To shift or not to shift:
Can feedback alter criterion shifting?

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Abstract

When faced with uncertainty in a recognition memory judgment, being able to shift between conservative and liberal criteria is important to maximize the outcomes of memory-based decisions. However, some people fail to shift criteria, even when it is advantageous to do so. The purpose of this study is to investigate people's decision-making tendencies in order to understand what aspects may influence criterion shifting. This was done by providing feedback on a recognition memory task that encouraged criterion shifting, with the goal of positively influencing their decision-making to maximize decisional outcomes. Across 3 sessions, participants conducted a recognition memory task without feedback (session 1), the same recognition task with trial-by-trial feedback (session 2), and the recognition task again as well as a novel visual detection task, both without feedback (session 3). In Study 1 a base rate manipulation substantially increased criterion shifting when participants were provided with feedback that encouraged the optimal response type (from session 1 to session 2), whereas in Study 2 a payment manipulation resulted in a much smaller increase in the extent of criterion shifting. Across both studies, participants on average tended to shift criteria to similar extents from session 2 to session 3 within the same recognition memory task, suggesting that the effect of session 2 feedback generally transferred to a subsequent testing session. The effect of session 2 feedback did not transfer as well to a novel visual detection task in session 3. However, there was a lot of individual variability, with some individuals being able to transfer criterion shifting strategies from session 2 to the visual detection test in session 3 while others tended to revert back to criterion shifting strategies from session 1. There exist several nuances to the role feedback plays in criterion shifting such as the manner in which the feedback is given, the type of reward of the task, and the individual differences in responding. The results of the current study indicate that feedback can influence greater criterion shifts that transfer to separate testing sessions, but this effect is attenuated for novel tasks in a different decision domain.

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Our everyday lives are filled with countless faces, images, and scenes. Remembering all of these unique stimuli is possible because of recognition memory - our ability to correctly identify previous faces, images, and scenes (Starns & Olchowski, 2015). Recognition memory involves weighing the strength of familiarity of a particular stimulus and making a decision as to whether or not the stimulus was previously encountered. Since the familiarity of items can carry uncertainty, people should adopt a decision strategy that improves decisional outcomes. When maintaining a liberal criterion, people will identify items as old even when the strength of familiarity is weak. A conservative criterion requires strong memory evidence before making a decision that an item is old. These decision criteria play an important role in the outcomes of recognition memory judgements.

Previous studies have shown that manipulating the known prevalence of old items (e.g. 70% old faces, 30% new) as well as monetary incentives are enough to make many individuals shift criteria during recognition memory tests, however the role of feedback on individual criterion shifting tendencies is understudied (Kantner et al., 2015). Individual feedback has shown to be effective in inducing criterion shifting at a group level as it allows participants to learn about their decisions and alter their decision criterion in order to answer optimally (Rhodes

& Jacoby, 2007). This study will aim to investigate the impact of feedback on participants' criterion shifting tendencies across sessions and decision domains, with the ultimate goal of increasing the extent that individuals shift criteria.

Rhodes and Jacoby (2007) performed an experiment in which feedback was given on half of the tasks for the participants. Some participants received feedback on the first two trials and none on the last two and vice versa. This way, they are able to discern if feedback actually affects criterion shifting performance. If feedback is effective at manipulating criterion shifting, then those receiving feedback in the first two trials should shift criteria to a lesser extent in the final two trials. The results showed that most trials receiving feedback displayed large differences in response criterion, specifically for liberal conditions in which participants viewed predominantly old faces. However, when the feedback was taken away, the criterion shifts diminished with their responses approaching neutrality (Rhodes & Jacoby, 2007). To add, other experiments have shown that when manipulating base rate probabilities on recognition memory tasks, shifting was shown to be inconsistent (just like feedback) across all tasks (Singer, 2009). In other words, participants on one task may have shifted a lot, not shifted at all, or shifted half the time. They hypothesized that continuous adjustment of one's criteria was due to lack of cognitive resources, new and useful information, and motivation. This brings up further issues questioning whether or not individuals can keep a stable criteria, and when they do, how consistent that will be. This area of research is complicated because of the nature of the subject. Shifting one's decision criteria has shown to be impacted by a variety of factors, one of which is individual differences. Because of this, there are many confounds that may influence the results of the experiment. This study will look to gain a better grasp on the mechanisms by which *individuals* choose to shift their decision criteria with or without feedback and if it is possible for more optimal criterion shifting strategies to be learned.

