in proportion of positive framing from early to late mission occurred at both levels of novelty, $F(1, 507)=5.48$, $p<0.05$. There was also a significant main effect of novelty level, $F(1, 507)=7.71$, $p=0.01$, such that there was a higher rate of positive framing on the low novelty sols within each phase of the mission. Because decreased plan novelty is associated with increased expertise, the effect of novelty on framing was actually the opposite of the effect of the mission phase expertise measure. There was no interaction between these two measures of expertise.

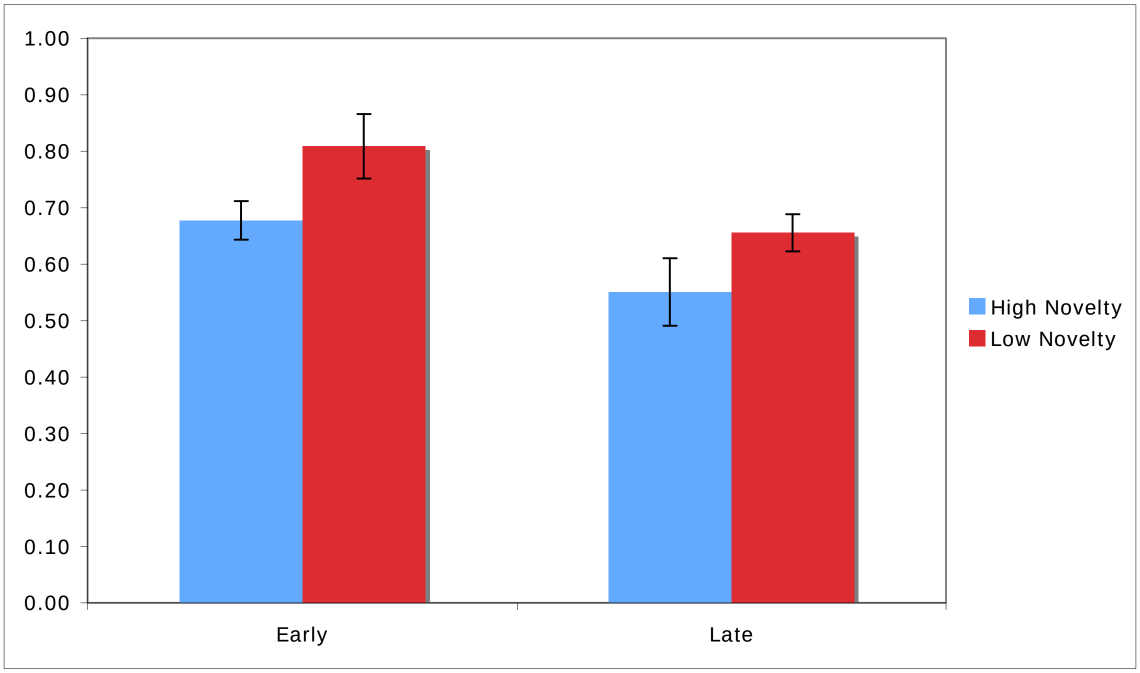

Figure 9. Proportion of Positive Framing by Expertise (Mission Phase) and Plan Novelty

One possible explanation for why the two measures of expertise had opposite effects is that the specificity of experience represented by each measure may have been different. Reuse of developed plan material is a sign of expertise because it is more efficient than developing a plan from scratch and increased efficiency is often a natural result of having more experience. At the same time, if an operation sequence has been used before, then the outcomes that are likely to result from it have also been specifically experienced before. Therefore a general increase in experience may have made planners more cognizant of the negative possibilities, which might explain the observed rise in non-positive frames during late mission. At the same time, specific experience with particular activities would have given the planners actual knowledge of what would be gained by doing those activities. The real gains might then have been used to motivate the reuse of operational procedures in favor of untried procedures where the outcomes were still unknown, which might explain why framing was more positive on the low novelty sols. Furthermore, because the outcomes of used procedures became matters of record immediately, the planners' general level of experience would not influence this process, which would explain the observed consistency of the difference in both early and late mission phases.

In sum, the effects of expertise and workload on frame selection appear to be mixed with respect to the two measures of expertise and task complexity. When the task is simpler, a general increase in experience with the task leads to a decrease in the tendency to use positive framing. When the task is harder, the rate of positive framing remains high regardless of experience. In contrast, when expertise is measured in terms of plan reuse, the prior experience with the operation under consideration appears to increase the rate of positive framing.

3.4 MOTIVATION

There were several dimensions that contributed to an assessment of motivation effects on framing. One set of analyses focused on the general mode of motivation. Recall that there were four modalities that could be associated with statements; actual, possible, ideal, and necessary. In addition to using a particular modality, the speaker could also indicate whether he or she was personally in favor of or opposed to the action referred to (positive and negative advocacy, respectively).

A statement made with either an ideal or a possible modality, and also given positive advocacy, was thought to be indicative of an *aspiration* mindset, where the goal is to achieve some desired outcome (e.g. “We’ve been saying we want to do something with this stuff and I think we should do it while we have the chance.”). In the same way, a positively advocated statement made with a modality of necessity would more likely suggest an *obligation* mindset, where there is explicit desire to meet constraints (e.g. “I’m in favor of it, especially since we have to get it done at some point anyway.”).

Although modality was associated with all of the statements, this analysis was limited by the low frequency of explicit advocacy in the statements. There was only one instance where an obligation action was associated with an outcome. There were 48 aspiration actions associated with outcomes. There were also 47 aspiration actions and five obligation actions that did not have outcomes associated with them. As such, the overall proportion of decision thoughts in which some motivation mode was explicitly exhibited was 17% (S.E.=0.02, n=597). Out of the 48 framed aspiration actions, however, 85% (S.E.=0.05, n=48) of them were framed positively, such that aspiration was significantly related to preference for positive frame, $X^2(1, n=597)=7.68$, $p<0.01$.

Some additional considerations need to be addressed. First, it is possible that the advocacy and the modality dimensions are individually predictive of outcome framing. Since there were so few advocated actions associated with outcomes, a Fisher’s Exact test was done comparing positive and negative advocacy to positive and non-positive framing. The effect was not quite significant (p=0.07). Negative advocacy appears to be given equally to positive and non-positive outcomes, but positive advocacy was strongly associated with positive framing (76%, S.E.=0.06, n=55).

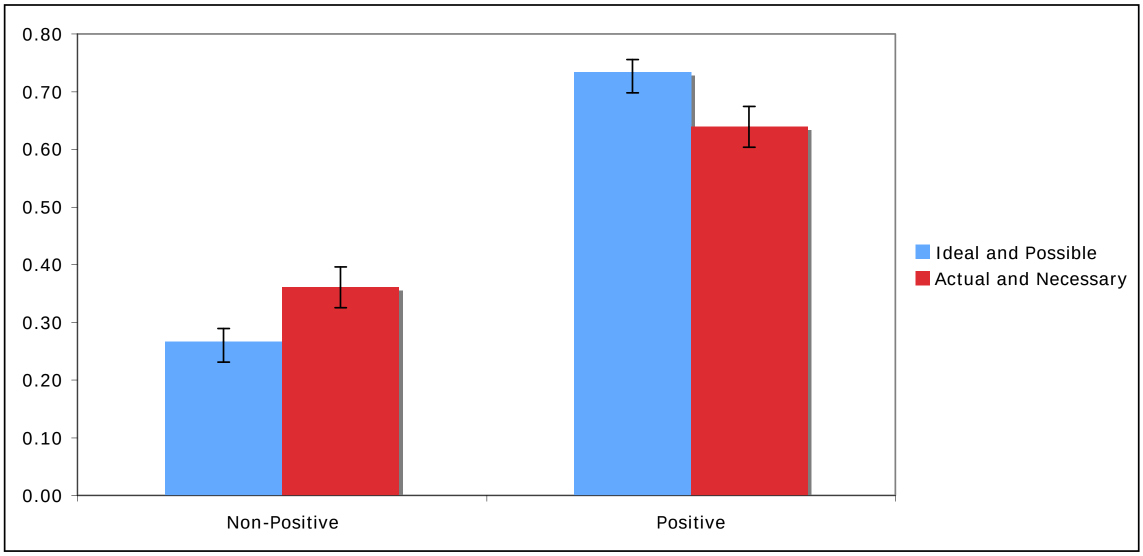

Figure 10. Proportion of Framing Relative to Modality

In terms of modality by itself, aspiration includes both possible and ideal modalities. When the actions stated with these modalities were compared to the actions stated with the non-non-aspiration modalities (actual and necessary), the interaction with framing was significant, $X^2(1, n=597)=5.27$, $p<0.05$ (see Figure 10). The difference between the proportions of positive and non-positive framing was larger among aspiration modalities (73% and 27%, respectively, S.E.=0.02, n=390) than it was among the non-aspiration modalities (64% and 36%, respectively, S.E.=0.04, n=183). There were no significant relationships with outcome framing observed for any modalities by themselves. Within all of the modalities, positive framing constituted the majority frame.

