Regulatory Fit Effects in a Nonlinearly Separable Category Learning Task

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Abstract

The regulatory fit-cognitive flexibility hypothesis was tested in two experiments using a non-linearly separable category set, where cognitive flexibility was hypothesized to be advantageous for category learning. A promotion or a prevention focus was induced and subjects performed the task with either a gains or losses reward structure, creating two conditions of regulatory fit (promotion/gain, prevention/loss) and two conditions of regulatory mismatch (promotion/loss, prevention/gain). It was predicted that subjects in the regulatory fit conditions would be more likely to reach a criterion of performance and learn a complex rule, while subjects in the regulatory mismatch conditions would be less likely to reach a criterion of performance and more likely to use a suboptimal rule. Regulatory fit advantages were not apparent in either the gains or losses versions of the task.

Keywords: Category learning; motivation; regulatory fit; nonlinear separability

Introduction

While it is obvious that motivation and cognition interact, this interaction has only recently received attention in cognitive psychology (Maddox, Baldwin, & Markman, 2006). One possible reason as to why this interaction has not received much attention prior to date is that motivation can be difficult to operationally define in cognitive terms. However a theory of motivation from the social psychology literature has proven useful in understanding how motivation affects cognition, specifically in how motivational focus can affect category learning. We present this theory of motivation below and two experiments that seek to add to what is known about the interaction between motivation and cognition.

Higgins' (1997) regulatory focus theory posits that the human motivational system is focused either on potential gains or potential losses in the environment. People can have a *promotion focus*, which is characterized by a focus on the achievement of desired outcomes and possible gains or nongains in the environment, or a *prevention focus*, which is characterized by a focus on the avoidance of undesirable outcomes and possible losses or nonlosses in the environment. Everyday examples of a promotion focus include trying to catch a flight or hit a home run. Examples of a prevention focus include trying to protect a child from running out into the road or eating healthily to avoid heart disease. Regulatory focus can be induced experimentally, although it is also thought that people have an internal regulatory focus that is constant through time (Higgins, 2000). The situations necessary to induce a promotion or prevention regulatory focus can consist of task instructions emphasizing either gains/nongains or losses/nonlosses respectively (Higgins, 1997).

Crowe and Higgins (1997) found that experimentally induced regulatory focus engenders different strategies of goal pursuit. A promotion focus encourages people to pursue goals with eagerness means (ensure hits, ensure against misses), while a prevention focus encourages people to pursue goals with vigilance means (ensure correct rejections, ensure against false alarms).

Higgins (2000) introduced the idea that the way people attempt to reach a goal can either match or mismatch with their regulatory focus. Regulatory fit is present when one's method of goal pursuit and regulatory focus match. Regulatory fit increases the value of reaching one's goals and results in an increased feeling of fluency of one's actions. A promotion focus and a strategy focused on gains or a prevention focus and a strategy focused on losses are instances of regulatory fit. Conversely, a promotion focus and a strategy focused on losses or a prevention focus and a strategy focused on gains are instances of regulatory mismatch.

Maddox et al. (2006) argued that in addition to the feeling of fluency that is posited to develop from a state of regulatory fit, regulatory fit also increases cognitive flexibility. Cognitive flexibility is defined as an increase in the ability or willingness to try different strategies for the purpose of achieving a goal. This increase in flexibility is in contrast with a strategy where gradual, incremental changes are necessary in order to achieve a goal. In a series of experiments, Maddox et al. (2006) found that when cognitive flexibility is advantageous for category learning, subjects in regulatory fit conditions perform better than subjects in regulatory mismatch conditions but when cognitive flexibility is disadvantageous for category learning, subjects in a regulatory mismatch condition perform better than subjects in a regulatory fit condition. A promotion focus was induced by telling subjects they would be entered into a draw for $50 if they reached a criterion of performance, while a prevention focus was induced by telling subjects they had been entered into a draw for $50 and would be able to keep the entry if they reached a criterion of performance.

