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Trait individual difference of reinforcement-based decision criterial learning during episodic recognition judgments

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Although it is known that there are personality characteristic variances in the sensitivity to environmental feedback, the trait individual difference has scarcely been explored in the context of recognition memory decision. The present study investigated this issue by examining the relationship between the feedback-based adaptive flexibility of recognition criterion positioning and personality differences in general sensitivity to non-laboratory outcomes. Experiment 1 demonstrated that veridical feedback itself had little effect on the recognition decision criterion whereas Experiment 2 demonstrated that biased feedback manipulations selectively restricted to high confidence errors, induced shifts even in the overall Old/New category criterion. Critically, individual differences in stable personality characteristic linked to reward seeking(Behavioral Activation System-BAS) and anxiety avoidance (Behavioral Inhibition System-BIS) has been shown to predict the sensitivity of subjects to this form of feedback-induced criterion learning. This data further support the idea that incremental reinforcement-based learning mechanism not often considered important during explicit recognition decisions may play a key role in criterion setting.

Keywords : Trait individual difference, BIS-BAS, Biased feedback, Recognition decision criterion

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Introduction

It is widely accepted that standard systems approach to learning holds that incremental reinforcement learning and episodic learning are two distinct cognitive processes based on discrete neural systems, each with different operating characteristics and conscious correlates (e.g., Poldrack, et al., 2001; Schacter & Tulving, 1994; Squire, 2004; Tulving, 1985). Due to this distinctive framework, a fundamental role of reinforcement learning in declarative memory has rarely been investigated in humans; though Wixted and Gaitan (2002) presented a framework for thinking about how reinforcement histories might govern recognition behavior. Recent findings using a feedback procedure, however, represent a direct challenge to this idea by showing a key role for feedback-decision relationships during explicit recognition judgments (Han & Dobbins, 2008, 2009; Rhodes & Jacoby, 2007; Verde & Rotello, 2007). For example, Han and Dobbins (2008) demonstrated that independent of the actual strength or quality of memory evidence available for the test items, subjects are adaptively and durably influenced by subtle differences in the validity of error-related feedback during recognition. The researchers subtly manipulated decision/ outcome contingencies during Old/New recognition retrieval in an attempt to encourage either misses (errors of omission) or false alarms (error of commission) in the context of feedback that was otherwise correct. The manipulation led to prominent and sustained shifts in the measured decision criterion. For example, if a subject receives biased feedback indicating that he or she is in fact *correct* during false alarm trials, then adopting an even a laxer recognition criterion is potentially desirable since further movement in this direction will yield an even greater ratio of positive, relative to negative, outcomes if the remaining feedback for the three other response types remains accurate. That is, the movement of recognition response tendency in the lax direction will reduce the correct negative feedback linked with miss without the usual opposing cost in negative feedback that would occur for false alarms, because the latter are falsely indicated as correct. More recent findings suggest that the effect was reliable even when the feedback manipulations were brought more in line with those used during information integration and probabilistic classification learning studies (i.e., false positive feedback to approximately 70% of incorrect endorsement) (Han & Dobbins, 2009), which is thought to rely upon procedural and reinforcement learning process (Gluck & Bower, 1988a; Poldrack, et al., 2005; Squire, 1992). Due to the probabilistic manipulation of biased feedback in the study, it was assumed that explicit strategies were not productive to induce criterion shifts whilst more incremental reinforcement learning led subjects to develop a gradually acquired response tendency as the manipulated probabilistic feedback accrued.

The data briefly reviewed above suggest that reinforcement learning mechanisms may gate or regulate the expression of episodic retrieval decisions by rendering subjects more or less cautious in the translation of mnemonic evidence into overt decisions or responses. Specifically, the findings begin to highlight some of the characteristics of this feedback-induced criterion learning. First, the learning of probabilistic relationships between types of episodic judgments and environmental outcomes via feedback modulates the recognition decision criterion (Han & Dobbins, 2009). Second, these learned criterion shifts remained for a considerable durations in the absence of any environmental support (viz., the no or neutral feedback tests) (Han & Dobbins, 2008, 2009). Taken as a whole, these learning-linked findings suggest a key role for reward process governing the expression of episodic information. Likewise, the obtained data also begin to contribute to the building of theoretical links between implicit category learning and explicit recognition retrieval domains by suggesting a mechanism by which recognition decision criteria are influenced by incremental reinforcement learning processes.