It should also be considered that possibilities are somewhat ambiguous with respect to motivation. In a general sense, they are motivationally neutral. Possibility was the dominant modality overall, regardless of advocacy, but in order to test whether possibilities really are motivationally neutral, a direct comparison was made between possible modality and the likelihood of actions being advocated. Of the actions stated as possibilities, 13% (S.E.=0.01, n=704) were associated with some advocacy. In contrast, of the actions stated with other modalities, only 5% (S.E.=0.01, n=626) were advocated either positively or negatively. This interaction was significant, $X^2(1, n=1330)=29.26$, $p<0.005$, and it suggests that possibilities are actually more likely to be associated with motivation than other modes of action. Therefore, possibility does not appear to be motivationally neutral, at least in this context.

To summarize, the dominant motivation mode in this context appeared to be one of aspiration. In addition, the overall base-rate of advocacy was low, which could mean that personal support for an action has only a small influence on framing or that advocacy is generally implicit in the decision making process. While advocacy by itself had only a marginal relationship with framing, the modalities that people with aspirations are expected to use were associated with framing independently of advocacy. In addition, possibility by itself was related to the likelihood of personally advocating actions.

There was one remaining dimension in the consequence that provided evidence of motivation as well and that was the *movement* with respect to the outcome. If the action was associated with approaching an outcome, the movement was positive. If an outcome would be avoided when the action was taken, the movement was negative. This dimension was statistically unrelated to both measures of motivation in the action (modality and advocacy). It was, however, related to frame selection. There were very few instances of explicit movement overall, so a Fisher's Exact test was again used and it yielded a significant interaction between movement and outcome frame (p=0.02) (see Figure 11). The proportions for negative movement indicated that positive and non-positive outcomes were equally likely to be explicitly avoided (43% and 57% respectively, S.E.=0.19, n=7). There was a strong association, however, between positive outcomes and explicit references to approaching them (positive movement with positive outcome = 86%, S.E.=0.06, n=36). Only 14% (S.E.=0.06, n=36) of statements with positive movement involved non-positive outcomes.

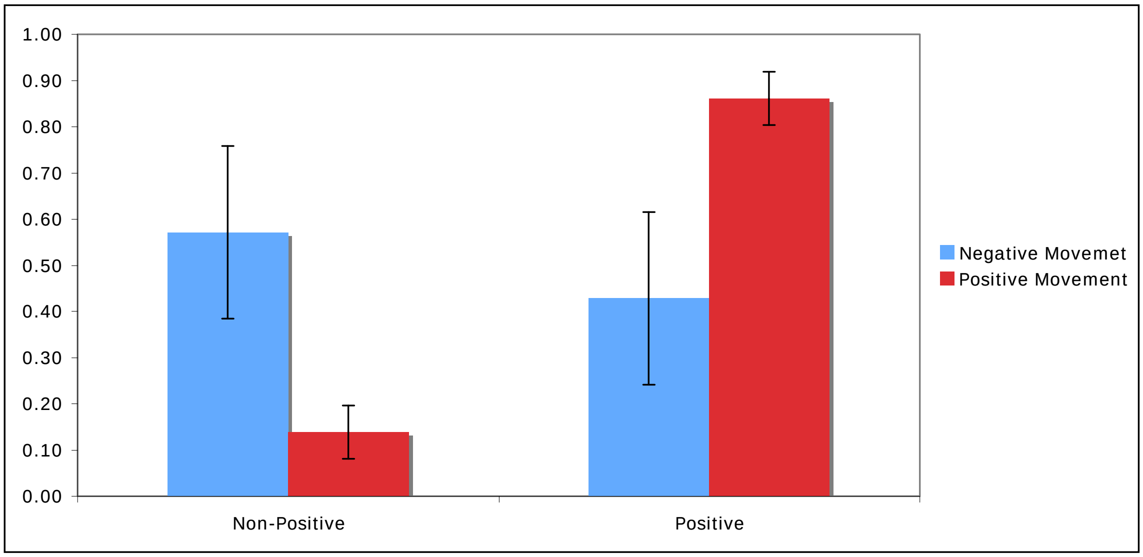

Figure 11. Proportion of Positive Framing Relative to Movement

In sum, although the effects are independent of each other, this effect of movement is congruent with the motivation mode pattern described above. In this decision-making context at least, attention appears to be anchored to positive outcomes and motivation is directed at making positive outcomes happen.

3.5 RATIONAL CHOICE

The remaining analysis, and the one which most directly connects this research with research on the framing effect, was an assessment of the relationship between the rate of action implementation and the selection of frame.

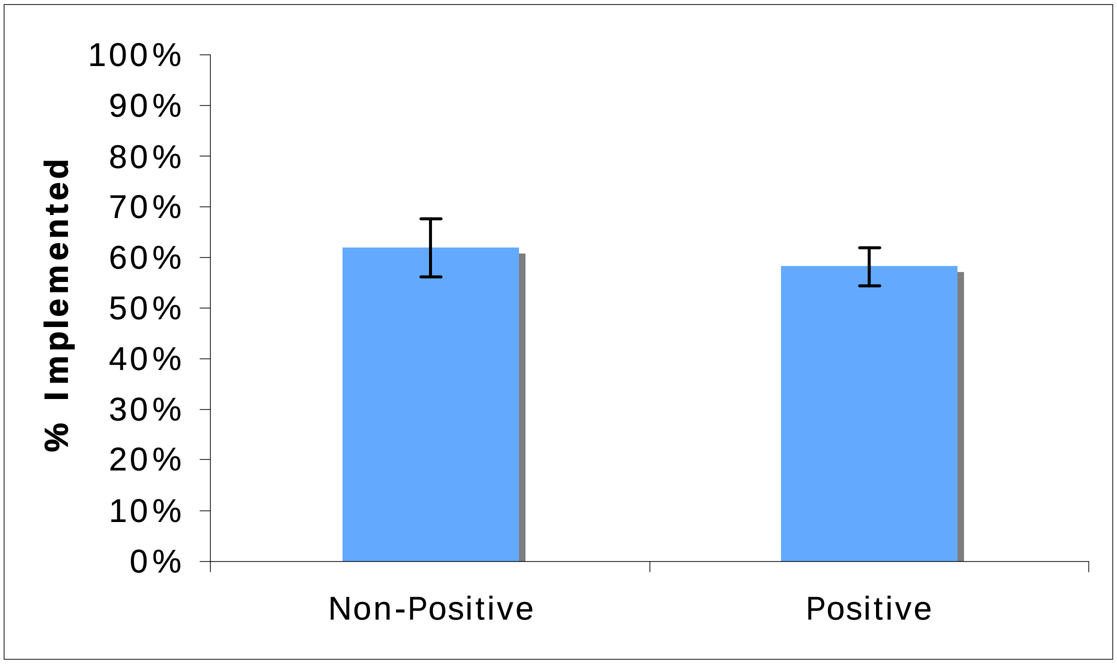

Figure 12. Rate of Action Implementation Relative to Framing

The rational choice model predicts that one representation (i.e. frame) is more likely to be used if it increases the likelihood of the suggested action being taken. Rational choice did not appear to be a consideration in this case, however. As shown on Figure 12, the rate of implementation for positive outcomes (70%) was not different from the rate of non-implementation (73%) (S.E.=0.04, n=248). As such, there was no practical advantage to selecting one frame over the other.

3.6 TESTS OF AUTOCORRELATION

One final aspect of these results that needs to be addressed is that, because each statement was part of a sequence of statements in dialogue, it was not independent of the statements surrounding it. Most dimensions had negligible correlations with themselves. The highest autocorrelation coefficients were observed among the levels of planning (SUPER: r=0.30, BASIC: r =0.37, and SUB: r =0.40). To some degree this is to be expected, however, since shifts in planning level that are too rapid would disrupt the coherence of the planning process. Possible and actual modalities were also moderately correlated with themselves (r=0.25 and r=0.28, respectively), however these two modalities together represented 80% of the planning statements, such that some degree of overlap was inevitable. Based on the analysis, it was concluded that autocorrelation did not have a significant effect on the results reported in the preceding sections.

