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THE IMPACT OF COGNITIVE BIASES ON DELAYS IN PRODUCT DEVELOPMENT TEAMS

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THE IMPACT OF COGNITIVE BIASES ON DELAYS IN PRODUCT DEVELOPMENT TEAMS

In this study, we conceptually establish and empirically examine the relationship between cognitive biases and incidence of delays in 25 product development teams. Results indicate that teams which reported a higher level of information/alternatives evaluation bias experienced more and different types of delays than low bias teams.

It seems obvious that one of the highest leverage points in organizations for shortening product development cycle time would be to minimize delays (Stata, 1989), yet, there is a paucity of research on this topic. While a number of studies describe types of disturbances or impediments that have delayed unstructured and strategic decision making processes, there has not been much systematic investigation into the sources of these delays, though there have been speculations to it's nature. In this study, we examine the impact of one such source on the incidence of delays in the product development process. Specifically, the study was designed to investigate the impact of cognitive process biases on the occurrence of delays in product development teams.

LITERATURE REVIEW AND BACKGROUND

Delays in Product Development

New product development efforts inevitably encounter anomalous problems which represent key choice points where a strategic or unstructured decision needs to be made (Bodewitz, DeVries & Weeder, 1988). Studies which have examined these decision making processes then are particularly relevant. For example, in their examination of twenty-five unstructured decision processes, Mintzberg, Raisinghani, and Theoret (1976) recorded six major disturbances which delayed development. The first set of disturbances was characterized as 'interrupts.' External interrupts were caused by changes emanating from the task environment. Internal interrupts were the result of either political impasses or new options being introduced late in the development process. Similarly, Stalk and Hout (1990) observed interrupts as higher level managers attempted to introduce new options in the development process, what they referred to as feature creep.' A second set of disturbances, timing delays,' were observed to involve incidences when the development process was intentionally slowed down by decision-makers. 'Scheduling delays', a third type of disturbance, occurred when tasks could not be performed because they were waiting in sequence. For example, scheduling delays occurred as developers were waiting in the queue to get a work request approved. The fourth disturbance was associated with 'feedback delays,' which amounted to waiting for the results of previous work steps. In the most complex and novel decision situations, a fifth set of disturbances--comprehension cycle delays--was observed to have occurred with the greatest frequency. Decisions were postponed as developers recycled back to earlier stages in order to more fully comprehend technology and design issues. Finally, 'failure recycle delays' occurred when no acceptable solution to a problem could be found.

In an examination of 150 strategic decisions, Hickson, Butler, Cray, Mallory and Wilson (1986) found that decisions most often encountered delays when participants expended an extraordinate amount of their time searching for information, solving problems, acquiring resources, reconsidering alternatives, and overcoming either internal or external politics. Specifically, their study identified nine impediments which delayed decision making processes: (1) sequencing delays; (2) coordinating delays; (3) timing delays; (4) searching delays; (5) problem-solving delays; (6) supplying/resource delays; (7) recycling delays; (8) internal resistance; and (9) external resistance. Of the nine impediments, the most frequently occurring delays were found to be the result of unsolved problems and influential political resistance.

Based on interviews of 38 managers and technologists involved in new product development projects across 12 large technology-based firms, Gupta and Wilemon (1990) identified several major reasons for product development delays. The most cited reason for product development delays was attributed to poor definition of product requirements which necessitated frequent and unplanned changes. Technological uncertainties as a general category was cited as the second major reason for delays. In corroboration with Mintzberg et al. (1976) and Stalk and Hout's (1990) identification of 'interrupts' and 'feature creep,' these delays were often compounded by desires to include the latest technical improvement. Other major reasons for delays were attributed to a lack of senior management support; a lack of resources; and poor project management. In an ethnographic comparison of two new product development projects in a high technology organization, Purser (1992) found delays to be significantly higher in the project where members denied the existence of problems or shortcomings in prototypes, even if there was contradictory data that indicated their solutions were problematic.

Cognitive basis for delays

The literature on strategic decision making in new product development suggests that one of the major factors contributing to delays is cognitive processing limitations (Purser, 1990; Emmanuelides, 1991; Purser & Pasmore, 1992). Mintzberg et al. (1976) maintain that the choice situation is subject to distortion due to cognitive limits and unintended as well as intended biases. Further, adoption of higher aspiration levels in the form of fast cycle time goals can inadvertently reduce the need to search for information and evaluates alternatives (Hogarth, 1987). Interestingly, in contrasting the 'variety amplification' abilities of Japanese product development teams to those in the U.S. which are biased towards action and "variety reduction,' Imai, Takeuchi and Nonaka (1985) conclude that a 'bias for action' may have unintended consequences that result in premature convergence upon the first available alternative.

