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14. ABSTRACT The theoretical framework that motivates our research program predicts a three-way interaction between global incentives, local rewards, and task structure, such that the optimal combination of incentives and rewards depends on the factors that govern optimal task performance. When optimal task performance requires cognitive flexibility, a "match" between the global incentive structure and the local rewards is advantageous. When optimal task performance requires a less flexible, incremental approach, a "mismatch" between the global incentive structure and the local rewards is advantageous. We found support for this three way interaction in a series of risky decision making/choice tasks as well as in the realm of stereotype threat. Specifically, we found that when exploration of the choice space was optimal, participants in a regulatory match (whether induced through regulatory fit or stereotype threat) performed better, whereas when exploitation of the choice space was optimal, participants in a regulatory mismatch performed better. Similarly, in a rule-based category learning task (that required flexible processing of the rule space) we found better performance for "match" participants, but in an information-integration category learning problem (that required incremental learning) we found better performance for "mismatch" participants. Finally, we developed a computational model of the motivation learning interface and applied it to data collected during the grant period.					
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Modeling the Motivation-Learning Interface in Learning and Decision Making

Final Report for FA9550-06-0204

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A. OVERVIEW

Action requires both information processing and motivation. Cognitive Psychology has typically focused on the information processing aspects of action. However, the selection of behaviors in an environment is also strongly determined by a person's motivational state to approach positive outcomes or avoid negative outcomes. The selected behavior is also determined by whether the individual is working alone or with a group.

The influence of active goals on behavior has been the focus of recent social psychological research (Higgins, 2000), but little work has examined the effects of motivation on learning (Busemeyer & Stout, 2002). A complete understanding of the relationship between learning and behavior requires a focus on the interplay between motivation, interdependence, and cognition (Carver & Scheier, 1998; Higgins, 1987).

The broad aim of proposal (FA9550-06-0204) was to extend a motivation-cognition framework developed by Maddox and Markman (Maddox & Markman, in press; Maddox, Markman, & Baldwin, 2006) to examine motivational influences on learning and decision making. As a starting point, we drew on Higgins' (Higgins, 2000) regulatory focus theory. Our research to that point had provided support for the idea that when a person's motivational state matches the reward structure of the environment (i.e., there is a *regulatory fit*), their learning performance is more flexible than when it mismatches the reward structure of the environment (Maddox, Baldwin, & Markman, 2006; Maddox, Markman, & Baldwin, 2006; Markman, Baldwin, & Maddox, 2005). The goal of our AFOSR grant was two-fold. First, we explored the relationship between regulatory fit and flexibility in the context of decision making. Second, we examined the effects of the social environment on people's regulatory states.

This work has direct relevance to AFOSR for at least three reasons. First, military service creates strong attention to potential gains and losses in the environment, and so the motivational effects we study should be particularly potent in military personnel. Second, as we discuss below, most of the extant research in cognitive psychology has focused on a particular kind of regulatory fit in which people are sensitive to potential gains in the environment and they are rewarded for good performance. This motivational state may fail to capture important aspects of the situations in which many military personnel serve. Third, the social environment of the military also has a powerful motivational effect, and these effects can be incorporated into our theoretical framework.

In this final report, we first discuss our motivational framework in detail, providing clear definitions for the concepts of regulatory focus, reward structure and flexibility. Then, we provide a comprehensive summary of the significant accomplishments from our research

B. THE REGULATORY FIT FRAMEWORK

Regulatory Focus Theory

The motivation literature makes a distinction between approach goals—positive states that one wishes to achieve, and avoidance goals—negative states that one wishes to avoid (Carver & Scheier, 1998; Lewin, 1935; Markman & Brendl, 2000). Higgins (Higgins, 1987, , 1997) proposed *regulatory focus theory* that argues for psychological states of readiness or sensitivity for potential gains or losses that tune the sensitivity of the motivational system. One key factor that is well-known to influence a person's current regulatory focus is the *situational incentive*. A situational incentive is induced by the global outcome aspects of a current situation. An incentive promotion focus is activated by situations in which there is a global gain or non-gain at stake, while an incentive prevention focus is activated by situations in which there is a global loss or non-loss. For example, in our work supported by AFOSR a situational incentive promotion focus is induced by telling people that that they can earn an entry into a drawing for \$50 if they exceed a performance criterion during the final block of experimental trials. That is, there is a potential gain (entry into a drawing) or non-gain (failure to receive an entry). A situational incentive prevention focus is induced by giving people an entry into the drawing for \$50 when entering the lab, but then telling them that they have to exceed the (same) performance criterion to keep the

entry. In this case, there is a potential loss (of the ticket they were given) or non-loss (if they are able to keep the ticket).