Given that such learning does not require explicit rule use, and indeed is prevalent in species likely unable to formulate such rules (Herrnstein, 1970), the previous findings further suggest the learning is largely implicit. The question to be addressed in the present study is, given that the learning is implicit and linked to feedback processing, whether the flexibility of criterion position is related to stable personality characteristics that reflect sensitivity to environmental feedback. If so, there may be substantial individual variances in the ability to process the feedback information that modulates recognition behavior. Several previous works showed that affective reactivity was closely linked to individual differences in other cognitive control areas such as working memory performance (Eysenck & Calvo, 1992; Gray, 2001; Gray & Braver, 2002; Lieberman, 1999). The present study aims to look at individual differences in sensitivity to environmental outcomes during episodic recognition judgments. Unlike the ability to utilize explicit instructions or rules to govern response tendencies, procedural learning phenomena critically depend upon changes induced by positive and negative feedback outcomes (i.e., Gluck, Shohamy, & Myers, 2002; Meeter, Myers, Shohamy, Hopkins, & Gluck, 2006). The present study hypothesized that the adaptability of an individual subjects' recognition decision criteria might be linked to differences in trait sensitivity to environmental reward and punishment.

The possibility above is closely linked with an often cited neurobiologically inspired model of motivation referred to as Reinforcement Sensitivity Theory (RST) (Gray, 1970; Gray, 1982). The basic RST model holds that individuals have tonic differences in their sensitivity to both punishing and rewarding outcomes. These differences are thought to depend on separate neurobiological systems globally referred to as the Behavioral Inhibition System (BIS) and Behavioral Activation System (BAS), respectively. Whereas the former is tentatively linked with a septo-hippocampal circuit and thought to regulate inhibitory behavior in the face of potential punishment, the latter is thought to depend upon dopaminergic striatal pathways and regulates behavior linked to potential gains in reward (i.e., Gray, 1982, 1990). This division is closely linked with early ideas separating approach from avoidance systems. For example, as early as 1923, Tolman suggested that animal behavior seemed to be governed by general response tendencies towards "tending to continue and get more" (i.e., approaching a desired outcome) or "tending to remove" of stimulus (i.e., avoiding an undesired outcome) (Tolman, 1923; see also Amodio, Shah, Sigelman, Brazy, & Harmon-Jones, 2004; Shah, Higgins, & Friedman, 1998). Within the field of personality theory there are currently many ongoing debates regarding the dimensionality and interdependence of traits linked to reward and punishment sensitivity and these lie outside the scope of the present research. Nevertheless, to the extent that existing personality scales capture individual differences in the sensitivity or reactivity to environmental rewards and punishments then these scales may be sensitive to the wide differences observers display in response to the biased feedback manipulations used in the current research.

EXPERIMENT 1 - Control study: Unbiased Correct Feedback during Old/ New Recognition

Before assessing the efficacy of the biased feedback manipulation, a control experiment investigated whether the correct feedback procedure during recognition retrieval would, in and of itself, affect accuracy or criterion placement. Prominent influence of correct feedback on either accuracy or criterion estimates would complicate explanation since the criterion shift is potentially unreliable when confounded with concomitant accuracy changes (see Pastore, Crawley, Skelly, & Berens, 2003; Wixted & Stretch, 2000). Another potential concern that might arise from the design of consequent alternating study-test paradigm is that the Old/ New criterion might have become more lax naturally across the three test runs due to fatigue or proactive interference effects. For completeness and to guard against any confounds, the effect of feedback presence was directly tested.

Methods

Subjects

Eighteen Duke undergraduates participated in return for course credits. Informed consent was obtained, as required by the human subjects review committee of Duke University. Two subjects exhibited poor discrimination (detection theoretic sensitivity measure d’ < .5) and were excluded from the analyses.