Purser (1990), drawing on the work of Driver and Streufert (1967), suggests that product development teams must effectively perform both perceptual and executive subsystems tasks. Driver and Streufert (1967) maintain that creative solutions to complex decisions are processed through, and depend upon, the effective functioning of the perceptual and executive subsystems of a group. Dysfunctions in the perceptual subsystem of a decision-making group will show its effects in reduced data search, faulty diagnoses, and a limited ability to code, interrelate, evaluate and store input. Hence, if the perceptual capacity of a problem-solving or decision-making group is impaired, it is unlikely that errors and deviations will be monitored or detected when they do occur. Similarly, executive subsystem dysfunction is symptomatic of the inability of a problem-solving or decision-making group to translate perceptual input into decisions, actions, or implementation strategies. Thus, we argue that most delays in new product development teams are symptomatic of perceptual and executive subsystem dysfunctions.

Cognitive biases

Theory and research in the fields of cognitive psychology and behavioral decision making have identified a number of general inferential rules that people seem to use when evaluating uncertainty (Kahneman, Slovic, & Tversky, 1982; Nesbitt & Ross, 1980). These rules are often referred to as 'process biases' or 'heuristics' which come into play in simplifying uncertainty and may lead to negative consequences such as poor and faulty decisions. As Tversky and Kahneman suggest; 'In general these heuristics are quite useful, but sometimes they lead to severe and systematic errors.' (Tversky & Kahneman, 1982: p.1.) The impact of these biases can be expected to be more prevalent in conditions of high uncertainty, complexity, and ambiguity, such as strategic planning (Schwenk, 1984; Barnes, 1984), nuclear power plant emergencies (Reason, 1990), or organizational diagnosis (Armenakis, Mossholder & Harris, 1990). When exposed to high environmental uncertainty, complexity, and ambiguity, decision makers may repress awareness of the uncertainty, modify their perceptions of the environment so that it appears more certain, and tend to act on a simplified model of reality which they construct (Schwenk, 1984). These simplification processes are essentially a defense to counteract the dissonance experienced when exposed to a state of psychological uncertainty (Michael, 1973).

Comprehensive lists of cognitive simplification processes have been developed (Hogarth, 1987; Schwenk, 1984; Slovic, Fischhoff, & Lichenstein, 1977; Kahneman, Slovic & Tversky, 1982; Nesbitt & Ross, 1980). Of particular relevance is an excellent summary by Schwenk (1984) of eleven cognitive simplification processes which he proposes can impact different stages of the strategy formulation process, namely problem identification, alternatives generation, and evaluation/selection. His focus is on simplification processes for which laboratory evidence exists and field examples can be identified, and 'which has some probability of affecting decision making' in strategy formulation (p. 114).

The eleven biases considered include: (1) *prior hypothesis bias,* where an erroneous hypothesis about the relationship between variables guides decision making even if abundant evidence over numerous trials suggested the hypothesis was wrong (Levine, 1971; Kozielecki, 1981); (2) *adjustment and anchoring,* where initial judgments about values of variables are not revised as new data is reported, consequently, final estimates of values are biased towards initial values (Tversky & Kahneman, 1974); (3) *escalation of commitment* is a tendency to allocate more resources to projects which are failing in the hope of salvaging an already substantial investment (Staw, 1981); (4*) reasoning by analogy* entails the application of analogies and images from simpler situations to complex problems (Steinbruner, 1974); (5) *single outcome calculation,* occurs when focus is limited to a single goal and a single alternative course of action to achieve it, bolstered by arguments to magnify the attractiveness of the desired alternative (Steinbruner, 1974; Janis & Mann, 1977); (6) *inferences of impossibility* involves identifying negative aspects of non-preferred alternatives in order to convince oneself they are not possible to implement (Steinbruner, 1974); (7) *denying value trade-offs* is a tendency to over-value a favored alternative by denying value trade-offs (Steinbruner, 1974); (8) *problem sets* occur when there is a repeated use of one problem-solving strategy (Newell & Simon, 1972); (9) *representativeness bias* (Tversky & Kahneman, 1974) is a tendency to overestimate the extent to which a sample is representative of population and can include generalization from a few vividly described cases and overestimating accuracy of predictions (Nesbitt & Ross, 1982); (10) *illusion of control* is an overestimation of the extent to which the outcomes of a strategy are under one or other's personal control (Langer, 1975); and (11*) devaluation of partially described alternatives,* as the name suggests, is devaluing the alternative that is partially described (Yates, Jagacinski, & Faber, 1978). Schwenk's (1984) framework is very germane to the product development process in light of the fact that, typically, product development teams encounter conditions of high technical, organizational, and market uncertainty (Moenart & Souder, 1990; Souder, 1987; Emmanuelides, 1991) and their decision making, similar to strategic decision processes, is characterized by novelty, complexity and open-endedness (Mintzberg et al., 1976). Further, product development processes similar to strategy formulation have been characterized by stages of problem identification, alternatives generation and evaluation/selection (Kanter, 1988; Steele, 1989).