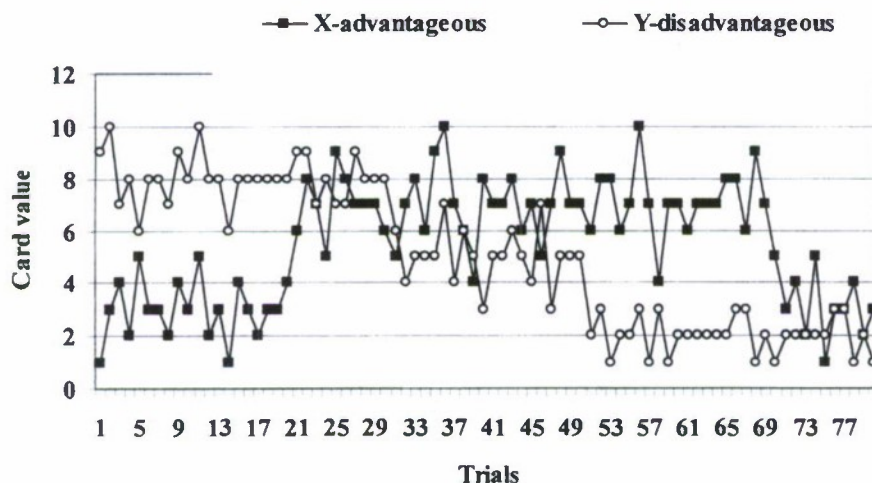
Regulatory focus alone does not determine the likelihood that individuals will perform a cognitive task successfully. Instead, the style of cognitive processing that they bring to the task is influenced by the *regulatory fit* between their (situationally-induced) regulatory focus and the *reward structure of the task*. For example, in some cases one might gain points for responding correctly, whereas in others they might avoid losing points when responding correctly. Higgins (Higgins, 2000) suggested that people might perform best when there is a regulatory fit between the situational incentive focus and the reward structure of the task. Shah et al (Shah, Higgins, & Friedman, 1998) found some support for this regulatory fit notion in a task that required participants to solve anagrams.

We suggest that regulatory fit promotes *cognitive flexibility*. We can define flexibility rigorously within the domains we study, but for now it suffices to assume that cognitive flexibility involves an increase in one's predisposition to try different (often low salience) strategies across trials to achieve some stated goal, as opposed to sticking with a single strategy and making small incremental changes during learning. So our hypothesis is that a fit between a person's situationally-induced regulatory focus and the reward structure of the task will result in flexible performance on cognitive tasks. Whether a person performs "well" on the task they are given, however, depends on whether cognitive flexibility is advantageous for the task being performed.

C. REGULATORY FIT AND FLEXIBILITY IN DECISION MAKING

Regulatory Fit in Choice. To examine the influence of regulatory focus and reward structure on decision making we used a modified gambling task. Participants are told that they will be playing a game in which they select 80 cards from a pair of decks. Each card they draw has a point value. In the gains condition, participants gain the number of points listed on the card with each draw. In the losses version, participants lose the number of points shown on the card with each draw. In the gains version of the task, the performance criterion requires exceeding 450 points. In the losses version, the performance criterion requires losing fewer than 450 points. As before, a promotion focus is instantiated by telling participants that they will receive an entry into a drawing to win \$50 if their performance exceeds the criterion. A prevention focus is instantiated by giving a ticket to participants prior to the task, and telling them that they can keep the ticket as long as their performance exceeds the criterion, in which case they lose the ticket.