Grimm et al. (in press) supported the regulatory fit-cognitive flexibility hypothesis in two experiments that looked at both rule-based and information-integration category learning. In Experiment 1, using a gains reward structure, subjects in a regulatory fit condition reached a criterion of performance more quickly than subjects in a regulatory mismatch condition on a simple rule-based task. In Experiment 2 using a losses reward structure subjects in a regulatory fit condition reached the criterion more quickly than subjects in a regulatory mismatch on the same simple rule-based task, although this difference did not reach significance.

Regulatory fit has been proposed to increase cognitive flexibility and thus enhance classification learning when flexibility is advantageous for category learning. This hypothesis has recently been supported but is not yet well understood (Maddox et al., 2006, Grimm et al., in press). For example, although previous research has indicated a regulatory fit enhancement in learning rule-based categories, it is not known if this enhancement extends to situations in which rules must be supplemented with exceptions. Exception learning requires an additional stage of exploration beyond finding a rule.

We were interested in exploring regulatory fit in category learning using a category set that required subjects to learn a complex rule, as well as exceptions to that rule in order to achieve good or perfect performance. The regulatory fit-cognitive flexibility hypothesis was tested by manipulating subjects' situational regulatory focus and task reward structure in two experiments. All subjects learned a non-linearly separable (NLS) category set (Smith & Minda, 1998). The NLS category set, shown in Table 1, has two clear exception items (A7 and B7) and two complimentary items to those exceptions (A5 and B4). Thus NLS classification learning via a single-dimensional rule is impossible. Subjects in our experiments were asked to learn the NLS category set while in one of two regulatory-focus conditions: promotion or prevention. In Experiment 1 a gains task reward structure was used and in Experiment 2 a losses task reward structure was used. We predicted that subjects in the two regulatory fit conditions (promotion/gain, prevention/loss) would perform better on the NLS classification task than subjects in the two regulatory mismatch conditions (prevention/gain, promotion/loss). This is expected because subjects in regulatory fit conditions should experience increased cognitive flexibility compared to subjects in regulatory mismatch conditions and this increase in flexibility would allow subjects to perform the task better.

Experiment 1

Method

Subjects 50 adult undergraduate subjects from the University of Western Ontario participated for course credit, 25 in the Promotion condition and 25 in the Prevention condition.

Materials A six-dimensional nonlinearly separable (NLS) category set was used. Each of the two categories consisted of seven stimuli. This NLS category set is shown in binary in Table 1. Note that the first stimulus in each category (A1, B1) is the prototype for its category. The following five stimuli (A2-A6; B2-B6) each contain five features from that prototypical stimulus and one feature from the other category. The last stimulus for each category (A7, B7) contains only one feature belonging to that category and five that belong to the other category: these are the exception items. By attending to only one feature subjects could achieve either 71% or 86% accuracy, depending on which feature they based their responding on. For instance if a subject pays attention to the first feature of each stimulus, they would respond "category 1" when it is "0" and "category 2" when it is "1". This would result in 71% accuracy, whereas paying attention to the fifth feature would result in 86% accuracy. To achieve perfect performance subjects must learn to pay attention to more than one stimulus feature and learn that one stimulus from each category looks like it belongs in the opposing category but is actually an exception item of the other category (A7, B7). Subjects were presented first with instructions and then the NLS classification task on a computer screen. Stimuli consisted of six colored ovals that were described in the instructions to the subject as a "pattern". An example of the NLS category stimuli is shown in Figure 1.

Table 1: Nonlinearly separable category set.

Category 1		Category 2	
A1	0 0 0 0 0 0	B1	1 1 1 1 1 1
A2	1 0 0 0 0 0	B2	0 1 1 1 1 1
A3	0 1 0 0 0 0	B3	1 0 1 1 1 1
A4	0 0 1 0 0 0	B4	1 1 0 1 1 1
A5	0 0 0 0 1 0	B5	1 1 1 0 1 1
A6	0 0 0 0 0 1	B6	1 1 1 1 1 0
A7	1 1 1 1 0 1	B7	0 0 0 1 0 0

Figure 1: Nonlinearly separable category set prototypes.