One study explored the impact of feedback in which participants completed various recognition memory tasks and were given feedback meant to avoid critical errors and encourage hits. While there was a greater criterion shifting effect that improved overall accuracy and reduced critical errors for the most part, those receiving feedback still committed these types of errors on 25% of trials (Kantner et al., 2015). Further research needs to explore individual shifting tendencies as well as the most effective feedback in helping participants make the most optimal decision. Moreover, it has been shown that shifting can transfer outside of a specific testing domain. That is, participants' abilities to criterion shift during recognition memory tests can be seen in other testing domains, such as visual detection and visual discrimination tests (Frithsen et al., 2018). Can trial-by-trial feedback that encourages optimal responses reliably improve how individuals adapt a decision criterion to a particular situation? Is it an effective way to "learn" criterion shifting?

This study will assess whether trial-by-trial feedback can improve the extent of criterion shifting across time and decision domains as well as whether shifting can be "learned" from previous recognition memory tasks and be applied to a novel visual detection task. Participants completed 3 testing sessions. In session 1, participants conducted a recognition memory task without feedback, in session 2 participants received trial-by-trial feedback that encouraged the optimal response type (regardless if the response was correct or not), and session 3 did not provide feedback during a recognition memory test and visual detection test. In this area of research, it's essential to understand the degree to which feedback can improve the extent of criterion shifting, particularly for individuals who typically do not shift their criteria a lot, given the importance decision criteria has on recognition memory performance. Even so, when participants complete multiple recognition memory tasks in a given study, some participants choose to keep a stable criterion to avoid the extra energy and effort that goes into adjusting one’s decision criteria (Stretch & Wixted, 1998). This idea that shifting one’s decision criteria is a demanding process brings to light more research that needs to be done on more efficient ways in which shifting can be learned, while at the same time keeping participants’ motivation high.

The purpose of this study is to analyze the effect of feedback on recognition memory tests and whether it can improve criterion shifting tendencies on a separate session and on a novel visual detection test. We predict that on average trial-by-trial feedback should increase the extent of *C* regardless of the manipulation, and this feedback should then transfer to a subsequent testing session and decision domains. However, there likely will be individual differences in how well feedback improves criterion shifting, how well it transfers to another testing session, and how well it transfers to a different decision domain. Because past research has shown that criterion shifting can be affected by a variety of factors such as strength of memory, willingness to shift, and cognitive style, it is likely there are several nuances to how feedback can alter the extent to which individuals shift criteria (Aminoff et al., 2012). Regardless, this experiment will give more attention to research surrounding the importance of shifting in hopes to gain more insight into strategies for more successful recognition memory and better decision-making.

Methods

Participants

For Study 1, fifty-four participants from the UCSB undergraduate population were recruited. For Study 2, seventy-five participants from the UCSB undergraduate population were recruited. Both subject pools were recruited through the UCSB SONA participant database. Eight subjects were excluded from the data from Study 2 for not completing all three parts of the study. The subjects' ages ranged from 18-22 years old. In Study 1, participants were compensated with credit while in Study 2 participants were compensated with $5-15 for their participation in each of the three sessions based on their task performance.

Materials and Apparatus

Participants conducted all tasks on a computer using MATLAB version R2016B that incorporated open source code from Psychophysics Toolbox, v3 (Brainard, 1997). A total of 1,280 face images were used for the entire study and 256 scene stimuli were used during the visual detection task in session 3. The scene stimuli had 2 versions, one with a single person and another edited version where the person was removed.