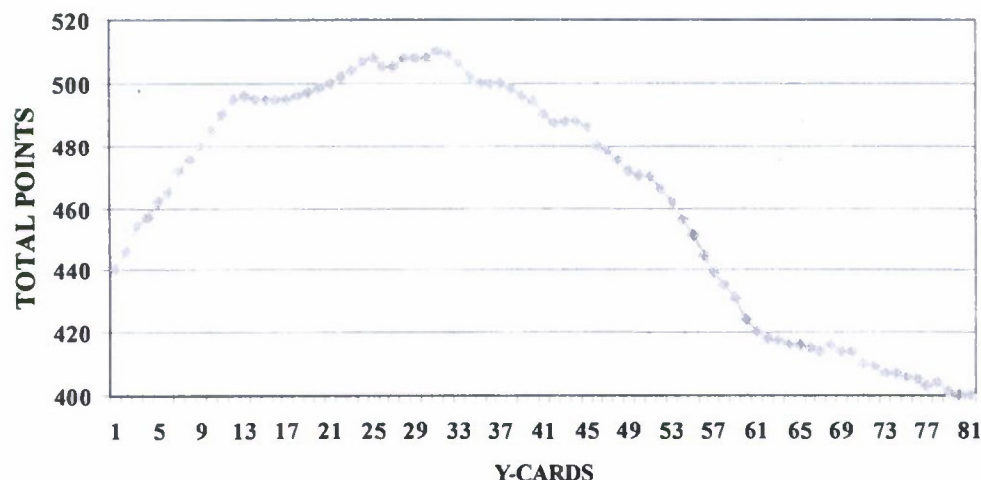
The point distributions for a pair of decks in a gains version of the task that require participants



to switch (i.e., show cognitive flexibility) are shown in the figure below. This figure shows the number of points that are won for cards drawn from two decks of cards labeled X and Y. The first card drawn from the deck receives the value associated with Card 1 from that deck, the second card receives the value associated with Card 2, and so on. Thus, as shown in the figure, the first card Drawn from Deck X

gives the subject 1 point (even if the subject has already drawn cards from Deck Y). A loss deck with the same characteristics can be created by subtracting 11 points from each value shown in the figure

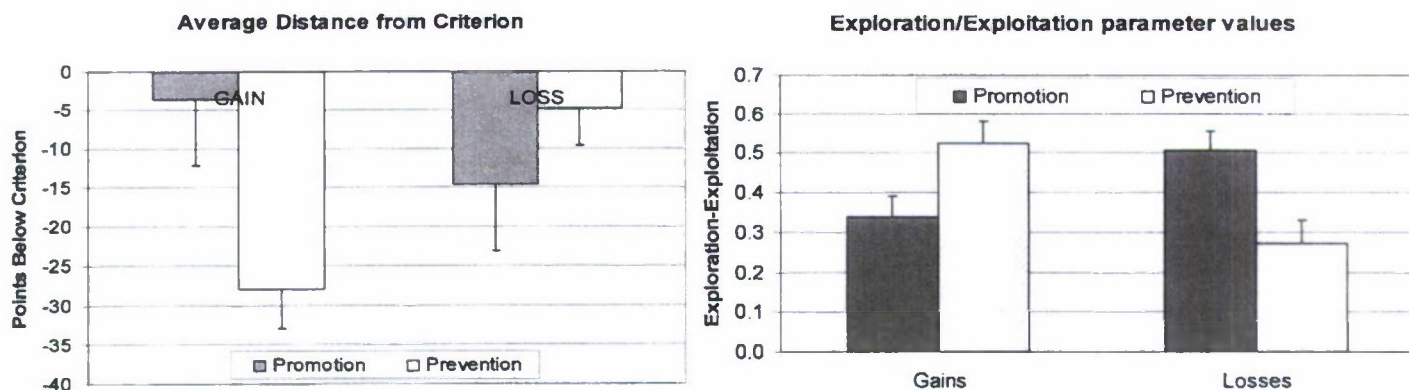
By convention, Deck X starts with relatively small values and ends with relatively large values. Deck Y starts with relatively high values and ends with relatively small values. The figure below shows the number of points that a subject can receive (in the gain version of the decks) as a function of the number of cards drawn from the Y deck. As this figure shows, subjects cannot exceed the performance criterion of 450 points if they draw cards from only one deck over the course of the study. They must draw at least 3 cards from the Y deck, but no more than 55 cards from the Y deck in order to reach the criterion. Thus, even though the Y deck starts out providing the most points, subjects must eventually switch to the deck that starts with the fewest points. Thus, the mark of flexibility in this task is people's ability to switch from taking cards from the deck that was advantageous initially to drawing cards from the deck that was not advantageous initially.