4.0 GENERAL DISCUSSION

This research set out to determine what factors would influence the use of positive and negative information for decision framing. Past studies of framing effects have provided support for the conclusion that manipulations on the information level can influence responses on the behavioral level. The key contribution of this work, however, is that it studied a decision-making situation in which decision makers were actually free to do their own decision framing. Consequently, this study was able to capture the natural framing process without imposing manipulations or restrictions on the representations that were generated.

Ironically the results of this research suggest that people do not operate on the information level when they are in the process of setting up or generating decision representations. Among the information level dimensions that were examined (e.g. operations, modality, negations, etc.) there were only a few small relationships to differences in positive and negative framing observed. Instead the patterns of frame selection were best accounted for by the factors of task complexity, cognitive workload, and expertise, all of which function above the information level.

The implications of this research will be considered further in the sections that follow. After a brief review of the critical findings in the next section, a new hypothesis will be proposed to account for frame selection. This will be followed by sections devoted to addressing additional concerns that might be raised from each of the theoretical perspectives that were examined. Some general methodological concerns and potential future research directions will then be addressed as well before concluding this thesis.

4.1 KEY FINDINGS AND CONCLUSIONS

All of the theoretical approaches to decision-making and reasoning about decisions seem to accept the hedonic principle as a core assumption about peoples' motivations; people seek pleasure and avoid pain. A translation of this principle into information-level terms suggests that people have an affinity for positive events (e.g. outcomes, features, consequences) and an aversion to negative events. The aversion to negatives is often touted as having the greater influence on decision-making based on demonstrated framing effects. Whether or not it has a greater effect on decisions made when provided to passive decision makers, the results of this research suggest that the affinity for positives is a more naturally occurring behavioral tendency.

Each of the theoretical approaches that were drawn from suggested different ways of measuring frame selection and in each of these measures a preference for positives was observed. First, with respect to behavioral economics, and the associated mental accounting considerations, the preference for positive outcomes was dominant overall. Positively framed decision statements outnumbered negatively framed statements in each level of mental accounting, and with roughly the same proportion, since there were no interactions between mental accounts and framing. In terms of reasoning and expressions of statements, consistent with the expectations, negations received minimal usage overall. In addition, there was no relationship between the selection of positive versus negative frames and the probability of negations being used.

The results of the motivation-related analyses also provided only partial support for the expected patterns. Aspiration mode was significantly related to a preference for positive frames, but this correlation was offset by the fact that motivation mode was a low frequency phenomenon in general, and thus not as useful of a framework in this setting. In the end, there were not enough instances of obligation mode to assess which frame they are more likely to be associated with.

The dimensions with which a clear differential selection of frame was observed were those that function above the information level. As the missions progressed and the decision-makers become more familiar with their task, the increased experience (or expertise) led to a decrease in the proportion of positive framing (and thus, an increase in negative framing). In terms of general workload, it would seem that experts are better able than novices to handle the possibility of negative outcomes resulting from untried actions. In addition, when it came to re-using plans as a way to compensate for workload, it appeared that experts were more successful than novices at accessing the advantages (positive outcomes) of plans that had already been done before. In sum, it was specifically the workload and expertise dimensions that were able to provide an account for when people select one frame over another. It may be that a more comprehensive account of framing can also be found at a higher level of cognitive processing.

4.2 FRAMING BY OPPORTUNITY

This research revealed that people have a strong affinity for positive elements exhibited in multiple areas of psychological activity (i.e. behavioral decision making, reasoning, and motivation). One way to explain these findings is that people's approach to decisions is generally oriented toward goal achievement. That is, unless people are forced to choose from a set of alternatives that are framed negatively, people will naturally focus first on what they see as *opportunities* to achieve goals. Grounds for this *framing-by-opportunity hypothesis* can be found both within the observed data and from other prior research. This hypothesis explains the main result of this study as well as several of the general patterns observed in the data.

In this study, it was an increase in expertise that led to greater differentiation in the valence of selected frames. Prior research has shown that one thing that distinguishes experts from novices is their ability to identify the information that is most critical to progress within the situation (Chase & Simon, 1973; Chi, Feltovich, & Glaser, 1981; Chi & Glaser, 1985). Chase and Simon (1973) showed that expert chess players had better memory for meaningful configurations of chess pieces than novice players. Although every option is a potential course of action, it is only when an option has a meaningful connection to a goal that it is really recognizable as an opportunity. Furthermore, different options may sometimes accomplish the same goal. Each option would use a different method from the others, would involve different degrees of effort, and would differ from the others in the overall likelihood of accomplishing the goal. Each option can therefore be evaluated with respect to the quality of opportunity that it represents. Chi and Glaser (1985) referred to research showing that, in problem-solving tasks, experts were better able than novices to recognize which moves were the best and generally gave them first consideration.

This analysis showed that an increase in expertise across mission stages corresponded to a significant decrease in positive framing. If experts are indeed better able to distinguish higher quality opportunities from those that are less effective, it is expected that an increase in expertise will lead to an increase in critical evaluation and thus a decrease in the number of positive targets identified. At the same time, this drop in positive framing interacted with task complexity, such that the decrease only held for those sols where the planning task was relatively easy. The level of positive framing was the same on the hard planning days regardless of when they occurred in the mission. It could be that opportunities were more difficult to evaluate on those days due to the higher workload of increased complexity so that the focus remained primarily on the salient positive aspects of the proposed options.

Three other general patterns in the data are explained by the opportunity-framing hypothesis as well. First, it is important to note again that the majority of proposed actions (55%) were unframed. One reason why people might omit references to consequences is that the consequences of an action might not be known at all or known with enough certainty to justify bringing them up in discussion. Another reason for leaving consequences unstated is that they may be so obvious that it is not necessary to even mention them. It is likely that each of these reasons accounts for some of the instances of unframed actions. However, in the cases where the outcomes are obvious, it may be that the value of the outcome is so closely tied to the action that mentioning the action automatically frames the alternative that it is associated with. As such, explicitly identifying an opportunity to perform an action has the added effect of framing the decision of whether or not to take the action.

Second, out of all the actions that were proposed, 53% were expressed as possibilities (i.e. in *possible* modality). This preference for the one modality over all of the others combined is striking, and it suggests that the planning process may have been more heavily driven by the availability of alternatives than by constraints. Depending on the situation, a person might think of constraints as limitations in his or her ability to act, associating them with frustration and other negative feelings. In contrast, simply having the ability to do something might be associated with a sense of freedom and might thus have positive value in itself. With the analytic scheme used in this study, one way to express constraints was by using statements of necessity (i.e. “We *need* to X”). The fact that possible modality was favored over necessary modality could indicate that the positive connotation of having many options may have been stronger than the negative connotation of sometimes being constrained. At the very least, it was shown that possibilities are not motivationally neutral, but there was also insufficient basis for saying that they are inherently associated with one regulatory focus or the other.

Directly tied to the preference for possibilities is the third observation that several of the resources that were most frequently framed were completely about gains and losses of opportunities. As discussed in the methods section, if taking one action resulted in the ability to take some other action (or the loss of such ability), the *opportunity* to take the latter action was a consequence of the first one. Two other resources that were specifically about opportunity were obtaining scientific data and increasing the distance driven by the rovers. No action could cause a loss of previously collected data or previously obtained mileage, but a chance to gain more by doing one thing could be lost by doing something else. Indeed, behavioral economists specifically refer to foregone alternatives as “opportunity costs” (Larrick, Nisbett, and Morgan; 1993), and just as people feel regret over what *might have been*, they may derive hope from what *can be*.

Finally, research on self-regulation and goal-related behavior provides a basis for an opportunity-framing hypothesis as well. In one series of studies, Shah and Kruglanski (2003) showed that peoples’ memory for goals could be primed by encountering the means necessary to achieve them. They also found that this effect was moderated by how instrumental the means were to accomplishing the goal, indicating that the memory priming was actually based on functional features, rather than superficial semantic associations. In other words, when opportunities arise to pursue a goal, it is more likely to come to mind, rather than being primed by blockers to a goal or other negative aspects. In sum, there is evidence that that people associate value with opportunities to take action and achieve goals, and that opportunities themselves are evaluated with respect to how likely they are to result in goal accomplishment.