Procedure

Study 1 and Study 2 were identical in almost every aspect of the study. Franks and Hicks (2016) explored participants' shifting tendencies in a blocked versus unblocked task in which participants were either allowed to shift and maintain a decision criterion for the entire block or shift rapidly on a trial-by-trial basis. While feedback wasn't explicitly utilized in this study, this demonstrates that the characteristics of a task can affect the stability of criterion shifting. Thus, this provides a rationale for using the same recognition memory tasks across all sessions in order to better isolate the effect of feedback on criterion shifting. In this experiment, participants completed 3 different sessions. During each task, there were four cycles of study/test phases. 64 images were shown each study phase with each image shown for 300 ms followed by a 100 ms crosshair. The test phase included one conservative (64 images) and one liberal (64 images) test block presented in a random order. Test images remained on the screen until a response was made. In session 3, there were 2 cycles of study/test phase for the recognition memory task and 2 cycles of study/test phase for the visual detection task. In the visual detection task scene, images (collected from a variety of open source databases) were shown for 200 ms followed by a 200 ms noise mask to destroy the perceptual after image. Participants then had unlimited time to respond "present" or "absent" as to whether they viewed a person in the image or not. Study 1 used a probability manipulation in which either 25% or 75% of the images are old, whereas Study 2 utilized a payment manipulation in which 5 cents were given for a correct response, -10 cents for a critical error (a false alarm in the conservative criterion condition and a miss in the liberal criterion condition), and no penalty for a non-critical error.

To begin the study, participants walked into the testing room, sat at a computer, and filled out a consent form that says they can be contacted for future paid studies based on their results. They repeated this each time they arrived for a session. After signing the consent form, the tasks begin with instructions on what the participants will be doing throughout the task. Participants were asked to identify old or new faces after viewing a set of random faces. The participants proceeded to go through a practice session, so that they were familiar with how the actual task will be, and then completed the actual task. After the task was over, they were then asked to complete a questionnaire. Some questions included how much motivation they had to perform well during the task and how much they relied on their memory. When finished, the screen showed how much money they made during the task (minimum $5).

Two days later, subjects were asked to come back to complete additional recognition memory tasks. In Study 1, all of the participants received feedback during the second session, whereas in Study 2, half of participants received trial-by-trial feedback (odd subject numbers) whereas the other half did not (even subject numbers). The purpose for not providing feedback to half of the participants in Study 2 was to rule out practice effects on the extent of criterion shifting. The type of feedback depended on each decision the participant made such that correct optimal responses followed with “Great decision!”, incorrect optimal responses were followed with “Good decision”, correct suboptimal responses were followed with “Okay decision”, and incorrect suboptimal responses were followed by “Terrible decision!”. In the liberal condition (75% old), hit/false alarms were encouraged, while miss/correct rejections were encouraged in the conservative condition (25% old). It is important to note that the response type was encouraged, rather than whether a person provided a correct response or not. The purpose of the feedback was to attempt to induce participants into making the most optimal decision. Participants were not informed of which response types led to the different feedback prompts.

When finished with the task, subjects completed the same questionnaire and were paid ($5 minimum) again. Two days later, the same subjects were asked to complete a final task that included both a recognition memory task and a visual detection task without feedback.

Statistical Analysis

An equal-variance signal detection theory (SDT) model was used to calculate discriminability (*d'*), criterion placement (*c*), and criterion shifting (*C*) (Macmillan & Creelman, 2005). For each test condition, we summed the number of hit (H), miss (M), correct rejection (CR), and false alarm (FA) trials to compute hit rate (HR), false alarm rate (FAR), and percent correct (PC). SDT measures through were calculated using following equations:

HR= H / (H+M)
FAR= FA / (CR+FA)
d'= z(HR) - z(FAR)
c= -0.5 *[z(HR) + z(FAR)]
C= c(conservative) - c(liberal)

Pearson *r* correlations were used to assess the consistency of criterion shifting tendencies across sessions and decision domains, and Cohen's *d* measures were used to assess the mean differences in the extent of criterion shifting to see how much feedback increased the extent of criterion shifting. For Pearson *r* correlations and Cohen's *d* measures, 95% confidence intervals are provided. Any confidence interval that does not include zero is considered statistically significant.