Materials and Procedure

A total of 600 English nouns were randomly drawn for each subject from a pool of 1,216 words total (average of 7.09 letters and 2.34 syllables, with Kučera-Francis corpus frequency of 8.85). From the list, three lists of 200 items (100 old, 100 new words for each cycle) were constructed for use in three study-test cycles. Computers were used for item presentation and response collection. Prior to the experiment, subjects were required to study a list of nouns while counting the syllables of each word and instructed that they would be immediately tested on memory for the items. They were not forewarned that feedback would be provided during testing. During study session, subjects were required to report the number of syllables for each serially presented word. Each word appeared with the syllable counting task cue (“Counting syllables 1/2/3 more than 4”) underneath for a limited amount of time (2 sec). During test session, old (studied 100 items) and new (100) items were randomly intermixed and presented serially for Old/New recognition judgments (“Is this OLD or NEW? 1

= OLD 2 = NEW") and confidence ratings ("Confidence? Unsure = 1 2 3 = Certain") using pre-assigned keys on the keyboard. Subjects made self-paced responses. Prior to the experiment, there were 10 practice trials for each study and test phase and subjects pressed a key to begin the study proper.

Feedback manipulation:

All recognition test runs were accompanied by feedback that noted the accuracy of each memory response. Feedback immediately followed the confidence rating.

Results & Discussion

The analyses employed the detection theoretic estimate of accuracy, d'. Criterion was estimated using the false alarm rate (FAR[1]) (Benjamin & Bawa, 2004; Morrell et al., 2002).

Accuracy (d') and Decision Criteria (FAR): A one-way ANOVA for d' with factors of Test (Test 1, Test 2, or Test 3) yielded no significant effect ($F < .79$, $p = .47$) (Table 1). ANOVA on the FAR revealed no evidence that the criterion shifted

Table 1: Experiment 1 accuracy and decision criterion across Tests

	Correct Feedback- Correct Feedback- Correct Feedback					
	TEST1		TEST2		TEST3	
Hit	.69	(.10)	.68	(.12)	.66	(.12)
False Alarm	.25	(.09)	.23	(.10)	.25	(.08)
d'	1.20	(.40)	1.27	(.43)	1.15	(.38)

Note: Values in parentheses indicate standard deviations.

during the course of testing ($F < .22$, $p = .81$). The null effect of veridical feedback procedure in Experiment 1 indicates that any potential criterion changes observed in the feedback procedure in the following Experiment 2 may not be either due to the physical presence of feedback outcome information or resulted from fatigue or proactive interference effects across test runs.

EXPERIMENT 2 – Recognition Criterion Learning and Personality Characteristics Linked to Reinforcement

Given that Experiment 1 revealed no accuracy or criterion changes induced by veridical feedback procedure, Experiment 2 directly examined whether recognition decision criterion is sensitive to relatively skewed reinforcement contingencies during memory attribution. Despite an absence of main effect of Test Experiments 1 indicates considerable individual variability of criterion placement when given veridical feedback in each Test (Table 2A), suggesting potential sensitivity variances across subjects to trial

Table 2: Mean, Standard Deviation, Range for criterion placement for each Test (Test 1, Test 2, Test 3)in Experiment 1 (A) and the amount of decision criterion change across Tests (Test 2 – Test 1) in Experiment 2 (B).

	Mean	SD	Range (Min~Max)
(A). Experiment 1			
Test 1	.25	.09	0.13~0.52
Test 2	.23	.10	0.12~0.46
Test 3	.25	.08	0.12~0.38
(B). Experiment 2			
Test 2-Test 1	.09	.08	-0.07~0.20

Note: SD = Standard Deviation

specific information relevant for assessing the suitability of currently held decision criteria. Experiment 2 examined this possibility by measuring trait sensitivity to environmental reward and punishment via self-report questionnaire, and correlating these scores with subjects'sensitivity to the probabilistic biased feedback manipulation (see below for more details).

The probabilistic delivery of biased feedback was limited to a subset of errors, namely, those trials in which "Certain" confidence endorsements followed incorrect "Old" responses. Therefore, a group of observers were encouraged to become lax (e.g., saying more "Old") by administering the biased feedback following high confidence false alarms. All other responses received correct feedback. Besides the probabilistic control for the incremental learning, there were also two additional motivations underlying the restriction of the procedure to high confidence errors of endorsement. First, at least in terms of updating general knowledge beliefs, it has been demonstrated that feedback to errors of high confidence yields more durable corrections than feedback to errors of low confidence (Butterfield & Metcalfe, 2001). This so called "hypercorrection effect" makes sense in light of reward processing models that stress prediction error (Schultz & Dickinson, 2000) and that implicate striatal brain regions thought to support procedural and reinforcement learning.