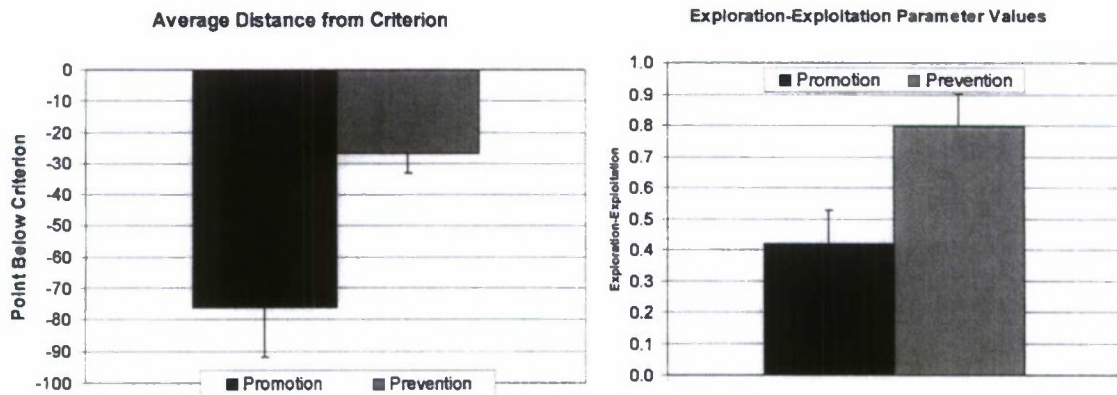
A related task in which switching (cognitive flexibility) was disadvantageous was also constructed. Worthy et al (Worthy, Maddox, & Markman, 2007) examined the impact of regulatory focus and task reward structure on the two versions of the gambling task. Data from the flexibility is advantageous condition is presented in the figure below that shows the deviation between the

participants' point total and the criterion. As predicted those in a regulatory fit performed better.

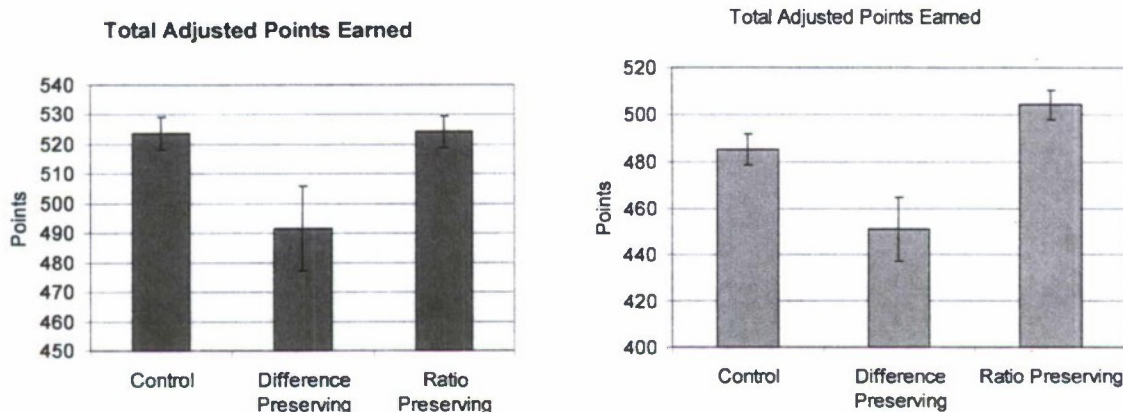
Model based analyses with a reinforcement learning model were also conducted. Importantly the model included an exploitation parameter that provided a measure of exploitative behavior. Again as predicted, participants in a mismatch were more exploitative (i.e., less exploratory). These data are presented in the figure below.