Results

Study 1

Between the first and second recognition memory tasks, mean *C* differed significantly between session 1 (*M*= 0.66, *SD*= 0.67) and session 2 (*M*= 2.19, *SD*= 0.54), *d*= 1.92, 95% *CI*= [1.46, 2.38]. A Pearson correlation indicated a moderate positive association in the extent of *C* between session 1 and session 2, (*r*(52 = 0.33, *CI* = 0.07, 0.55). In the second and third recognition memory tasks, mean *C* did not significantly differ between session 2 (*M*= 2.19, *SD*= 0.54) and session 3 (*M*= 2.14, *SD*= 0.57), *d* = 0.05, 95% CI [-0.33, 0.43]. However, the extent of *C* during session 3 remained much higher for the memory task versus visual detection task (*M*= 1.35, *SD*= 0.48), *d* = 0.84, 95% CI [0.45, 1.24]. Pearson correlations suggested a large positive association in the extent of *C* between the recognition memory tests in session 2 and 3, (*r*(52)= 0.72, *CI*= 0.56, 0.83), and a large positive association between the session 3 recognition memory task and the session 3 visual detection task, (*r*(52)= 0.67), *CI*= [0.49, 0.79], demonstrating that criterion shifting tendencies remained quite consistent across testing sessions and decision domains. *Figure 1.* shows individual differences in the extent of *C* across the three sessions ordered from left to right based on shifted criteria.

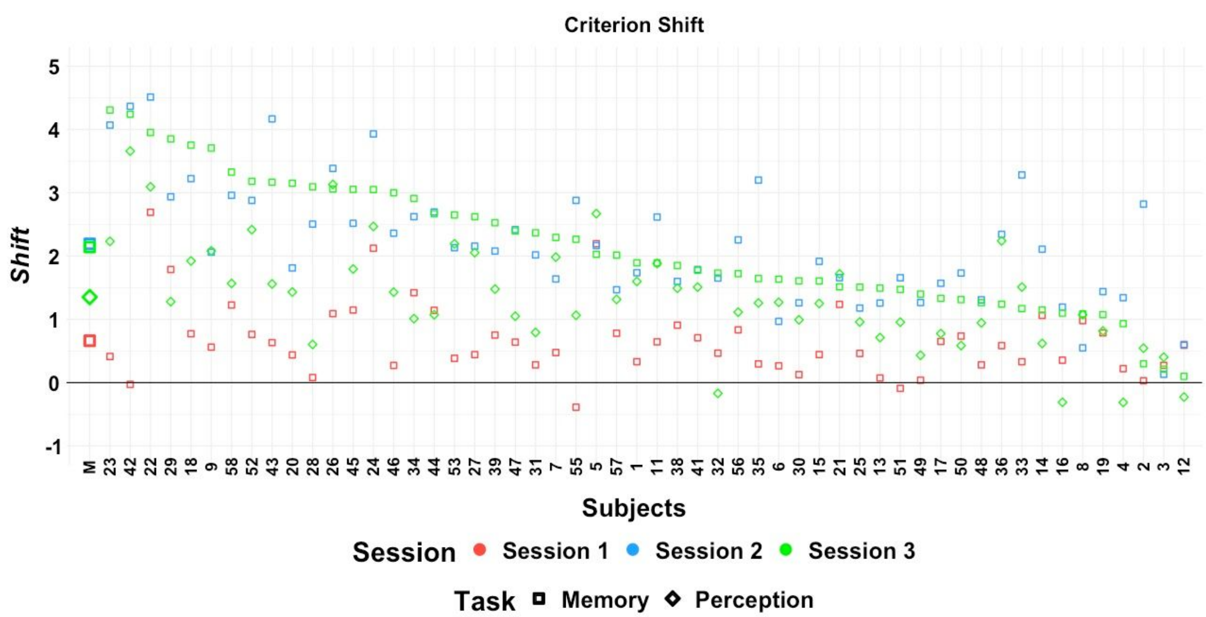

Figure 1. Data from Study 1 illustrating the extent to which participants shifted criteria on each of the three sessions and in the recognition vs. visual detection (Perception) tasks. Participants

are ordered from left to right based on who shifted criteria the most during session 3 of the recognition memory task. Mean (M) *C* is reported on the left side of the graph.