4.3 OTHER CONCERNS OF BEHAVIORAL ECONOMICS

There are many facets to decision making behavior in general and some additional issues need to be considered. Although the framing-by-opportunity hypothesis may account for peoples' affinity for gains, there are a couple of other key aspects of framing effect theory that cannot be ignored. Perhaps the first question a behavioral economist would ask is whether loss aversion is a factor in selecting a decision frame. With so few exhibited references to negative information in the data, how does this study account for the common maxim that *losses loom larger than gains*?

One response to this question is that the influence of loss aversion on frame selection is specifically to be found in the absence of negative information. Consolidating losses is one strategy for reducing direct awareness of losses when one is engaged in mental accounting or decision editing processes (Thaler, 1999). Even more effective, however, is to not bring them up in the first place.

Another possibility is complementary to the earlier discussion of opportunity value. Perhaps people are not expressing potential losses at the information level, but that loss aversion is in effect in the background. Just as general awareness of opportunities lends positive valence to the decision process, a general awareness that opportunities may run out at any time creates a negative undercurrent in the situation as well. This sense might be labeled as the *sniper-on-the-hill* effect. Even when things are running smoothly, there is always the sense that something catastrophic could occur at any time that would end the endeavor completely or at least sharply reduce the number of possibilities. To the extent that this prospect is on the minds of decision makers, then, there is the urgency to accomplish as much as possible before time runs out. Ironically, the aversion to loss in the general background may actually be motivating a preference for positive frames.

The other major concern from the behavioral economic perspective is with the role of risk and/or uncertainty in the framing process. The traditional framing effect is defined not just by valence, but also by response to risk. Under positive framing people are risk averse, but under negative framing people are risk seeking. In addition, Kahneman & Tversky (1979; Tversky & Kahneman, 1981) have also discussed the *certainty effect*, wherein a constant reduction in the probability of an outcome has more influence when the outcome is initially certain than when it is initially only probable. In other words, certainty increases both the aversiveness of losses and the desirability of gains.

An attempt was actually made to code for uncertainty in these discussions using a key-phrase based scheme that was constructed by Schunn and Saner (Schunn, Saner, Kirschenbaum, Trafton, & Littleton, 2007). By this scheme, uncertainty about information is represented by particular types of phrases, such as qualifying statements (e.g. “you can’t tell whether…”), hedging statements (e.g. “It is not clear whether…” or “It may be that…”), and estimating statements (e.g. “It is more or less…”). If any of the phrases were used with respect to an action or a consequence, it was coded as uncertain. Unfortunately these codes were unreliable, and therefore could not be used to draw inferences about the framing process.

The most likely explanation for this lack of reliability is the ambiguity of the phrase, "I think." In the coding process, this phrase was interpreted in two possible ways. On one hand, it was an indicator of psychological uncertainty (e.g. "I think it will work to grind it on that side."). At the same time, it was also one of the key components in the expression of individual advocacy for an action (e.g. "I think it would be great to drive."). In the first case, it represents an attempt to hedge one's assessment of the situation. In the second case, it announces that the statement is the person's own opinion. Distinguishing these senses had to be done on a case-by-case basis and no practical way to get around this could be found.

Be that as it may, there is no question that uncertainty is an influence on decision-making in general (Boiney, 1993; Thaler, 2000; Fox & Weber, 2002). It may be that, in real world settings, people do not separate risk from other negative connotations in the assignment of negative framing to outcomes. Perhaps, in some cases at least, risk and uncertainty are non-specific and cannot be detected at the information level. Part of why the sniper-on-the-hill effect creates a negative tone in the situation is because decision makers have no way of knowing when the critical failure will occur.

Finally, it may be that risk is simply seen as a given in real world contexts; that no outcomes are sure things and that risk therefore does not bear mentioning. However, precise estimates of risk are usually seen most frequently in situations where operation timing and changes in resources must monitored closely. The fact that the MER context was such a situation makes it that much more surprising that probability estimates of success or failure were almost never mentioned in these meeting dialogues. In any case, for whatever reason this analysis was not sensitive to effects of risk and uncertainty and future work would require a new approach to measuring it.

4.4 OTHER CONCERNS FROM THE REASONING APPROACH

4.4.1 Other Influences on Cognitive Processing

Research on reasoning is extremely diverse, so additional considerations to this work could come from any number of directions. One important question is what other measures there are, besides the use or non-use of negations, for how decision frames are simplified or otherwise processed. One potential factor is the decision-maker's temporal proximity to the expected outcome. In temporal construal theory (Trope & Liberman, 2000, 2003), the key assumption is that the level of information detail that is included in the representation is influenced by the amount of time (i.e. temporal distance) between when a representation is formed and when an outcome of a choice will actually be experienced.

The general prediction is that events that are farther away in time will be construed at a relatively high level (abstract and with little detail), such that the representation includes the core structural aspects of the problem and describes the superordinate goals associated with the situation. In contrast, more proximal events will have lower-level (concrete and more detailed) representations that are anchored to the superficial features and subordinate goals of the situation. With respect to predicting frames it is expected that increased temporal distance will lead to an increase in the value of high-level construals and a decrease in the value of low-level construals. Trope & Liberman (2003) substantiate these predictions by noting that, in many cases, it is difficult to know all of the details of a situation until one gets closer to the actual event and that people are often not forced to finalize decisions and preferences until that point anyway.

Temporal construal theory clearly offers some basis for predicting mental accounts (super-ordinate and sub-ordinate) and when they will have positive or negative value associated with them. The primary obstacle to using this theory in drawing predictions for this analysis, however, was that the temporal proximity of the actions to their outcomes was not clear for many of the framed actions. Occasionally there were explicit references made to the proposed actions being part of a multi-sol plan, but it was not clear when a particular action would specifically take place or how long after it the outcomes would be evident.

Another factor that would likely affect valence framed representations is the degree to which decision makers hold special, or "protected values," related to the decision at hand (Bartels & Medin, 2007; Tanner & Medin, In Press). Protected values are generally those derived from moral or ethical principles, and as Bartels and Medin have shown, people with protected values may be less concerned about consequences than those without protected values.

One theory that is focused on the role of larger representations in decision-making is image theory (Beach, Puto, Heckler, Naylor, & Marble, 1996; Dunegan, 1995). According to Dunegan (1995), image theory proposes that decision-makers have three "images;" an image of morals, principles, and predispositions that guide the decision-making process (value image), an image of goals or objectives (trajectory image), and an image of plans and methods for reaching goals (strategic image). Taken together, these images define the decision situation and allow two types of decisions to be made. "Adoption" decisions involve choosing alternatives and "progress" decisions are made to determine whether selected alternatives are indeed getting the decision-maker closer to his or her objectives. Progress decisions are made by performing a compatibility test, which is a subjective assessment of how effective the current methods are at moving toward the goal.

Because it was a dynamic decision process that spanned several months, the MER planning task involved both adoption and progress decisions, so image theory may have been a good way to model this data. Although there was documentation to support characterization of the trajectory and strategic images, however, it could only be assumed that there was some form of value image at work in the context as well. The analyzed dialogue expressed strategies directly, and in some cases, gave clues to the trajectory that the mission was following in some of the high level statements made. The degree to which these statements were related to underlying values could not be ascertained with confidence. The other issue with using image theory is that it is difficult to make general predictions about framing behavior based on it. Image theory requires a very well defined set of context specific priorities, so it may have provided a model of framing in this context, but the likelihood of generalization would have been diminished as a result.

One factor that was not touched upon in this investigation was the influence of activity on the neural and physiological levels. There is a growing body of research being conducted in the emerging field of "neuroeconomics" (Camerer, Loewenstein, & Prelec, 2005; Fehr, Fischbacher, Kosfeld, 2005; Singer & Fehr, 2005), which examines the link between cortical processing and behavioral decision-making. One of the goals of this work is to locate the areas of the brain that are related to value (e.g. rewards and punishments, gains and losses, trust and fairness, etc.) and trace the paths of activation associated with decision conditions. Loewenstein (1996) has also put forth a theory about how visceral factors (i.e. immediate physical needs to satisfy appetites) influence decision behavior. The question of how these factors affect desires and goals is indeed important, but the focus of this study was on cognitive influences, so they were beyond the scope of this inquiry.