Procedure All subjects completed the NLS category-learning task after being assigned to one of two regulatory focus conditions.

In both conditions subjects were told that they would be presented with colored patterns and asked to classify them. Subjects saw each stimulus on a computer screen and were instructed to press the "1" or the "2" key to indicate category 1 or category 2 respectively. After responding, subjects were given feedback indicating a correct or an incorrect response: the word CORRECT appeared for 800 milliseconds or the word INCORRECT appeared for 1200 milliseconds. The stimulus remained on the screen while feedback was given and then another trial began. Stimuli were presented in a random order within each block of 14 stimuli and blocks were presented in an unbroken fashion.

In the promotion/gain (regulatory fit) condition, subjects were told that they would be entered into a draw for a $40 gift card if they reached a criterion of performance. The task continued until subjects reached the criterion of performance (360 correct responses) or until they completed 40 blocks (560 trials), at which point the experiment ended. A correct response-counter was visible on the right-hand side of the computer screen that advanced for each correct response subjects made. It did not advance for incorrect responses and subjects were told they had to fill up the counter bar to reach their criterion.

The prevention/gain (regulatory mismatch) condition was identical to the promotion/gain condition except that subjects were told that they had already been entered into a draw for a $40 gift card and would lose their entry if they did not reach a criterion of performance (360 correct responses). As in the promotion/gain condition, subjects could watch the correct response-counter advance for each correct response on the right-hand side of the computer screen.

We reasoned that if regulatory fit increases cognitive flexibility, then subjects in the regulatory fit condition (promotion/gain) should show better performance on the NLS category-learning task than subjects in the regulatory mismatch condition (prevention/gain). This is because the NLS category set requires subjects to find a complicated, two-dimensional rule to achieve perfect or near perfect performance and it is hypothesized that cognitive flexibility would be advantageous for finding this complex rule.

Results

Criterion Reachers We looked at how many subjects reached the criterion by regulatory focus and task reward structure. More promotion/gain subjects (n=18) reached the criterion than prevention/gain subjects (n=16). This difference did not approach significance when a chi-square goodness-of-fit test was performed, $\chi^2 = 0.12$, df=1, *ns*.

Trials to Criterion We were interested in whether regulatory fit subjects (promotion/gain) would reach the criterion in fewer trials than regulatory mismatch subjects (prevention/gain). We looked at how many trials it took subjects to reach the criterion by regulatory focus and task reward structure. Subjects who did not reach the criterion were assigned a trial count of 560. The mean number of trials it took promotion/gain subjects (M=514.48) was not different from the mean number of trials it took prevention/gain subjects (M=515.28) to reach the criterion and a t-test with regulatory focus and task reward structure did not approach significance, t= -.07, df=48, *ns*.

Learning Rate We looked at the averaged performance of subjects in the promotion and prevention conditions in the first ten blocks (140 trials) of learning. We wanted to see whether regulatory fit subjects would show faster learning than regulatory mismatch subjects before subjects reached the criterion. We predicted that subjects in the regulatory fit condition (promotion/gain) would show more accurate performance than subjects in the regulatory mismatch condition (prevention/gain). However we did not find a regulatory fit advantage: promotion/gain subjects (M=56.74) did not perform better than prevention/gain subjects (M=58.86) when a one-way analysis of variance was performed, F=1.76, df=19, *ns*.

Performance Quality We calculated the average accuracy of all subjects in their final full block of the experiment, shown by regulatory focus and task reward structure in Figure 2. Looking at the final full block of each subject provided a way of looking at subject performance after learning had occurred. A t-test found that promotion/gain subjects (M=0.82) were significantly more accurate than prevention/gain subjects (M=0.70) in the final full block of performance, t= 2.52, df = 48, p <0.05.

Modeling Performance We were interested in whether more subjects in a regulatory fit condition learned a complex rule than subjects in a regulatory mismatch condition. To investigate this we used two well-known computational models of category learning: the Generalized Context Model (GCM, Nosofsky, 1986) and a Prototype Model (PRT, Minda & Smith, 2001). We used two models to ensure that our findings were not subject to controversy. Both of these models estimate attention weights for each of the six dimensions in the task and can be used to gauge subjects' attention strategy. We assumed that the model would indicate greater attention to dimensions 4 or 5 for the regulatory fit condition, reflecting better rule and exception item learning.