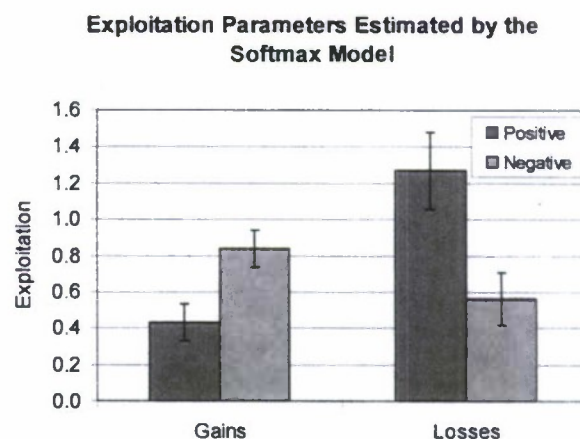
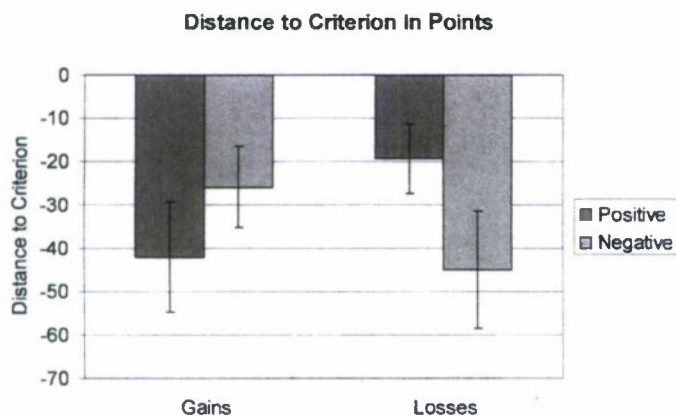
An exploitation optimal condition was also completed and those data are presented below. Again they support the regulatory fit-flexibility hypothesis.



Ratios and differences in Choice. Another study was published that examined the impact of ratio and difference comparisons of expected rewards in decision making (Worthy, Maddox, & Markman, 2008). Several models of choice compute the probability of selecting a given option by comparing the expected value (EV) of each option. However, a subtle but important difference between two common rules used to compute the action probability is often ignored. Specifically, one common rule type, the *exponential* rule, compares EVs via a *difference* operation, whereas another rule type, the *power* rule, uses a *ratio* operation. We tested the empirical validity of each rule type by having human participants perform a choice task in which either the difference or the ratio between the reward values was altered relative to a control condition. Results indicated that participants can compare expected rewards by either ratio or difference operations but that altering the ratio between EVs produces the most dramatic changes in behavior. The point totals obtained in each condition are presented below.



Affect and Choice. A number of other studies are being written up for publication. One that is of particular interest is a version of the choice that replaced the raffle ticket manipulation with a simple affect manipulation. Participants in the positive affect condition saw decks with happy faces on the back and participants in the negative affect condition saw decks with sad faces on the back. Half of each group was run with a gains or a losses reward structure. An exploitation-optimal task was utilized such that a regulatory fit should lead to better overall performance. As predicted those in a mismatch performed better and this was accompanied by larger exploitation values (see figures below).



D. SOCIAL INFLUENCES ON REGULATORY FOCUS

The second critical aim of this proposal is to extend our understanding of motivational factors that influence the motivation-cognition interface. This issue is particularly important, because we believe that a number of observations about the influence of motivation on cognitive performance may be manifestations of the effects of regulatory fit or regulatory mismatch, though they have not been recognized as such. In this section, we examine the influence of stereotypes about team members on classification performance (Steele & Aronson, 1995).

We believe this work is important to the AFOSR mission, because military personnel are often placed into groups with others, and the overall performance of the group depends on the performance of group members. Furthermore, military personnel are a racially and ethnically diverse population. Thus, people's beliefs about the capabilities of their team members and about their own capabilities relative to those of team members are crucial for their performance.