Finally, a remaining comment with respect to reasoning is that there was admittedly a very limited discussion of linguistic representation factors in this study. The effects of using particular types of terms were discussed earlier, but those references barely scratch the surface of the number of influences on framing related to language. Questions can be asked about what the true semantic associations are with particular terms or combinations of terms, or if any terms ever have a universally positive or negative connotation. There are many questions related to the pragmatic level as well (Sedivy, Tanenhaus, Chambers, & Carlson, 1999; Sedivy, 2003) What makes a person choose one term or formulation over another when framing a situation? Is frame formulation driven more by the motivation to characterize the situation accurately or to accomplish rhetorical goals? These are questions that have not really been addressed in studies of framing effects either, but if the broader question is how representations are formed, this is an important avenue to pursue further.

4.4.2 Absence of a Rational Choice Effect

Perhaps the most important question with respect to reasoning about framing is why there was no relationship between framing and implementation observed in this context. Because it is known that presented frames predict preference, one might wonder why selected frames are interesting to study if they do not predict behavior. The best explanation for this unexpected result can be found in the fact that decision-makers themselves generated the frames.

A number of studies in cognitive psychology have demonstrated that *generated* information can often be more useful to people than information that is *given* to them. In their work on reasoning with analogy, for example, Blanchette and Dunbar (2000) have shown that there is greater depth of processing and less focus on superficial characteristics when people generate their own analogies. Gick and Holyoak (1983) have shown that people will not engage in deep processing of analogies that are given to them unless prompted to do so. It has also been observed that students who generate their own elaborative explanations of course material learn the material more effectively than those students who rely only on external explanations (Chi, Bassok, Lewis, Reimann, & Glaser, 1989).

Framing is, by definition, a superficial feature of the decision, which is why framing effects were so surprising when they were originally shown. However, if generating one's own frame decreases one's reliance on superficial features, as suggested by the results of Blanchette and Dunbar, it is not surprising that there would be no relation to choice. Gick and Holyoak's results support the passive response assumption of Thaler, et al. (1997) that was discussed earlier. However, there is direct evidence from a study by Jou, Shanteau, & Harris (1996) that providing a rationale for features of the decision situation also leads to the elimination of framing effects, presumably by prompting deeper processing of the decision.

Jou, et al. (1996) devised rationales for the Asian disease situation and compared patterns of preference between participants who were given the rationales and those who were not. They found that, given the scenario without a rationale, people were significantly more risk averse under positive framing than under negative framing; a pattern that is consistent with the framing effect. When people were given rationales for the situation, however, there was no difference in risk-aversion between positive and negative framings. This pattern is analogous to what was found for frame preference in this study. When people have more reason and opportunity to think deeply about the decision, the impact of superficial features of the representation is eliminated.

Finally, given the Chi, et al. (1989) results, it is reasonable to suppose that, when decisions are framed by those who make them, the preferences derived from the frames will be more authentic. In the long run, the best performance measure for a decision is whether it contributes to reaching one's goals. If self-generation of representations does indeed lead to better performance in general, then it would seem that self-framing is most likely to help people achieve their goals.

4.5 OTHER CONCERNS FROM THE MOTIVATION APPROACH

The factors related to motivation that were addressed in this study focused on achievement of goals, which may individual only or group-group influenced, as well as rhetorical, which is really only relevant in contexts involving multiple people. Motivations, however, is a very complex phenomenon and the factors that were examined barely scratch the surface. Motivation related to individual personalities is another factor that was not touched upon in this study.

One potential influence on frame selection is optimism versus pessimism. This dimension is distinct from regulatory focus, which prompts selective attention and concern for particular outcomes (positive and negative). Optimism and pessimism involve valence-biased attitudes about the occurrence of outcomes in a situation, attitudes that may or may not be justified in the particular situation. The general attitude of the optimist is that positive outcomes will occur and that negative outcomes will not occur, for whatever reason. The pessimist automatically assumes the opposite; that negative outcomes will occur and positive outcomes will not. These attitudes are often so strong that they may lead a person to discount those outcomes that represent counter-examples to their expectations. That is, a pessimist who experiences a positive outcome may attempt to re-frame it to give it a more negative connotation and an optimist is likely to look for the "silver-lining" in any negative outcomes. These traits may contribute to the accomplishment of goals in some cases, but can also be simply self-serving attitudes in others, and the interpretation of frame selection patterns may be inaccurate to the degree that they are held by decision makers.

Optimism and pessimism is just one example of a personality dimension that might affect framing behavior. Different metrics of personality measure different dimensions, and no measures of personality were used in this study. Given that this was a group context, introversion and extroversion may have affected what frames were added to the public dialogue. With respect to the generation effect described above, it must also be noted that some people have stronger motivations toward deep cognitive processing than others, which would also influence these results. In sum, motivations are rarely pure or singular, such that the influence of personality on framing would be another issue to pursue in further research.

4.6 METHODOLOGICAL CONCERNS

4.6.1 Blindness to Framing Effects

Independent of any particular theoretical approach, there are those who might still take issue with the methods used in this study. One concern that is likely to come from the behavioral economics perspective, which is more related to method than content, is that it is difficult to predict framing effects using this method. This is true to a degree, but can be accounted for by defining framing effects appropriately for the level of analysis.

A look at prior work demonstrates that definitions of framing effects run along a spectrum of specificity. Li's (1998) definition is broad, referring to a framing effect as simply “a *change* in response behavior as a result of different descriptions of the same gamble,” while Dunegan (1996) defines the framing effect more narrowly as, "dissimilar choices triggered by objectively equivalent terms that have positive or negative connotations." And on the other end of the spectrum, Kuhberger (1998) identifies a framing effect even more specifically as “a general tendency of risk aversion for positively framed problems and a general tendency of risk-seeking for negatively framed problems.” In a general sense, any significant change in behavior resulting from different but equivalent descriptions of alternatives might be interpreted as a framing effect. Depending on the research design, however, one may be able to specify what direction the behavior will go in relative to the specific changes in the description.

A first step to addressing this issue is exemplified by the implementation analysis that was reported earlier. If it had been shown that the likelihood of implementing alternatives was significantly related to how they had been framed, there would have at least been a difference in the *effectiveness* of one frame over the other. That result would not have been a framing effect though. All definitions of framing effects are clear that any change in the description of alternatives must maintain the equivalence of their expected value. Because of this constraint, different effects of valence manipulation must be distinguished.

One example is the difference between a “framing” effect and what has been termed a “reflection” effect (Fagley, 1993). To illustrate, consider the Asian disease problem again.

Given a choice between the prospects “200 people will be saved” and “A one-third probability of saving all 600 people” people favor the first alternative. To get a framing effect, the valence of the prospects is changed (from “will be saved” to “will die”), but the numbers are changed as well. By using complementary information, the expected value of both prospects will still be equivalent (“400 people will die” vs. “A two-thirds probability that 600 people will die.”), but it generally causes people to favor the second alternative.

If just the valences are changed and all the numbers kept the same (“200 people will die” vs. “A one-third probability that 600 people will die.”), the expected values of the alternatives are now different so that it is now a new choice rather than a *re-framing* of the same one. In this case, a change in preference toward the risky alternative represents a reflection effect, rather than a framing effect. For a framing effect to occur, changing the valence must not change the essential character of the acts or the outcomes and it must not change the actual contingencies between the elements. If it does, the effect cannot be viewed as a “framing” effect. The reflection effect is a valence-based effect, but one that is distinct from a true framing effect.

In this study, no additional information was presented and the frame was not manipulated, so it was impossible to measure the effect of framing in the traditional way. There was no way to ensure that every representation that was naturally constructed would be matched to an equivalent counterpart of opposite frame. Because decision-makers were producing their own frames, some choice would result from whatever description was used, but to call any such result a “framing effect” would void the meaning of the term. As such, any effects related to positively or negatively valued information that were observed in this context can only be labeled *valence effects*.

4.6.2 Pitfalls of Exploratory Methods

Otherwise there are more general issues that might be raised with the methods as well. One potential critique is that this study was not driven by or even linked tightly to any *one* theory of decision-making. As discussed earlier, however, this is as much an advantage as it is a disadvantage. One of the responsibilities of psychology is to establish the psychological reality of theorized constructs. The in-vivo method is used to find evidence of the natural occurrence of behaviors. The best example in this study is rooted in the fact that the vast majority of studies done on framing effects have involved manipulations done at the verbal description level and a great deal of theory has been hung on these methods. This analysis did a detailed decomposition of verbal descriptions of decision thoughts and found no strong relation between selected frames and other elements involved in formulation. This result does not invalidate the research on framing effects, but it does raise into question whether the manipulations that researchers use to frame decisions are the same manipulations that people use in general.