The second reason for restricting the biased feedback to high confidence commission errors was to verify that subjects were using this information to change the overall Old/New decision or response tendency and not simply to inform confidence. More specifically, within Signal Detection Theory confidence reports result in additional criteria placed along the decision axis (Fig. 1 see also Macmillan & Creelman, 1991). These criteria are typically assumed to be equivalent to the criterion that separates the Old/New category distinction. Under such a framework, one might expect that individual criteria, such as a high confidence Old criterion, could be moved without affecting the position of the overall Old/New criterion (Fig. 1A). Thus from a Signal

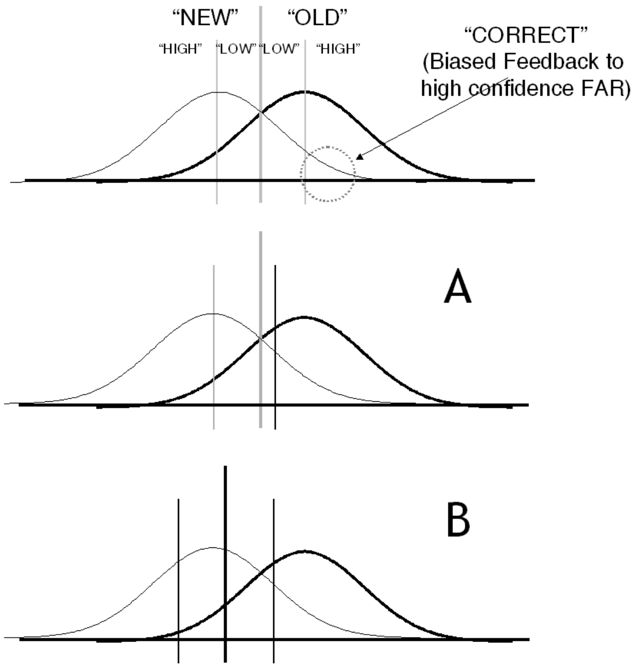

Figure 1. Illustration of the possible movement of the confidence criteria as a function of biased feedback manipulation. (A) Selective shift in the high confidence Old criterion and (B) overall criterion shift representing general Old/New category distinction changes. Note: FAR = False alarms

Detection perspective there is no a priori reason to predict that restricting the biased feedback procedure to the high confidence Old criterion should lead to concomitant changes in the position of the Old/New criterion. In contrast, if subjects are using environmental information to inform them more generally about the overall category distinction between old and new items, then the overall Old/New criterion should shift despite restricting feedback to the high confidence false alarms (Fig. 1B). In order to estimate each observer's initial criterion position, an initial test was given with no feedback. Following this, a second test was given using the restrictive biased feedback procedure. Finally, the subjects were tested with feedback removed in order to examine the durability of any induced criterion shift.

Methods

Subjects

Seventeen Duke undergraduates participated in return for partial course credit. Informed consent was obtained in accordance with the human subjects review committee of Duke University. Subjects were asked if they were aware of any abnormalities or systematic inaccuracies in the feedback, in response to the question "Did you find the feedback to your "OLD" or "NEW" answer helpful? If not, please specifically explain why." No subject indicated that they were potentially aware of the manipulation on the post-experiment questionnaire.

Materials and Procedure

Three lists of 200 items (100 studied- and 100 lure- items) were constructed using the same pool as in Experiment 1. uring testing, the studied and lure items were randomly intermixed and presented serially for recognition judgments ("Is this OLD or NEW? 1=OLD 2=NEW"). Following the old/new response, the subject then rated their confidence on a two-point scale ("Confidence? Unsure =1 2= Certain"). Other than this change, the procedures were identical to Experiment 1. To measure individual differences in general sensitivity to inhibit action that leads to anxiety-provoking negative consequences (Behavioral Inhibition System-BIS) and the tendency to actively seek rewarding outcomes (Behavioral Activation System-BAS) the BIS-BAS self-report questionnaire (Carver & White, 1994) was used to see subscale scores correlated with the level of feedback-induced criterion learning across participants. The instrument has four subscales, one of which targets BIS and three that target different aspects of BAS (Reward Responsiveness, Drive, and Fun Seeking). Examples of items from each of the subscales are presented in Appendix 1. A Likert-type 4 point scale was used to respond to each question. Subjects were given the BIS-BAS self-report questionnaire after the recognition test.