Thus, the proposed research in this section focuses on the influence of beliefs about the self and about group members on performance. As a starting point, we focus on recent research suggesting that regulatory focus may be influenced by people's beliefs about groups to which they belong (Seibt & Forster, 2004; Steele & Aronson, 1995). This research has been carried out under the label of stereotype threat.

Stereotype Threat

Racial, ethnic, and gender differences between participants and partners may influence performance through mechanisms of *stereotype threat* (Steele & Aronson, 1995; Steele, Spencer, & Aronson, 2002). Stereotype threat occurs when an individual is part of a group. If the individual believes that group is at a disadvantage in performing the current task, then the individual's performance in the task may suffer when group membership is made salient before the task is performed. For example, women who believe that men are better than women at math perform worse on math tests when the stereotype is activated prior to taking the test than when it is not.

The conditions that lead to poor performance by the threatened group are well-understood. In particular, the relevant stereotype must be activated, and the individuals must identify with the task. For example, Aronson et al. (1999) found that the performance on a math test by White males was hurt by activating the stereotype that Asians perform better on math tests than do Whites. This effect occurred for participants who identified math as important to them, but not for participants who did not.

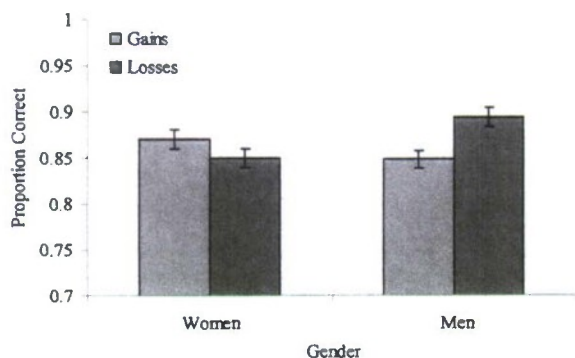
The factors that cause the decreases in performance are less well understood than are the conditions that lead to stereotype threat. We are interested in the degree to which regulatory focus factors may affect stereotype threat. In particular, it is possible that individuals experiencing a stereotype threat are given a strong situational prevention focus. Preliminary evidence for this

possibility comes from studies by Seibt & Forster (2004), who found that when a positive self-stereotype of an individual was activated that person tended to have a promotion focus, but when a negative self stereotype was activated, that person tended to have a prevention focus.

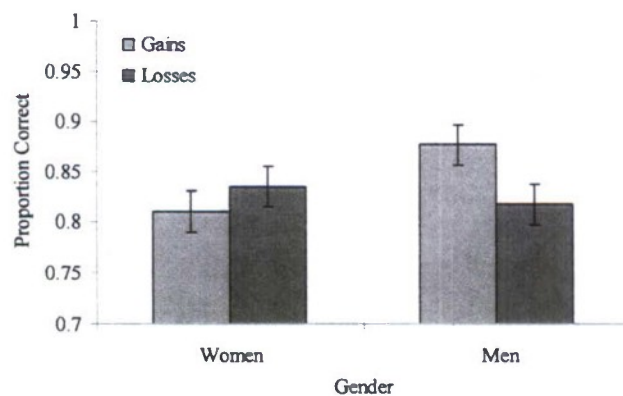
On this view, the poor performance experienced by individuals experiencing a stereotype threat might arise from a regulatory mismatch between typical tasks (which have a mild gain reward structure) and the prevention focus. This work suggests that stereotype threat effects might parallel those of other prevention focus manipulations. Thus, whether a participants' performance suffers or improves following stereotype threat depends on the reward structure of the task as well as the task itself. Because most studies of stereotype threat have set up a regulatory mismatch and have tested performance using tasks that require flexibility, stereotype threat is seen as harming performance. However, performance might improve for threatened participants when they experience a task that requires flexibility with a loss reward structure or when they experience a task that does not require flexibility and a gain reward structure.