At the same time, because this study examined several levels of psychological activity (i.e. cognitive, motivational, etc.), one might ask whether using verbal measures was justified in all cases. It is true that some of the theories were stretched somewhat in order to arrive at the dimensions coded here, and some constructs were particularly challenging to operationalize, but the major challenges have already been discussed. Uncertainty could not be coded with sufficient reliability and particular difficulties of coding operations were described in the methods section. Outcome framing and negations were the most straightforward dimensions, with the fewest disagreements, the clearest cues, and the closest conceptual links to their source theories. Inferring motivation from speech elements was perhaps the biggest inferential leap. However, the fact that there were some effects associated with them indicates that these dimensions captured something about behavior as well. In any case, because framing manipulations are indeed done most often on verbal information, some methodological liberty seemed justified for the sake of learning more about the relatively unmapped realm of decision framing.

Finally, a person might also have reservations about the coding of this data not being done with complete blindness to the hypotheses. The likelihood of this causing a bias in this case is low, however, because the second coder was aware only of what phenomenon was being researched and had not been informed of the predictions. In any case, what constitutes a gain or loss changes from situation to situation as the set of important resources changes. The ability to judge what is a positive or a negative outcome within a context like this requires a great deal of familiarity with the decision task. Both coders were well-trained on the jargon that was being used by the planners to describe operations, on the key technical features of the rovers, and on the particular structure of the planning process used in these missions. Without that background knowledge, the analysis of the situation would not have been possible.

4.6.3 Group Influences on Individual Behavior

It has already been observed that individual framing of planning statements may have been somewhat unnatural given that this was a group setting. Statistical methods for tracking the group influences were not applicable in this study, however some potential factors can still be identified for consideration. First, is the question of how a decision is reached across contributed statements from multiple people. There are many theories about how meaning emerges within group dialogues (Stasser & Dietz-Uhler, 2001; Tindale, Meisenhelder, Dykema-Engblade, & Hogg, 2001). One question is the degree to which knowledge is shared by members versus distributed among members. It may be that not everyone involved needs to know everything and that some distribution of knowledge reduces everyone's cognitive load. At the same time, for a decision to be made by the group, there must be a shared understanding of what the alternatives entail before consensus can be reached. Tindale, et al. (2001) note also that, in some situations where the best alternative cannot be determined objectively, the "correct" choice is often dictated by majority rule, regardless of whether it is or is not the most optimal option. Aside from the issue of efficiency, however, another consequence of the majority rule process is that the individual preferences of some group members may have been overshadowed by the majority preference.

A second potential influence is that, regardless of whether the group decision is ultimately congruent with each individual's preference, in a group setting a person may feel compelled to censor his or her suggestions to begin with, either because of emerging group majority opinions or because individual members who are of higher status are given precedence. In the MER planning context, the possibility of power differences as an influence was kept in check somewhat by a continuous rotation of meeting leaders from among the collaborating scientists. No single sub-group or individual served as sole facilitator for mission planning across the whole mission. At the same time, there was a spectrum of individual expertise, both within and between the science groups, ranging from tenured senior professors to graduate students. It may have been that only those who were at or above a certain level of expertise contributed significantly to the decision-making process. Because the video cameras that recorded the meetings were left stationary, the recordings did not follow individual speakers. As such, even with records of who was present at a given meeting, it was impossible to link individual statements to individual people in this context.

Pragmatic conversational norms might be a third factor at work in this context. Although people may have a natural tendency to pursue cognitive economy, as we develop language skills over time, we are also socialized to observe certain rules of conversation, such as Grice's maxims (Taylor & Taylor, 1990). There are four maxims attributed to Grice's cooperative principle, the first of which specifically implores that people should only provide as much information as is required in their statement. It would be quite difficult to distinguish adherence to this principle from concern for cognitive economy as the cause of a person's statement formulation. The maxim assumes that it is the common ground between both speakers that allows the rule to be applied, but otherwise the purpose of both rules and cognitive economy is to not overload the person to whom you are speaking. Other principles mandate truthfulness, relevance, clarity, and brevity. This factor and other aspects of conversational practice (e.g. speech acts, turn-taking, etc.) are important, but discourse analysis was beyond the scope of this study.

These are just a few examples of how behavior in groups might be different from behavior of individuals on their own. It may be that the general preference for positive framing that was observed was due to an in-group bias to keep matters as positive as possible. There are also issues of individual's sense of personal identity while in groups, general social network connections that could not be reliably mapped, and communications that took place outside of the recorded formal meetings. Because the recorded meetings were archived, it was impossible to control for these potential variables. In as much as the group decisions were an emergent result of the individual suggestions of members, however, these results are a valuable step toward understanding general frame selection tendencies.

4.6.4 Ability to Generalize

Finally, a constant concern in research is whether the results can be generalized. This concern is even more critical here because the coding was dependent upon an understanding of the specific context. To address this, one must consider what important features are common to all situations within a class of decision tasks. This planning process was functionally similar to any other planning situation in which there is a particular objective known to all participants, a particular set of resources or interests at stake, and a need to satisfy the interests of several individuals/groups (to name a few). One would expect to see similar patterns of framing in other environments where the task is similar, such as legislative sessions or corporate board meetings.

The group factor discussed earlier is an important defining feature of this particular decision task, and one potentially useful way to classify the MER planning process is as a *consensus* task (Regenwetter, Kim, Kantor, & Ho, 2007). The most common example of a consensus task is a political election. One or more stages of candidate nomination are conducted until a ballot is finalized. At that point, each voter decides on one candidate in each category and the candidates with the most votes are put into office. With respect to this study, every suggested action could be seen as a candidate nominated for election into a plan (i.e. a set of actions). Once the proposed general plan was constructed, each action was either in or out on the basis of time and/or engineering constraints. That final go/no-go decision on each action would correspond to the point of choice, but considering that the ballot is the final representation used for making the choice, this study was more interested in the ballot development process and how nominations were framed along the way.

In any event, decisions are made in different way in different situations. It is reasonable to generalize these results to other consensus situation, but one would have to be cautious about forming expectations about decision situations in which the task is very different. In military command, for example, decisions are made by individuals who use framed information from multiple sources to construct representations (e.g. departments or stations). In contrast, an employer attempting to choose an applicant to hire has a clear cut set of candidates to choose from, but he or she must frame each candidate based on the information that they provided in their application. As such, the type of decision task one is faced with might dictate the degree to which positive and negative information is used.

Alternatively, it is also possible that some decision situations are more positively or negatively oriented than others. Perhaps people are more positive in groups than they are individually. The MER context was defined by scientific goals to gain as much data as possible. Earlier, the framing-by-opportunity strategy was proposed as a general explanation for the predominance of positive framing that was observed. It may be that science is a particularly positive endeavor and that this framing strategy would not as well in other contexts. A medical triage situation may be predominantly negative, since the primary task there is to separate the *bad* from the *worse*. An efficiency expert making suggestions to an organization about how to improve their operations may present a more balanced mix of positive and negative frames; identifying both the costs and benefits of each options. Given the results of this study, however, that too could be moderated by expertise. At any rate, accounting for these possibilities also requires comparison of groups, so additional research is necessary to clarify further.

As a final note, whether the task type or the situation is the stronger influence, framing is always done either for oneself when making one's own decision or it is done specifically to influence someone else decision making process. When researchers present framed scenarios to participants in the laboratory, the researchers expects that the offered frame will influence the participant. In the MER situation, even though all the speakers had stakes in the decisions being made, the fact that they framed suggested alternatives for others to consider made this context a rather appropriate test of how people formulate framing with the intention of having an effect on choice.

4.7 FUTURE DIRECTIONS

A key advantage of the method used for this study is that it served as a first glance down multiple possible approaches to the question of decision framing. There are several avenues of follow-up research that appear especially promising. First, in order to determine whether there is real substance to the framing-by-opportunity hypothesis, it would be helpful to conduct some experimental tests on the phenomenon. Using a simpler planning task and manipulating the situational features with respect to how many options there objectively are would help sort out the conditions under which it is a viable representation strategy. Based on the results of this study, it would be useful to explore further the influences of task complexity and expertise as well. These factors are by no means new, but their impact on framing specifically deserves further attention.