Feedback manipulation

Feedback, if given, immediately followed the confidence rating. The perceptual characteristics of feedback were the same as in Experiment 1. The biased feedback was probabilistically given only in Test 2 by being limited to a subset of errors, namely, high confidence false alarms while all other responses received correct feedback to selectively encourage lax responding. Approximately 8% of the total false alarm trials in test 2 received false positive feedback “That is CORRECT”. To establish each observer’s baseline old/new criterion position, no feedback was given in the first test. In the second test the false feedback manipulation was applied to high confidence false alarms to encourage lax responding. Finally, in the last test, no feedback was given in order to examine the durability of any criterion learning induced in test 2. All responses during testing were self-paced.

Results & Discussion

Accuracy

A one-way ANOVA for d' with factors of Test (Test1, Test2, Test3) yielded a significant main effect ($F(2,30) = 21.29$, $p < .001$, $\eta^2_p = .59$) (Table 3). Pair-wise

Table 3: Experiment 2 accuracy and decision criterion across Tests

	No Feedback-LAX-No Feedback					
	TEST1		TEST2		TEST3	
Hit	.76	(.09)	.76	(.08)	.75	(.07)
FAR Most Conf	.08	(.06)	.19	(.15)	.16	(.13)
FAR Overall	.23	(.08)	.32	(.10)	.34	(.12)
FAR New	.59	(.20)	.62	(.23)	.69	(.21)
d'	1.53	(.37)	1.23	(.37)	1.11	(.38)

Note: Values in parentheses indicate standard deviations. FAR = False alarm

comparisons showed that the first test block was more accurate than the second, ($t(15) = 4.84$, $p < .001$, $d = 2.50$),and the third test, ($t(15) = 6.94$, $p < .001$, $d = 3.58$). There was no difference between the second and the third tests.

Decision Criteria

The estimates for three criteria (the most confident Old criterion, the overall Old/New decision criterion, and the New criterion) are shown in Figure 2 and Table

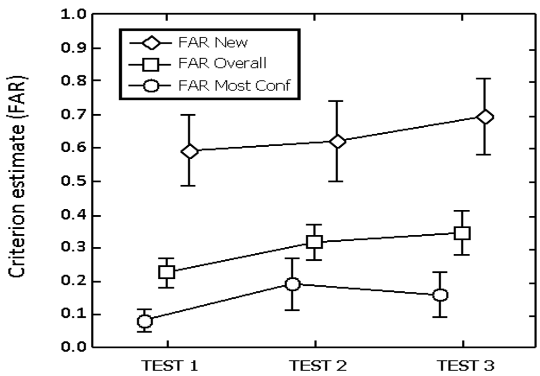

Figure 2. Experiment 2 decision criteria shifts across Tests.

3. ANOVA for FAR with factors of Criteria and Test (Test 1, Test 2, Test 3) yielded a significant main effect of Criteria ($F(2,30) = 75.47$, $MSe = 3.03$, $p < .001$, $\eta^2_p = .83$), a significant main effect of Test ($F(2,30) = 15.74$, $MSe = .13$, $p < .001$, $\eta^2_p = .51$), and a significant interaction of Criteria and Test ($F(4,60) = 3.42$, $MSe = 0.01$, $p < .05$, $\eta^2_p = .19$). The main effect of Test demonstrated that the criterion became more liberal in Test 2 ($t(15) = 4.02$, $p < .01$, $d = 2.08$) and in Test 3 ($t(15) = 6.20$, $p < .01$, $d = 3.20$) compared to Test 1. There was no difference between Test 2 and Test 3 ($p = .27$). Critically, the pattern of criterion movement demonstrated in the main effect was also clearly evident in the overall Old/New criterion when considered in isolation. ANOVA on the FAR revealed a main effect of Test (Test 1, Test 2, Test 3) ($F(2,30) = 17.24$, $p < .001$, $\eta^2_p= .53$), demonstrating that the Old/New criterion was affected by the feedback manipulation, even though biased false feedback was restricted solely to high confidence errors of commission. This demonstrates that participants used the feedback to generally inform them about the Old/New category distinction, as opposed to simply increasing their tendency to express high confidence following old report. Post hoc pair-wise comparisons demonstrated that the criterion (FAR) was significantly more liberal in Test 2 ($t(15) = 4.56$, $p < .001$, $d = 2.35$), and Test 3 ($t(15) = 6.16$, $p < .001$, $d = 3.18$), compared to Test 1. There was no difference between Tests 2 and 3 ($p = .26$), suggesting that the induced liberal criterion shift persisted when the feedback was removed in Test 3.