FOCUS OF THE PRESENT STUDY

As a strategy to reduce product development time, Emmanuelides (1991) calls for increased information processing capabilities to be built into product development teams in order to overcome cognitive limitations.

Likewise, Purser and Pasmore (1992) contend that cognitive biases and faulty decision heuristics can potentially lead to bottlenecks and mistakes in the knowledge conversion process. While there has been an uniform call for exploring the impact of cognitive processing limitations on product development delays, no specific empirical studies examining the relationship have been documented. Further, since many of the biases have been examined exclusively in laboratory settings, the need for documenting their existence and effects has been emphasized (Schwenk, 1984). Accordingly, this study was exploratory in nature, and was designed to empirically investigate the impact of cognitive biases on the occurrence of delays in product development teams. Specifically, this study was designed to explore the following research questions:

1. Is there a significant relationship between the reported incidence of cognitive biases and the reported occurrence of delays in product development projects?
2. Is there a significant relationship between specific cognitive biases and specific types of delays?

METHODS

Subjects

The subjects for this study were scientists and technical personnel employed in the research and development center of the Pharmaceutical division of a major consumer products company. Data was collected as part of a larger sociotechnical system change effort initiated for redesigning the center. A survey was administered to all of the 197 research and development personnel. Of the 158 subjects whom responded, 49 percent were Ph.D.s with specializations varying from chemistry, life sciences, toxicology, medicine and biopharmaceutics. The total responses produced a return rate of 80%. The subjects were organized across 25 concurrent and ongoing drug development project teams; subjects were instructed to respond to survey items based upon real-time project deliberations. In addition, only professionals who spent the majority of their time on a single project were included in the analysis.

Delay scale

Based on our earlier review and synthesis of the literature, we developed a delay scale. This nine item scale describes different types of delays and is scored so that a high score (7) reflects a high frequency of the particular delay and (1) reflects a non-incidence or infrequent occurrence of the delay. Items one and two--having to do with theory development and drug testing--were constructed for measuring the frequency of comprehension cycle (Mintzberg et al., 1976), problem-solving and searching (Hickson et al., 1986) type delays. Based on Gupta and Wilemon's (1990) study, item three measures the incidence of delays related to frequent changes in product requirements and the new option interrupts as described by Mintzberg et al. (1976). Delays in acquiring and coordinating the necessary resources were measured using items four and five; these items correspond to the scheduling delays as noted by Mintzberg et al. (1976), the coordinating and supplying/resource delays as described by Hickson et al. (1986), and the lack of resources delays as cited by Gupta and Wilemon (1990). Item six measures the incidence of delays related to unrealistic time schedules, which is equivalent to the timing delays as noted by both Mintzberg et al. (1976) and Hickson et al. (1986). Delays in recognizing and responding to failures were measured using item seven. This item is based on Gupta and Wilemon's (1990) category of delay having to do with managers' unwillingness to learn from past failures and Purser's (1992) observation of dysfunctional project team behavior. Item eight measures delays in getting management approvals which is directly related to the sequencing delays described by Hickson et al. (1986). Finally, item nine--delays in overcoming internal resistance and politics-was also derived from the internal and political resistance delays as reported by Hickson et al. (1986).