We took the last four full blocks of each subject's performance and fit each subject's data with the GCM and the PRT. The last four blocks of performance were chosen because we could look at performance on the exceptions over time (the final four full blocks) but after learning had occurred. We minimized the root mean squared deviation (RMSD) between the observed data and the predictions with a hill-climbing algorithm. We then chose the model that best fit each subject's data and averaged the mean of each attention weight to see how much attention each subject paid to each of the six stimulus features. We were particularly interested in whether subjects in the regulatory fit condition (promotion/gain) would show greater attention to the features that were best predictive of category membership (features four and five) than subjects in the regulatory mismatch condition (prevention/gain). We found that promotion/gain subjects (M=27.64) paid more attention to features four and five than prevention/gain subjects (M=21.76), although this difference did not approach significance, t=1.06, df=98, *ns*.

Both models provided a good fit for the data; for the promotion/gain condition, the average GCM fit was 0.15 and the average PRT fit was 0.19. For the prevention/gain condition, the average GCM fit was 0.18 and the average PRT fit was 0.20.

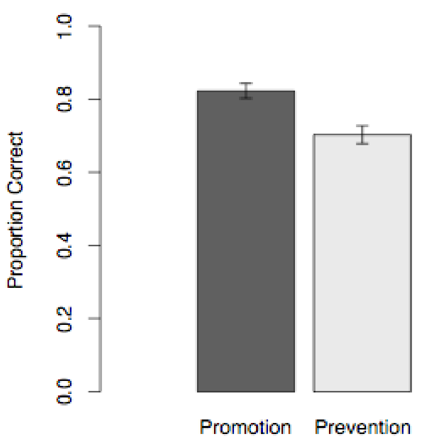

Figure 2: Final full block performance.

Discussion

In Experiment 1 we had predicted that subjects in the regulatory fit condition (promotion/gain) would be more likely to reach a criterion of performance and would do so more quickly than subjects in the regulatory mismatch condition (prevention/gain). The results of Experiment 1 did not reveal a regulatory fit advantage in terms of the number of criterion reachers, how long it took subjects to reach the criterion, or rate of learning. However there was a regulatory fit advantage when we looked at subjects' final block performance, with promotion/gain subjects showing greater accuracy than prevention/gain subjects. We also predicted that an increase in cognitive flexibility would be advantageous for the learning of a nonlinearly separable category set but our findings are not entirely consistent with this hypothesis. Subjects in a regulatory fit condition were not more likely to find and apply a complex rule than subjects in the regulatory mismatch condition. Computational modeling did not show support for the hypothesis that subjects in the regulatory fit condition were better able to find and apply a complex rule than regulatory mismatch subjects.

Experiment 2

In Experiment 1 we did not find a regulatory fit advantage using a gains task reward structure. In order to fully explore the hypothesis that regulatory fit increases cognitive flexibility we replicated this experiment using a losses task reward structure, where subjects watch their points counter decrease with each incorrect response. In Experiment 1 the fit between regulatory focus and task reward structure was promotion/gain and the mismatch was prevention/gain but with a losses task reward structure the regulatory fit condition is prevention/loss and the regulatory mismatch is promotion/loss.

Method

Subjects 50 adult undergraduate subjects from the University of Western Ontario participated for course credit, 25 in the Prevention condition and 25 in the Promotion condition.

Materials The same design, regulatory focus manipulation and category structure as in Experiment 1 were used.

Procedure The procedure used is identical to that used in Experiment 1, with the exception of the task reward structure, which now involves losses as opposed to gains.

In the promotion/loss (regulatory mismatch) condition subjects were told that they would be entered into a draw for a $40 gift card if they did not lose all of their points before the end of the experiment. On the right-hand side of the computer screen was an error-counter bar that decreased with each incorrect response subjects made. It did not decrease or increase for correct responses. Subjects were told to try not to lose all of their points before the experiment was over. If subjects finished the experiment with 120 points leftover they were considered to have met the criterion and would earn their entry into the drawing.