Correlation with Personality scale (BIS-BAS)

Table 2B above depicts means, standard deviations, and range for criterion placement, indicating a relatively broad range of individual variations in the magnitudes of the shifts in Experiment 2. This individual variability could reflect different sensitivities, on the part of the subjects, to the positive and negative outcomes that are assumed to motivate or trigger the criterion shifts. Correlation analyses were performed in order to examine the relationship between criterion learning in response to feedback, and self-reported general sensitivity to positive/negative environmental outcomes outside the laboratory. BIS-BAS subscale scores for each subject were summed and correlated with an estimate of criterion flexibility as defined by the difference between the FAR for the Test 2 minus Test 1. If participants are highly sensitive to the feedback manipulation, then this difference score will tend to be large (viz., lax).

The BIS subscale score positively correlated with the false alarm change score ($r = .50$; $p < .05$). These findings indicate that subjects who self-report being more sensitive to negative outcomes in life, demonstrated more pronounced shifts of the criterion in response tothe biased feedback procedure. Thus one component of the induced criterion movement is the tendency to avoid negative outcomes linked to the non-manipulated incorrect response category (in this case “New”responses) and this tendency is moderated by self-reported sensitivity to negative outcomes outside the laboratory. Additionally, the BAS reward responsiveness scale positively correlated with the FAR change score ($r = .55$; $p < .05$) (Fig. 3). This data suggest that a second factor driving the biased feedback induced shifts is the approach or seeking of

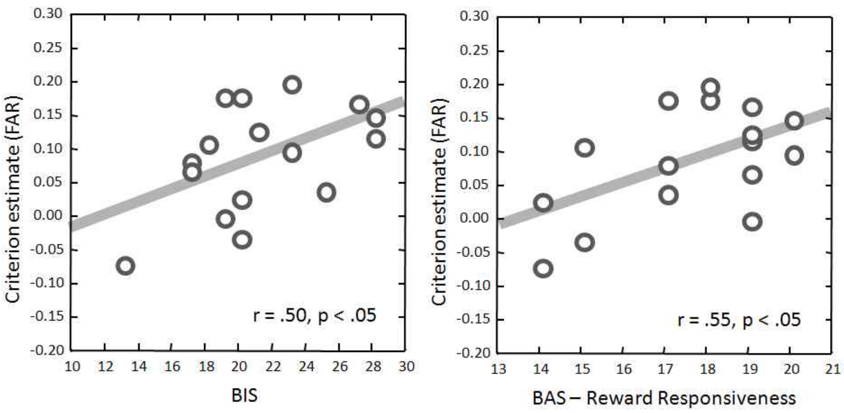

Figure 3. Experiment 2 correlation analyses between BIS-BAS personality index and changes of decision criterion (False alarm rates) across Tests (Test 2 - Test 1)

rewarding feedback outcomes. The other two BAS subscale (Drive, Fun-Seeking) failed to show correlation ($r = .07$, $r = -.45$ with Drive and Fun-Seeking, respectively). BIS and BAS scores were also significantly correlated ($r = .58$, $p < .05$). Finally, correlation between the initial placement of each subject's criterion (FAR in the first block) and BIS-BAS scales did not reach significance. This demonstrates that although the lability of the criterion shifts was correlated to personality variables, the initial starting point of the criteria in Test 1 was not.