Cognitive biases scale

Drawing mainly from the summary of Schwenk (1984), a scale was constructed to measure cognitive biases. We reframed the items in a language that was most fitting to the pharmaceutical R&D population. Termed 'common pitfalls in selecting and evaluating alternatives' this scale consisted of fourteen items. Subjects were asked to rate the extent to which each bias was experienced as impacting the deliberations of their project team on a seven point response format ranging from 'To no extent' to To a great extent. Both scales were pre-tested on fifteen subjects to assess clarity and face validity.

Analyses

In order to assess the construct validity of the scales employed, two factor analyses were undertaken. To decide the number of factors to be extracted, the latent root criterion was used with a minimum eigen value specification of one. The eigen value criterion of one is a well accepted standard when component factor analysis is chosen as the basic model (Hair, Anderson, Tatham, & Grablowsky, 1984). Principal component factor solutions utilizing varimax rotation were obtained for both scales. Reliability analyses for the two scales were conducted. In addition, an overall delay score was computed for each product development team by 10 averaging across all items of the delay scale. Subsequently the teams were classified into High and Low bias teams based using median splits of the four factors scores which emerged from the factor analysis of the bias scale leading to 16 low bias teams and 9 high bias teams for factor one, 18 low and 9 high for factor two, 17 low and 8 high for factor three, t 5 low and 10 high for factor four. MANOVAs were used to establish that the dichotomization into Low and High bias teams were in fact statistically significant. Further, to test for significant differences between the low and high bias teams on the delay factors and items, MANOVAs and ANOVAs were conducted.

RESULTS

As indicated in Table 1, four factors emerged from the factor analysis of the cognitive bias scale. The first factor which included items such as favored hypothesis bias, oversimplification, overemphasizing a problem solving strategy, overconfidence in the illusion of prediction, illusion of one's personal control and illusion of another's personal control was identified as **Problem Framing bias** since many of the items such as favored hypothesis, oversimplification and overemphasizing a problem solving strategy had to do with how effectively a problem or idea was formulated. The second factor focused on biases concerning information and alternatives evaluation namely; using favored information sources, magnifying preferred alternatives, denying risk-benefit trade-offs, amplifying negative aspects of non-preferred alternatives, devaluing partially described alternatives, and limited generalization of theories, models, and findings and was termed as **Information and alternatives evaluation bias.** The third factor showed a positive loading of a single item-inadequate reasoning--which we **addressed as Reasoning bias.** The fourth factor also had a single item, which had to do with allocation of more resources to failing alternatives, was termed as **Escalating commitment bias.** Factor scores were computed by averaging across items. Reliability analysis on the cognitive bias scale showed good internal consistency with a Cronbach alpha value of .94, well exceeding the .70 value recommended by Nunally (1978).

Table 1

Factor Analysis of Cognitive Biases (Pitfalls) Scale

Items	Factor 1 Problem Framing Bias	Factor 2 Information and Evaluation Bias	Factor 3 Reasoning Bias	Factor 4 Escalating Commitment Bias
1. Favored hypothesis bias	.725	.178	.449	.140
2. Favored information sources	.185	.582	.532	.197
3. Allocating more resources	.199	.124	.141	.815
4. Inadequate reasoning	.178	.107	.911	-.004
5. Oversimplification	.620	-.116	.370	.175
6. Magnifying preferred alternative	.282	.623	.411	.269
7. Denying risk-benefit trade-offs	.453	.540	.357	-.250
8. Amplifying negative aspects of non-preferred alternative	.002	.849	.103	-.135
9. Devaluating partially described alternatives	.349	.518	.196	-.325
10. Overemphasizing a problem solving strategy	.758	.230	.291	-.185
11. Limited generalization of theories, models, and findings	.303	.789	-.028	.126
12. Overconfidence in illusion of prediction	.664	.556	-.081	.290
13. Illusion of one's personal control	.884	.235	.183	.089
14. Illusion of another's personal control	.844	.289	-.081	.032
Eigen value	6.49	1.615	1.23	1.21
Pct. of Variance	46.5%	11.5%	8.8%	8.6%

The factor analysis of the delay scale elicited three factors, as shown in Table 2. The first factor designated as **Timing and scheduling delays** included delays In responding to frequent changes in program activities, delays in getting resources. delays experienced due to over-optimistic schedules and delays in recognizing in that prior solutions were sub-optimal. The second factor composed of delays in getting crucial people together, delays in getting management approvals and sanctions, and delays in overcoming internal resistance and politics was labeled **Project management delays.** The third factor represented by delays in developing basic theory and models, and delays in synthesizing and testing new drug candidates was called **Comprehension delays.** Factor scores were computed by averaging across items. The Cronbach alpha for this scale was .80.