Second, although mental accounts were not found to be related to framing in these results, it would be premature to dismiss their relevance entirely. As noted above, perhaps the level of detail included in the frame, and the value associated with it, is related to the amount of time between action and outcome. Perhaps a study that uses a more accurate measure of temporal distance would reveal more interesting patterns.

Finally, it was observed, based on McKenzie and Nelson (2003) work, that people's descriptions of the situation at hand can be influenced by initial reference points just as preference for alternatives can. If that is the case, one aspect of this data that was not explored for this study was the set of statements coded as "information asides." These were the statements that established the current situation status in each meeting by reporting the outcomes of the previous day's implemented activity. As such, the most logical next step with regard to the in-vivo method would be to code for reference points in those statements.

4.8 CONCLUSION

Predicting peoples' representations is a complex and multi-faceted endeavor in general. The method used here showed how much more true this is in natural environments. If the results of this study indicate anything, however, it is that determinants of representations are not a matter of random chance. There are real patterns to be found in people's frame selection tendencies. In a general sense, people appear to focus primarily on positive aspects of the decision. At the same time, the evidence found here also suggests that greater experience with particular decision situations may lead to a more balanced consideration of positive and negative information. As important as it is to keep the positive aspects in mind, negative aspects cannot be ignored when considering what course of action to take. This research, and more like it, may be used to help people find the appropriate balance by understanding the sources from which their representations are derived.

APPENDIX A

DETAILED DESCRIPTION OF THE MARS EXPLORATION ROVER MISSION

A.1 THE ROVERS

The rovers are identical in construction. Each is equipped with solar panels for recharging power cells and a set of six treaded wheels for driving. Data is stored in a flash-memory device where it is buffered for transmission back to Earth. There are three different communication antennae on each rover; a low-gain, a high-gain, and a UHF. Signals between Mars and Earth may be exchanged directly if the rover in question is on the side of the planet that is in line with Earth. They may also be achieved with satellite assistance via the Odyssey satellite, which has been orbiting Mars and collecting data from space for a longer period of time.

To perform its data collection functions, each rover has six specialized scientific instruments, which are mounted on the rover in locations appropriate to the uses. Rising up vertically from the main body of the rover like a stem is the Pancam Mast Assembly (PMA). Mounted at the top of this column is the panoramic camera (Pancam), which is capable of taking multi-panel panoramic images of landscapes and atmospheric conditions. The navigational camera (Navcam) is also located on this mast. While the pancam may provide a general overview of what is ahead, the navcam is fine-tuned to gather information about the topology of the surface immediately in front of the rover. Images from this camera allow the engineers to select driving routes with the least likelihood of hazardous terrain. In combination, these cameras allow for all manner of remote sensing (see Figure 13).

Figure 13. Image of Mars Exploration Rover (MER)

Other instruments focus on the physical characteristics of Mars, including spectral, thermal, and material analyses. The Mini-TES is an interferometer that is housed in the main body of the rover, but receives data by way of the PMA. A mirror at the top of the PMA reflects light down to the Mini-TES like a periscope. The Mini-TES can analyze the material composition of the atmosphere based on the wavelengths of light it registers. Four more instruments are mounted on the Instrument Deployment Device (IDD), an arm that extends out from the front of the rover with one elbow joint. The Alpha-Particle X-Ray Spectrometer (APXS) and the Mossbauer Spectrometer can gather information about rock and soil composition by emitting different types of radiation and measuring the pattern that is reflected back. The Microscopic Imager is a high resolution camera (similar to the Pancam) that can be directed at surface features to record naturally reflected light. Different filters can be used when looking for evidence of particular materials. Finally, the Rock Abrasion Tool (RAT), can physically brush and/or scratch rocks in order to gain access to sub-surface composition.

A.2 THE PLANNING PROCESS

Each sol started with a downlink transmission from Mars containing data and status and a rapid analysis of that information by scientists and engineers. This was followed by several stages of planning, and then an uplink transmission to Mars containing an instruction set for the rovers to complete in the following sol. Figure 14 illustrates the high-level sequence of planning steps that occurred during each sol.

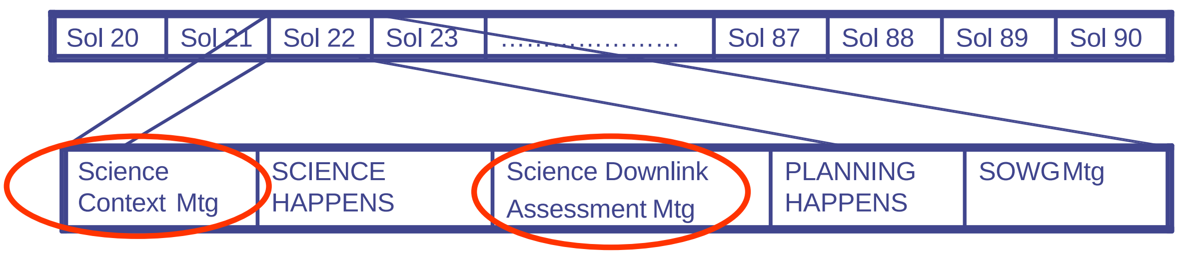

Figure 14. General Schedule of Planning Meetings Within a Sol

The first meeting on each sol, designated "*science context,*" was held to review what was returned from the previous sol's activities. After this initial meeting scientists met in their topic area groups to analyze and interpret the data that was pertinent to their interests. Not every group got new data each day, but each group was represented at the science context meeting in order to be updated on the status of the rover and to determine if there were opportunities available that their group would want to pursue.

The second big group meeting of the day, the "*science downlink assessment*" meeting, occurred in the early afternoons and scientists brought their requests for what data to collect to the table. The science context meetings were crucial to decision-making in terms of specifying the preconditions for the decisions, but the science assessment meetings are where the major choices were made about what activities to pursue. Between these two meetings, the situation status was monitored, advantages and disadvantages of different courses of action were weighed, constraints were considered, and trade-offs were negotiated until a rough conceptual plan was derived for what activities the rover would engage in during the following sol.

After a period of some finer grain tuning of the plan by the individual science groups, the "*science operations working group*" meeting took place to finalize the sequence of implementation for the selected operations. The purpose of this meeting was to verify previously decided-upon activities and to make sure that they fit into the time frame. No significant amount of additional decision-making took place at this point. Once the feasibility of the plan was verified from an engineering perspective the engineers coded the plan into an instruction set and transmitted it to the rover. This sequence of meetings and planning tasks was conducted each sol, for each rover, throughout the entire mission.

APPENDIX B

DECISION MAKING CODING SCHEME

A. Planning vs. Non-Planning

Planning = 1

- Talk related to an activity or observation that will take place on the following day or days
- Talk related to activity from the previous day that impacts the current day's plan but only when directly related to a planning activity. (e.g. we drove yesterday, so we'll RAT today)
- Talk referring to data that affects the current plan (e.g. according to this image, we can reach this and this with the IDD)
  - Within the speech segment, highlight the portions that correspond to parts of the decision thought and color them appropriately.
  - Count each reference, even if it appears to be a repeat. These will be sorted out later.

    Action- (BLUE), rover activities that will be done or are currently under consideration

    Consequence- (RED), anything that is expected to result from actions

Informational Aside = Info Aside

- Neutral contextual information that sets up a general motivation for the decision at hand
- Includes questions, unless they are the only explicit reference to action being planned

Meta-Planning = 2

- References to specific decisions that will be made (i.e. action-planning that will take place) at a future time
- References to current meeting logistics and assignments of specific tasks to people

Difficult to Determine = ?

- References to terms and concepts clearly related to planning, but with statements that do not predicate a decision or connect with those around them.

Non-planning = "/"

- talk that does not fit into the above categories

COMMENTS:

1) If multiple references are made to the same action, code them all as planning.
2) If it is observed that taking one action will affect the possibility of taking another action, for whatever reason, the statement is referring to a <u>consequence</u>.
   a. Ability to take an action is a resource.
   b. Increased information or knowledge is a resource.
   c. Time, storage space, and power are all resources.

3) If a stated motivation for an action refers to or implies a concrete gain or loss of something, then the statement is referring to a consequence. Otherwise it is a general reason.
4) If it is observed that an action is not possible, with a reason that refers to a consequence, the statement is referring to a planning action.
5) If it is observed that an action is just not possible, with no more than a general reason, the statement is referring to a constraint.
6) If it is observed that taking one action implies that another action will inevitably follow, the statement is referring to a contingency.
7) General constraints, contingencies, and reasons fall in the category of Information Asides.
8) If they are planning for several sols ahead during the meeting at hand, it is planning (1), but if they refer to what planning will be done in a later meeting, it is meta-planning (2).