The current results demonstrated that the degree of criterion learning displayed by subjects was influenced by stable personality differences linked to individual sensitivity to positive and negative outcomes outside the laboratory. This appears to be the first study linking memory decision criterion flexibility or positioning to stable individual personality characteristic differences (c.f., Benjamin, Wee, & Roberts, unpublished data). The results further provide an independent confirmation of the incremental reinforcement learning hypothesis of the phenomenon linking the shift of episodic memory decision criterion to reward-based learning mechanism. That is, considerable individual variances of the trait sensitivity to trial specific environmental feedback information governed observers' ability to assess the suitability of recognition criterion position and decided the amount of adaptive criterion shifts. Second, the induced shifts were observed in the Old/New criterion despite the fact that the false-feedback manipulation was restricted to high confidence errors. It is important to note that this means that BIS and BAS correlations reported above occurred with respect to a criterion that was not directly targeted by the feedback manipulation. Overall, this suggests that subjects are using the feedback to learn about the appropriateness of Old/New classifications more broadly, and not simply the appropriateness of reporting high confidence following an Old report.

Discussion

Previous research in non-recognition domains has proposed learning models in which subjects adjust criteria in response to feedback after errors occur (e.g., Dorfman, 1986; Dorfman & Biderman, 1971; Kubovy & Healy, 1977). Despite the prevalence of feedback manipulations in non-memory domains, the use of feedback information to influence memory decision criteria is surprisingly rare. The present study examined the adaptive flexibility of recognition decision criteria in light of reinforcement learning by measuring trait sensitivity to environmental reward and punishment via self-report questionnaire, and correlating these scores with subjects' sensitivity to the biased feedback manipulation.

Here, a combination of probabilistic biased feedback was used and restricted to only a subset of errors, namely high confidence false alarms. Thus the relationship between response types and outcomes was relatively opaque and indeed no subjects in this design reported being aware of anything odd or unusual about the nature of the feedback. Nonetheless, when feedback manipulations were restricted to high confidence errors, shifts were observed in the overall Old/New category criterion, which suggests that the learning that is evinced is with respect to the categorical distinction the subjects are making with respect to the memoranda. If instead the learning were specific to each confidence criterion then only the high confidence criterion would have been affected. Finally, there appears to be a fairly large range of reward reactivity or sensitivity across typical subjects and this may serve to regulate how effective these or similar reinforcement procedures are on individual subjects during testing. In other words, subjects who find the positive and negative feedback less salient or who are less reactive to these minor rewards and punishments may show less adaptation in the placement of their recognition criterion. More importantly, the level of criterion adaptation in response to the feedback manipulation was correlated with stable personality characteristics linked to reward reactivity outside the laboratory. Taken as a whole, these findings suggest a key role for incremental reward learning governing the expression of episodic information.

Along with the previous studies (Han & Dobbins, 2008, 2009), Experiment 2 provides evidence that the induced criterion change may reflect a type of implicit learning perhaps analogous to that which occurs during probabilistic classification learning paradigms (Gluck & Bower, 1988b; Knowlton, Squire, & Gluck, 1994). During the task, due to the probabilistic relationship between cue-outcome, explicit strategies are not productive until enough instances confirmed through cognitive feedback are accrued. Given that the current findings strengthens the links between criterion shifts and reward-based learning mechanisms, a natural prediction arising from this finding is that performance in category learning tasks might also be subject to similar personality dependencies. That is, those subjects who score highest on BIS and BAS subscales may acquire the category distinctions quicker in probabilistic classification and information integration tasks.

Although it appears that the questionnaire data and pattern of responding in the present studies are consistent with an implicit, response learning phenomenon, it is more important to note that the primary purpose of the current investigation was to demonstrate a flexible and adaptive criterion during testing that did not rely upon gross manipulations of the memoranda or upon explicit biasing instructions, but is linked to individual differences in trait sensitivity to environment reward and punishment. However, the current data also clearly suggests that further investigation of the characteristics and neural substrates of biased feedback criterion learning are warranted because the shifts demonstrated here may be fundamentally different than those obtained through explicitly warning subjects to be cautious or lax in responding (e.g., Azimian-Faridani & Wilding, 2006). A strong candidate for underlying neurobiological connectivity between reinforcement learning and episodic systems that might mediate recognition decisions is dopaminergic pathway linking frontal regions with basal ganglia (i.e., corticostiatal circuit), an associative loop underlying goal-directed behavior modulated as a function of reinforce values (e.g., Grahn, Parkinson, & Owen, 2008). Nonetheless, the present findings clearly indicate that the susceptibility to the feedback manipulation was correlated with stable personality characteristics linked to reward processing.