Table 2

Factor Analysis of Delay Scale

Items	Factor 1 Timing and Scheduling Delays	Factor 2 Project Management Delays	Factor 3 Comprehension Cycle Delays
1. Delays in developing basic theory and models	.205	.034	.864
2. Delays in testing and synthesizing new drug candidates	.020	.162	.863
3. Delays in responding to frequent changes in product requirements	.745	.171	.003
4. Delays in assembling sufficient resources	.650	.242	.152
5. Delays in coordinating and accessing crucial people	.347	.689	.043
6. Delays in response to unrealistic schedules	.808	.141	.037
7. Delays in recognizing and accepting that prior solutions were sub-optimal	.722	.160	.165
8. Delays in getting management approvals and sanctions	.074	.849	.182
9. Delays in overcoming internal resistance and politics	.279	.876	.040
Eigen value	3.57	1.35	1.17
Percent of variance	39.7%	15.1%	13.1%

Manovas ensured that the dichotomization of the teams into low and high bias conditions teams using median splits on the bias factors were significant. For Problem framing bias, a MANOVA suggested that the low and high bias teams significantly differed on all items constituting this factor ($F= 4.01$, $df= 5, 112$, $p < .001$), with all Items except one being significant at the .001 level. The Manova results for Information and Alternatives Evaluation bias were as follows; F= 5 23, df= 6l 91, $p < .000$. All items under the factor were significantly different at either the .001 level or .01 level. The Manova runs for Reasoning bias ($F= 8.57$, $df= 1, 127$, $p < .004$) and Escalating commitment bias ($F=7.21$, $df= 1, 127$, $p < .008$) showed that the low bias and high bias teams were significantly different also.

In order to test for significant differences between the low and high bias teams on the delay items and factors, MANOVAs and ANOVAs were conducted. Thus Low and high bias groups resulting from median splits of all four factors of the bias scale were compared on all the nine delay items, as well as the items constituting each factor of the delay scale}e.

For teams split on the basis of low and high **problem framing** bias, the MANOVA procedure suggested a significant difference between the groups for delay factor two, namely Project Management delays ($F= 2.72$, $df=3, 115$, $p < .04$). The ANOVAs indicated that the nine product development teams out of the twenty five reporting a high incidence of problem framing bias also reported a higher incidence of delays in getting crucial people together ($F= 6.21$, $df= 1, 119$, $p < .014$), and a higher incidence of delays in getting management approvals and sanctions ($F= 3.75$, $df= 1, 119$, $p < .05$). No significant difference was found on the third delay item constituting this factor, namely delays in overcoming internal resistance and politics. Table 3 presents the means, standard deviations, and results of the ANOVA. Also, no significant differences were found on the Manova tests for the nine delay items or the remaining two delay factors.

Table 3

Means, Standard Deviations, ANOVA[a] for Project Management Delay Items for Low and High Problem Framing Bias Teams

Items	Low Bias Teams Means	Low Bias Teams s.d.	High Bias Teams Means	High Bias Teams s.d.	F Statistics
Delays in coordinating and accessing crucial people	3.38	1.63	4.20	1.64	6.20**
Delays in getting management approvals and sanctions	3.51	1.59	4.14	1.71	3.75*
Delays in overcoming internal resistance and politics	4.13	1.76	4.57	2.04	1.43

[a] degrees of freedom = (1,119)
* $p < .05$
** $p < .01$

For teams classified into low (N= 18) and high (N= 7) bias conditions based on Information and Alternative Evaluation bias which was the second factor, a MANOVA using all the nine items of the delay scale as dependent variables, indicated significant differences between the two groups (F= 2.32, df= 9, 64, $p < .025$). ANOVAs revealed significant differences for five out of the nine items (see Table 4) . The teams displaying higher **Information and Alternative evaluation bias also reported** a higher incidence of delays in recognizing that prior solutions were sub-optimal (F= 4.63, df= 1, 73, $p < .035$) delays in getting crucial people together (F= 10.73, df= 1, 73, $p < .002$), delays in getting management approvals and sanctions (F= 5.98, df= 1, 73, $p < .017$), and delays in overcoming internal resistance and politics (F= 4.32, df= 1, 73, p

<.04). Also, to examine the overall effect of Information and Alternative Evaluation bias on the incidence of delays, a separate ANOVA procedure using the overall delay Score as dependent variable confirmed the findings from the earlier Manova that Information and Alternative Evaluation bias impacts most types of delays in product development teams.