B. Operations

(NONE)- Statement is consequence only
(SUPER)ordinate-Level:

- Mission- mission level goals; things that are true "in general"; comparisons to the other rover
  - e.g. "we should go to victoria crater"
  - e.g. "we need to do more drive sols to meet our goals" or "to reach 600 meters"
  - e.g. "we need to have X kb space available in flash at all times."
- Multi-Sol- sol-tree or current-stage goals; goals for a few sols
  - e.g. "we'll spend 3 days at Bob rock before we move on"
  - e.g. "as we drive the 100 meters to Bob rock we should sample the soil every 4 meters"

(BASIC)-Level:

- Sol- today's goals; discussion is often framed as "tomorrow" because the plan the team creates today is for tomorrow,
  - discussion of a single sol in the future (e.g., today is sol 20 and we want to do x on sol 25),
  - Discussion of the details of several successive sols, each listed individually (e.g. "on sol 24 we'll do X. Then on 25 we'll…" (more detail than multi-sol plan)
  - Reference to multiple options at once. (i.e. to a choice that must be made)
  - e.g. "we should stay and do RAT today instead of driving away from Bob rock"
- Instrument Category- several instruments mentioned at a high level
  - *Touch-and-Go's, Re-/Deploy IDD arm, IDD-ing, Remote Sensing, Driving, Naps*
  - e.g. "afternoon remote sensing with pancam and Mini-TES" on the current sol or a sol in the future; e.g. "lets brush and then RAT and then IDD",
- Science Instrument Without Target- where the discussion is about the activity in general,
  - Includes Routine, General Observations and Maintenance tasks
  - Includes references to target without specifying instrument and to sets of targets or sub-targets not specifically described
  - Instrument can be implied (e.g. "a panorama"= pancam, "full spectroscopy")
  - e.g. "should we take a Pancam or do we also need a Mini-TES?"

(SUB)ordinate-Level:

- Science Instrument With Target- instrument with target chosen
  - *RAT, APXS, MI, Mossbauer, Mini-TES, Pancam, Navcam (*can be implied*)*
  - Includes Non-routine, Specific Observations and Maintenance tasks
  - May be just instrument+target or instrument+parameter, but there must be instrument (specific or implied)
  - Drives to specific target (e.g. "we'll drive to Gusev") or of specific length ("drive for 50m")

  - Target can be implied (i.e. carried over from prior statement), but must have explicit, definite reference (even if only relative terms are used)
  - e.g. "I want to do a pancam of <X> rock"
  - e.g. “we should use the time between Odyssey pass and nap to brush Bob rock"
- Parameter- parameter level goals
  - Filters on images, autonav versus directed drive, etc.
  - *Specific comm. Antenna (HGA, LGA, UHF)*
  - e.g. “what is our specific target?” (sub-targets on larger target object/area)
  - e.g. “what kind of image quality (or compression) do we need?”
  - Includes specific scheduling/timing of operations, and prioritization of single operations

Parameters:
General- TARGET, time operation will be started/stopped, duration of operation
Of Target- name, size, reachable (i.e. within the work-volume) physical features, number of sub-targets

- Sub-Targets may be spoken of in terms of the same parameters

Of Drive- target/destination, long vs. short, specific distance, direction, actively direct or auto-navigated
Of Communication- antenna to be used (LGA/HGA/UHF),

- Of Odyssey Pass- timing, data to get

Of Simple Instrument Operations- Target (for all)

- IDD Arm- deploy/re-deploy, moved
  - RAT- brush vs. grind, grind time/depth
  - APXS- integration time
  - MI- (integration time?)
  - Mossbauer
- PMA- elevation, azimuth
  - Pancam- dimensions (e.g. 2*3), resolution, filters, compression, image quality
  - Mini-TES
  - Navcam
  - “Remote Sensing” may be a combination of Pancam and Navcam

Of Instrument Operation Sets/Sequences- Target (for all)

- Touch and Go- instrument/s to be used, drive parameters
- Go/No-Go- plan/operation under consideration

C. Outcomes

(POS)itive-

- Statement refers to *gaining* something of value or the action *profiting* them in some way
  - “We’ll get the data we need to figure out what that is.”
  - “We’ll be able to position the RAT better then.”
- Statement refers to *saving* or *preserving* something of value
  - “If we go with the other target, we’ll save time and energy.”
- Statement refers to a problem or issue that will be *resolved* if the action is taken
  - “This will take care of our energy problem.”
- Statement refers to a new *advantage* that will be experienced as a result of the action
  - “It will probably be a smoother drive in this direction.”

(N)eutral- No clear gain or loss; action will result in a new general condition, another action will inevitably/naturally follow from the action being referred to, etc.

(NEG)ative-

- Statement refers to *losing* something of value or the action *costing* them in some way
  - “We will not have another opportunity to look at this.”

    - “That will be really energy intensive.”
- Statement refers to a problem or issue that will be *experienced* if the action is taken
    - “We may have a flash issue if we try to get that image resolution.”
- Statement refers to a new *disadvantage* that will be experienced as a result of the action

  <u>**(NONE)**</u> **-** No consequence

D. Attributes- resources that are available and consumed in the course of the rover’s activities

- <u>Activity</u>- the gain/loss of the ability to do some operation or take some action
- <u>Data</u>- the gain/loss of scientific data or of information needed for further decision-making
- <u>Power/Energy</u>- the gain/loss of rover power (usually in watt/hours)
- <u>Time/Timing</u>- the gain/loss of time involved in doing activity; the added constraint on scheduling posed by a particular activity
- <u>Memory/Data Volume</u>- the gain/loss of flash drive space associated with action
- <u>Mileage/Distance</u>- the distance to a proposed target (drive cost), the amount of driving that will be done (gain toward mileage milestone)
- <u>Other</u>- something specific not listed here
- <u>NONE</u>- if the tone of the outcome is positive or negative, but there is no resource referred to

E. Negations

- Outcomes need to be coded independent of Negations
- NONE, One, Two
    - Negations of Actions
        - “Doing this will allow us broader maneuverability in the future” = POS
        - “<u>NOT</u> doing this will give us more drive time to work with” = POS
        - “If we don’t do this, we’ll run out of flash by sol 68” = NEG
    - Negations of Outcomes
        - “If we drive, we’re <u>NOT</u> going to get the science in.” = POS
        - “If we drive, we’re <u>NOT</u> going to lose any time.” = NEG
        - “There is <u>NO</u> disadvantage to waiting a little longer.” = NEG

F. Modality

<u>**Actual**</u>- when the activity is referred to as something that is definitely going to happen,

- When the activity is already in the plan
- “We will be doing X” or “When we do X…”

<u>**Possible**</u>- when the activity is referred to as something that can be done

- “If we do X…” -when a hypothetical consequence is evaluated relative to a certain activity
- “We can…,” “X is an option”
- When the action is just a reference to target/s- “there is this smooth area” or “X is in the work volume”

<u>**Necessary**</u>- when the activity is referred to as something that needs to happen

- “We really should drive today, or…”
- “This has to happen before we move on”
- “The mission manager asked us to…”

<u>**Ideal**</u>- when the activity is referred to as something that is preferable if circumstances allow it

- “It would really be great to…”
- “They want us to try to…”
- “…the best candidate/option…”

* References to the explicit priority of an activity are either required or ideal activities. Judge by context.

G. Advocacy

(POS)itive- any indication that an individual is actively in support of an action or pushing to have an activity happen

- "I would be in favor of…" or "I recommend…"

(NEG)ative- any indication that an individual is actively against an action or pushing to have an activity NOT happen

- "I'm not happy with the idea of…" or "It is not in our best interests to…"

(NONE)

- Does NOT include "I think we should…" (this would be Uncertain, Necessary)

H. Movement

(POS)itive-

- Statement refers to *moving toward* or *approaching* a positive or negative outcome
- "If we do the drive, we will be that much closer to our 600 meter benchmark."
- "If we do the integration overnight, that will allow us to mini-TES tomorrow."

(NONE)- the outcome (gain or loss) is immediate; (i.e. will be a direct result of action)

(NEG)ative-

- Statement refers to *moving away from* or *avoiding* a positive or negative outcome
- "If we go toward this other target, we will miss that rough patch."
- "We can definitely do the long drive, but we will forego any chance to do science."

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