The prevention/loss (regulatory fit) condition was similar to the promotion/loss condition except that subjects were told they had been entered into a draw for a $40 gift card and would lose the entry if they lost all of their points before the end of the experiment. If subjects did not lose all of their points they would be able to keep the entry. Subjects could watch the error-counter bar on the right-hand side of the computer screen decrease with each incorrect response.

Results

Criterion Reachers We looked at how many subjects reached the criterion by regulatory focus and task reward structure. More promotion/loss subjects (n=10) reached the criterion than prevention/loss subjects (n=6). This difference did not approach significance when a chi-square goodness of fit test was performed, $\chi^2 = 1.0$, df=1, *ns*.

Total Trials We were interested in whether regulatory fit subjects (prevention/loss) would complete more trials than regulatory mismatch subjects (promotion/loss). We looked at how many trials subjects completed. Subjects who reached the criterion were assigned a trial count of 560. The mean number of trials prevention/loss subjects performed (M=367.16) was greater than the mean number of trials promotion/loss subjects performed (M=357.24), however a t-test did not approach significance, t=.18, df=48, *ns*.

Learning Rate We looked at the averaged performance of subjects in the prevention and promotion conditions in the first ten blocks (140 trials) of learning. We wanted to see whether regulatory fit subjects would show faster learning than regulatory mismatch subjects before subjects started to lose all of their points. We predicted that subjects in the regulatory fit condition (prevention/loss) would show more accurate performance than subjects in the regulatory mismatch condition (promotion/loss). However we did not find a regulatory fit advantage in learning. Prevention/loss subjects (M=63.83) did not perform significantly better than prevention/gain subjects (M=61.03) when a one-way analysis of variance was performed, F=1.57, df=19, *ns*.

Performance Quality We calculated the average accuracy of all subjects in their final full block of the experiment. Looking at the final full block of each subject provided a way of looking at subject performance after learning had occurred. A t-test found that prevention/loss subjects (M=0.74) were no more accurate than promotion/loss subjects (M=0.74) in the final full block of performance, t= 0.97, df = 48, *ns*.

Modeling Performance We were interested in whether more subjects in a regulatory fit condition learned a complex rule than subjects in a regulatory mismatch condition. The same modeling procedures as in Experiment 1 were used. We were particularly interested in whether subjects in the regulatory fit condition would show greater attention to the features that were best predictive of category membership, features four and five than subjects in the regulatory mismatch condition.

Both the GCM and PRT models provided a good fit of the data; the RMSD of the GCM and PRT model for the prevention/loss condition was 0.20 and 0.21 respectively. For the promotion/loss condition the RMSD of the GCM and PRT model was 0.16 and 0.21 respectively. We found that more promotion/loss (n=20) subjects than prevention/loss (n=10) subjects were best fit by the GCM model than by the PRT. This difference approached significance when a chi-square goodness of fit test was performed, $\chi^2 = 3.33$, df=1, $p<.07$. One possibility is that the good fit of the CGM, which is better able to fit performance in the NLS categories, reflected greater mastery of the all the stimuli by subjects in the promotion/loss condition. The slightly better performance of the prototype model in the prevention/loss condition was likely due to less exploration and heavier reliance on the family resemblance structure of the NLS category stimuli.

However, when we examined attention weights, we found that promotion/loss subjects (M=18.40) paid more attention to features four and five than prevention/loss subjects (M=16.48), although this difference did not approach significance, t=-.397, df=98, *ns*.

Discussion

In Experiment 2 we tested the regulatory fit-cognitive flexibility hypothesis using a losses task reward structure, where prevention condition subjects experienced a fit between regulatory focus and task reward structure and promotion condition subjects experienced a mismatch between regulatory focus and task reward structure. We predicted that regulatory fit subjects would be better able to learn the NLS category-learning task than regulatory mismatch subjects. However we did not find a regulatory fit advantage when we looked at criterion reachers, total trials completed, learning rate, or final block performance. Computational modeling did not provide support for the hypothesis that subjects in the regulatory fit condition would be more likely to learn a complex rule than regulatory mismatch subjects. Subjects in the regulatory fit condition did not display more accurate performance and were not better able to find and apply a complex rule.