Table 4

Means, Standard Deviations, ANOVA[a] for Project Management Delay Items for Low and High Information/Alternative Evaluation Bias Teams

Items	Low Bias Teams		High Bias Teams		F
	Means	s.d.	Means	s.d.	Statistics
1. Delays in developing basic theory and models	3.82	1.90	3.97	1.83	0.107
2. Delays in testing and synthesizing new drug candidates	3.40	1.94	4.03	1.90	1.95
3. Delays in responding to frequent changes in product requirements	3.18	1.70	3.93	1.81	3.37
4. Delays in assembling sufficient resources	4.27	1.85	4.63	1.47	0.826
5. Delays in coordinating and accessing crucial people	2.91	1.90	4.07	1.64	10.73**

Table 4 (cont.)

Means, Standard Deviations, ANOVA[a] for Project Management Delay Items for Low and High Information/Alternative Evaluation Bias Teams

6. Delays in response to unrealistic schedules	4.64	1.70	4.57	1.78	0.356
7. Delays in recognizing and accepting that prior solutions were sub-optimal	3.09	1.71	4.00	1.91	4.62*
8. Delays in getting management approvals and sanctions	3.22	1.52	4.17	1.80	5.98**
9. Delays in overcoming internal resistance and politics	3.56	1.75	4.47	2.00	4.35*

[a] degrees of freedom = (1,730)
* $p < .05$
** $p < .01$

The low and high bias teams differed significantly on frequency of overall delays experienced ($F= 8.72$, $df=1, 120$, $p < .004$). The Mean overall delay score of the low bias teams was 3.60 ($N= 68$) and the Mean overall delay score of the high bias teams was 4.30 ($N= 54$). Significant differences between the teams were also observed for Project Management delays based on a MANOVA run ($F= 6.13$, $df= 3, 92$, $p < .001$). ANOVAs verified that teams displaying higher levels of Information and Alternative Evaluation bias also reported higher incidence of delays in getting crucial people together ($F= 16.1$, $df= 1, 95$, $p < .000$), delays in getting management approvals and sanctions (F= 9.92, df= 1, 95, $p < .002$), and delays in overcoming internal resistance and politics (F= 8.77, df= 1, 95, $p <.004$). MANOVAs suggested that differences on Comprehension delays were not significant while Timing and Scheduling delays were close to significance (F= 2.27, df= 3, 91, $p < .06$).

Comparison of the low and high groups dichotomized on Reasoning bias and Escalating Commitment bias did not show significant differences for any of the delay factors or delay items.

In summary, the results suggested that Information and Alternative Evaluation bias showed a strong relationship to the incidence of delays as a whole. It also impacted Project Management delays significantly as did Problem Framing biases.

Discussion

The results of the present study represent an important step in understanding the impact of cognitive biases on product development delays. First, these results provide strong empirical evidence that product development teams which experience a higher level of information and evaluation biases are likely to encounter more and different types of delays, which can negatively impact product development time. Specifically, product development teams which reported a higher level of information and evaluation biases experienced a significantly higher incidence of project management type delays. Product development teams which do not take the time to consider other available information sources and forgo the processes required for 'thinking hard and debating alternatives are likely to prematurely converge upon a preferred alternative which they may later regret. While such teams may appear to be more decisive and active, it is evident from the results that these same teams are also expending their energies in trying to overcome significant project management delays. Thus, teams which prematurely terminate their search activities and limit their options to a preferred alternative are less apt to have a viable fallback strategy if their efforts do not pan out. Consequently these teams encounter major project management delays as they scramble to regroup crucial people, await new management sanctioning and approvals, and attempt to overcome internal resistance and politics. Once these delays occur and political interests become more salient, these teams also experience delays in recognizing and accepting prior sub-optimal solutions (Hickson et al., 1986). Further, the relationship between information-evaluation bias and delays found here generally reinforces Eisenhardt's (1989) case study findings that faster decision-making occurs in teams that use more, not less, Information and consider more, not fewer alternatives. In general, then, our findings align with the theoretical views of Driver and Streufert (1969) who claim that effective perceptual subsystem functioning in an information processing group is reflected in the group's use of multiple and diverse sources of information.