Foot notes

1. It is worth noting that false alarm (FAR) may be a less problematic estimate across conditions in which the accuracy also changes. When accuracy changes across two conditions, detection theoretical estimates of criterion, c or ca also must change because of the way they are calculated (Pastore et al., 2003). More specifically, c or ca represents the distance of the criterion from the midway position where old and new item distribution overlap. Thus changes in the evidence distributions that result in accuracy changes will also influence the criterion, although these detection theoretic measure of criterion resulted in the analogous patterns of results. By contrast, false alarm rate as a measure of criterion is based on the assumption that the new item distribution does not change. For example, previous studies showed that false alarm rates remain constant across prominent changes in hit rates when target strength is directly manipulated (e.g., Verde & Rotello, 2007; Morrell, Gaitan, & Wixted, 2004). This suggests that false alarm rates may be a more appropriate measure of criterion since it does not change in the face of procedures directly manipulating the memorability of old items (hence change accuracy). This issue was not a problem in Experiment 1 analyses below because the accuracy was not different across test runs within subjects.

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요 약

일화 재인 기억에서 강화에 근거한 의사결정 준거 학습의 특성 개인차 연구

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이전의 연구들이 외부 피드백 정보에 대한 반응민감도에 성격특성적 개인차가 반영된다는 사실을 밝힌바 있지만, 재인기억과 관련한 의사결정에서 이러한 기질 혹은 특성적 개인차가 어떻게 관여하는지는 아직 알려진 바가 없다. 본 연구는 재인기억 과제에서 피드백에 근거한 의사결정 준거의 순응적 변화정도와 피드백에 대한 일반적 반응민감도의 개인차간 관계를 살펴보았다. 통제 조건인 실험 1에서는 올바른 피드백 조건이 의사결정 준거의 유동성에 영향을 미치지 않음을 보인 반면 피드백 조작이 이루어진 실험 2에서는 확신도가 높은 오기억 반응에만 선택적으로 편향된 피드백이 주어졌음에도 전반적인 Old/New 반응 범주의 결정준거 또한 순응적으로 이동함이 나타났다. 보다 중요하게 이 피드백에 근거한 의사결정 준거 학습에 나타나는 개별 피험자들의 반응민감도 차이가 강화 추구 혹은 불안 회피와 밀접하게 관련된 안정적 성격(Behavioral Activation System-BAS 혹은 Behavioral Inhibition System-BIS)의 개인차에 의해 유의미하게 예측될 수 있음이 나타났다. 이러한 결과는 그동안 외현적인 재인 기억 의사 결정에 있어서 중요하게 여기지 않았던 점증적 강화학습 기제가 결정 준거의 설정에 관여할 수 있음을 보여준다는 데에서 중요한 의미를 찾을 수 있다.

주제어 : 성격특성개인차, BIS-BAS, 편향된 피드백 절차, 재인기억의사결정준거

Appendix

BIS-BAS (Carver & White, 1994)

For each of the following statements, please indicate <u>**how much you agree with the statement.**</u> Please provide a rating from **1 to 4**, using the following scale:

1	2	3	4
Strongly disagree			Strongly agree

____ 1. If I think something unpleasant is going to happen I usually get pretty "worked up".

____ 2. I worry about making mistakes.

____ 3. Criticism or scolding hurts me quite a bit.

____ 4. I feel pretty worried or upset when I think or know somebody is angry at me.

____ 5. Even if something bad is about to happen to me, I rarely experience fear or nervousness.

____ 6. I feel worried when I think I have done something poorly.

____ 7. I have very few fears compared to my friends.

____ 8. When I get something I want, I feel excited and energized.

____ 9. When I'm doing well at something, I love to keep at it.

____ 10. When good things happen to me, it affects me strongly.

____ 11. It would excite me to win a contest.

____ 12. When I see an opportunity for something I like, I get excited right away.

____ 13. When I want something, I usually go all-out to get it.

____ 14. I go out of my way to get things I want.

____ 15. If I see a chance to get something I want, I move on it right away.

____ 16. When I go after something I use a "no holds barred" approach.

____ 17. I will often do things for no other reason than that they might be fun.

____ 18. I crave excitement and new sensations.

____ 19. I'm always willing to try something new if I think it will be fun.

____ 20. I often act on the spur of the moment.