General Discussion

We have failed to find strong effects of regulatory fit on the learning of nonlinearly separable categories. In Experiment 1, using a gains task reward structure, we found that subjects with a promotion focus were no more likely to display complex rule use than subjects with a prevention focus. Similarly, in Experiment 2, using a losses task reward structure, we did not find a regulatory fit advantage. Subjects with a prevention focus did not display better performance compared to subjects with a promotion focus. While we found a significant final block performance advantage for regulatory fit subjects in

Experiment 1, the main results of Experiment 1 and Experiment 2 do not support the regulatory-fit-cognitive flexibility hypothesis, namely that a regulatory fit results in an increase in cognitive flexibility that can improve category learning performance when cognitive flexibility is considered advantageous for category learning.

Our Experiments 1 and 2 provide a replication of Maddox et al.'s (2006) and of Grimm et al.'s (in press) research, which used both gains and losses task reward structures and looked at the learning of rule-based category sets. Prior results show that when there is a match between experimentally induced regulatory focus and task reward structure, subjects perform better than when there is not a match between regulatory focus and a gains task reward structure. Our results sought to go beyond the results of previous research and show these effects for nonlinearly separable categories. However we did not find a strong regulatory fit advantage in our Experiment 1 or our Experiment 2. This suggests that regulatory fit may not be capable of improving the learning of very complicated categories that require both rule and exception learning.

Why we did not find a regulatory fit advantage is not clear. While Grimm et al. (in press) did not find a significant advantage for prevention/loss subjects in a rule-based task, the results were in the expected direction, with regulatory fit subjects reaching a criterion of performance more quickly than regulatory mismatch subjects. In our case, prevention/loss subjects displayed performance equal to or below the performance of promotion/loss subjects.

There are some possibilities as to why we did not find consistently large effects on category learning performance between regulatory fit and regulatory mismatch conditions. One is that because the nonlinearly separable category-learning task involved multiple rules that increased in complexity and optimality, subjects found the task to be quite difficult, even in regulatory fit conditions. Perhaps because subjects could achieve relatively high accuracy rates (up to 86%) by paying attention to only one feature they were not motivated to learn the most complex rule. In the rule-based experiment by Maddox et al., (2006) the suboptimal rule resulted in 83% accuracy and the optimal rule resulted in 100% accuracy. It is possible that the 86% accuracy rate that could be achieved by paying attention to a single feature was high enough to reduce subject's motivation to look for the optimal rule.

Another related possibility is that our manipulation of regulatory fit was not effective. Unlike previous research (Maddox et al., 2006; Grimm et al., in press), we did not specify to subjects the criterion necessary for earning or keeping their entry into the draw. This could have decreased subject's motivation to learn the optimal rule. If we had broken the 560 trials into smaller blocks and given feedback as to whether subject performance was high enough to reach the criterion after each block it is possible that a regulatory fit advantage would have become apparent in our experiments.

Summary and Conclusions

This research tested the regulatory fit- cognitive flexibility hypothesis of classification learning in two experiments using a nonlinearly separable category structure. We sought to provide a replication of Maddox et al.'s (2006) research showing that a regulatory fit is advantageous for category learning when increased cognitive flexibility is advantageous. We found partial support for this hypothesis. Subjects in Experiment 1 showed better final block performance when they were in a regulatory fit involving a gains task reward structure. However we did not find differential performance in any other measures of performance in Experiment 1 and in Experiment 2, when subjects were in a regulatory fit involving a losses task reward structure we did not find any regulatory fit advantages or any differences in performance between conditions.

While the results of our experiments are not consistent with those of Maddox et al. (2006) and Grimm et al. (in press), they underline the importance of understanding how motivation can affect cognition, specifically even basic cognitive skills such as categorization.

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