One of our published studies uses gender as the dimension of stereotype threat. To implement the stereotype threat, we present participants with brief newspaper-style articles describing gender differences in learning abilities between men and women. The articles suggesting that men learn better than women focus on spatial abilities (an ability for which University of Texas students believe men are better than women). The articles suggesting that women are better than men focus on intuitive abilities (abilities for which University of Texas students believe women are better than men). These articles are formatted as if they appeared in real newspapers. Participants in the stereotype threat conditions are told that we are investigating gender differences in learning, and that we are exploring tasks for which the participant's gender are typically worse than the opposite gender. Participants read one of the newspaper articles to provide more background on the alleged gender difference. Then, participants perform a learning task. Participants in the control condition are not given any information about possible gender differences in the task. (As an aside, we have no evidence of any gender differences in our tasks.)

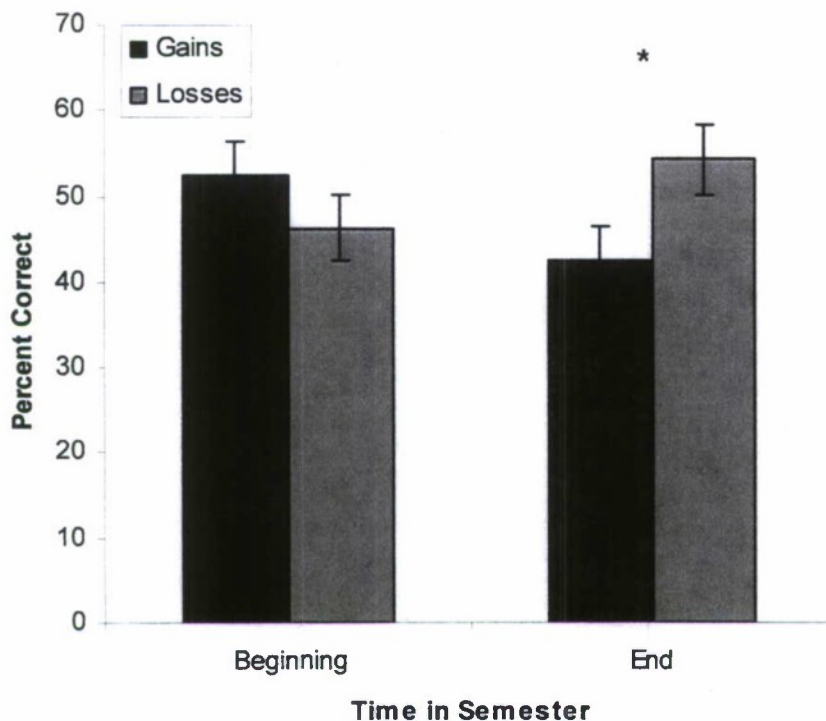
Given this manipulation of stereotype threat, we ran studies with gain and loss reward structures (Grimm, Markman, Maddox, & Baldwin, 2009). The gain reward structure should lead to a regulatory mismatch. The loss reward structure should lead to a regulatory fit. We utilized a task for which flexibility as optimal. In the figure below we present data from a case for which participants are told that women are better. As predicted, women did better under a gains reward structure and men did better under a losses reward structure.



We also ran the same study but participants are told that men are better. As predicted, men did better under a gains reward structure and women did better under a losses reward structure.



A followup that tested the hypothesis that individuals who complete tasks well before a deadline vs. very near a deadline was also conducted (Grimm, Markman & Maddox, 2009). The deadline was the end of the University semester and the task was mathematical ability. As predicted those who completed the task early in the semester performed better under a gains reward structure whereas those who completed the task late in the semester performed better under a losses reward structure



Several followups that utilized pressure as a stereotype threat manipulation were also examined. These showed the same basic pattern with those under pressure performing work under a gains reward structure but better under a losses reward structure (Markman, Maddox, & Worthy, 2006; Worthy, Markman, & Maddox, 2009a, , 2009b).

A number of additional publications were supported by the AFOSR grant. These included review articles as well as some related work (Maddox & Markman, in press; Markman, Beer, Grimm, Rein, & Maddox, 2009; Markman, Maddox, Worthy, & Baldwin, 2007).

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