Concerning the link between problem framing biases and project management delays, the results also emphasize the utility for product development teams to invest in multiple problem-solving strategies and to debate competing hypotheses (Eisenhardt, 1989). These activities can obviate that possibility of oversimplification and premature decision closure (Imai et al., 1985) while making explicit the trade-offs involved. Examining and interpreting multiple problem frames can also help team members and managers to make a more deliberate assessment of the risks associated with a particular choice situation (Dunegan, 1991). Comprehension delays were not impacted by any of the four cognitive bias factors. Neither did reasoning bias or Escalating commitment bias influence any of the delays. However, at this point we cannot comment on the nonsignificance of these factors since the study was exploratory in nature. We believe that the empirical identifications of these factors are themselves a worthwhile contribution. However, we do recognize the need for further examination and elaboration in the future.

The evidence extended by this study suggests that product development teams should pay conscious attention to the occurrence of cognitive process biases in their deliberations. However, this is not an easy task since by nature human beings process the world through their biases. As Hogarth (19873 succinctly states 'indeed, the activity is so common that most of us take it for granted. However, as it is true in many other domains, it is precisely those things that we take for granted that should be questioned.' (Hogarth, 1987, p. 232).

We submit that the first step in dealing with biases is raising awareness through provision for 'reflection' and 'feedback' mechanism in product development teams For example, Barnes (1984) reports a study by Fischoff, Slovic and Lichenstein in which they forced planners to reflect on their estimates through sensitivity analysis, which resulted in improved decisions. Others have suggested a use of decision aids to raise awareness of individual biases through reflection and feedback (Kleinmuntz, 1985). Different decision aids such as 'cognitive feedback strategies' (Sengupta & Te'eni, 1991) and 'problem structuring heuristics' (Abualsamh, Carlin & McDaniel, 1990) have been suggested and experimented with as a way of overcoming cognitive biases.

In contrast to outcome feedback, which describes the accuracy of a decision, cognitive feedback provides decision makers with insights into their decision making processes (Balzer, Doherty & O'Connor, 1989). It enables decision makers with a better understanding of their own decision-making processes and those of other members. A study by Sengupta and Te'eni (1991) employing cognitive feedback through a Group Decision Support system, found that groups receiving cognitive feedback came up with better quality decisions than those who did not. Burgess (1988) has suggested that creating causal maps of a situation and examining them can help overcome human information processing biases. Early experiments with SPIDER (Boland, Tenkasi & Te'eni, 1991) - a system created for coordinating decision making among product planners in a strategic planning environment appears to support the above suggestions. SPIDER allows product developers to create and exchange cognitive maps representing their understanding of the planning environment. This process of both creating and debating cognitive maps has heightened awareness of their individual biases. Also, decision making methods such as devil's advocacy and dialectical inquiry which generate divergent assumptions and perspectives can be employed (Schweiger, Sandberg, Rechner, 1989). Lastly, Emmanuelides (1991) suggestion of building skill differentiation in product development teams can help counteract biases.

One major limitation of the study was that it used self-reports to measure both biases and delays. Although our observations of meetings as well as interviews with some scientists suggested that they had a strong reflective orientation, and could recount instances from their work where they felt particular biases were in operation, self-reports are not an effective way of assessing an elusive and implicit phenomena as biases. More effective methods would entail field observations (Schwenk, 1984), subject's detailed descriptions of their own problem solving efforts (Mintzberg, et. al, 1976), or use of cognitive assessment strategies such as 'thought listing' (Cacciopo & Petty, 1981). Likewise, in addition to self-reports, more stringent external measures could be used to assess delays.

The study opens up a number of research possibilities mainly around inquiry into the sources of cognitive biases, namely individual, team, and task factors. For example, Hogarth (1987) attributes bias in information acquisition to both individual cognitive capacities and task environment attributes, such as complexity, emotional stress, and social pressures. An interesting extension of the current study would be to examine the group composition and deliberative processes of low bias and high bias teams as a mean for understanding some of the possible sources of these cognitive biases.

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