Study 2

Statistical analysis of Study 2 was the same as Study 1, using the same calculations to compare mean *C* across the three sessions. One important factor to remember is that in Study 1, all of the participants received the same treatment as the results were based on the extent to which individuals shifted throughout each session, while in Study 2, only half of the participants received feedback during the second session. This was to discern whether a change in shifting tendencies occurred because of the feedback or simply because of practice effects.

For subjects who received feedback during session 2, mean *C* increased to a modest degree from session 1 (*M*= 2.23, *SD*= 0.68) to session 2 (*M*= 2.85, *SD*= 0.46), *d* = 0.65, 95% CI [0.14, 1.15]. A strong positive correlation in *C* existed between the two sessions (*r*(31)= 0.63), *CI*= [0.37, 0.80]. For subjects who did not receive feedback during session 2, mean *C* did not significantly increase from session 1 (*M*= 1.88, *SD*= 0.51) to session 2 (*M*= 2.20, *SD*= 0.43), *d* = 0.30, 95% CI [-0.18, 0.79]. However, a large positive correlation in the extent of *C* was observed between the two sessions (*r*(32)= 0.85), *CI*= [0.72, 0.92]. To account for order effects, we subtracted each individual's *C* from session 2 to session 1 for subjects who received feedback during session 2 (*M* = 0.62, *SD* = 0.82) versus those who did not (*M* = 0.32, *SD* = 0.58), but did not find a significant effect, *d*= 0.43, 95% *CI*= [-0.07, 0.92]. This suggests that the increase in *C* from session 1 to 2 can be attributed to an order effect (at least partially), but the sample is likely underpowered as there appears to be a small effect of feedback on increasing the extent of *C*.

For subjects who received feedback during session 2, mean *C* in the recognition memory task did not significantly differ between session 2 (*M*= 2.85, *SD*= 0.46) and session 3 (*M*= 3.07, *SD*= 0.41), *d* = 0.23, 95% CI [-0.26, 0.73]. A large positive correlation existed between these two sessions, (*r*(31)= 0.87), *CI*= [0.75, 0.93]. In the second and third sessions for subjects not receiving feedback, mean *C* did not significantly differ for the recognition memory tests in session 2 (*M*= 2.20, *SD*= 0.43) versus session 3 (*M*= 2.49, *SD*= 0.52), *d* = 0.23, 95% CI [-0.26, 0.72]. Similarly, a large positive correlation was found between session 2 and 3, *r*(32)= 0.75, *CI*= [0.55, 0.87], for subjects who did not receive feedback. A measure of Cohen's *d* between session 2 versus session 3 for subjects receiving feedback versus those who did not receive feedback was statistically insignificant, *d*= 0.113, 95% *CI*= [-0.38, 0.60].

Comparably, the memory part of session 3 and the visual detection part of session 3 had similar results. For subjects receiving feedback, a moderate difference was observed between *C* in session 3 of the memory task versus visual detection task (*M*= 2.54, *SD*= 0.69), *d* = 0.50, 95% CI [0.01, 1.00] and a large positive correlation existed between the two tasks in session 3, *r*(31)= 0.73, *CI*= [0.51, 0.86]. For subjects not receiving feedback, mean *C* during session 3 showed a similar difference, though not quite statistically significant, between the recognition memory and visual detection task (*M*= 1.98, *SD*= 0.59), *d* = 0.46, 95% CI [-0.03, 0.96] and a large correlation was found between the two tasks, *r*(32)= 0.75, *CI*= [0.56, 0.87]. No significant difference was observed between the mean difference in *C* between the recognition memory versus visual detection task in session 3 for subjects receiving feedback (*M*= 0.54, *SD*= 0.80) versus those not receiving feedback (*M*= 0.52, *SD*= 0.78), *d*= 0.03, 95% *CI*= [-0.46, 0.51]. *Figure 2.* shows individual differences in the extent of *C* across the three sessions ordered from left to right based on shifted criteria for the group who received feedback (left) versus those who did not (right).

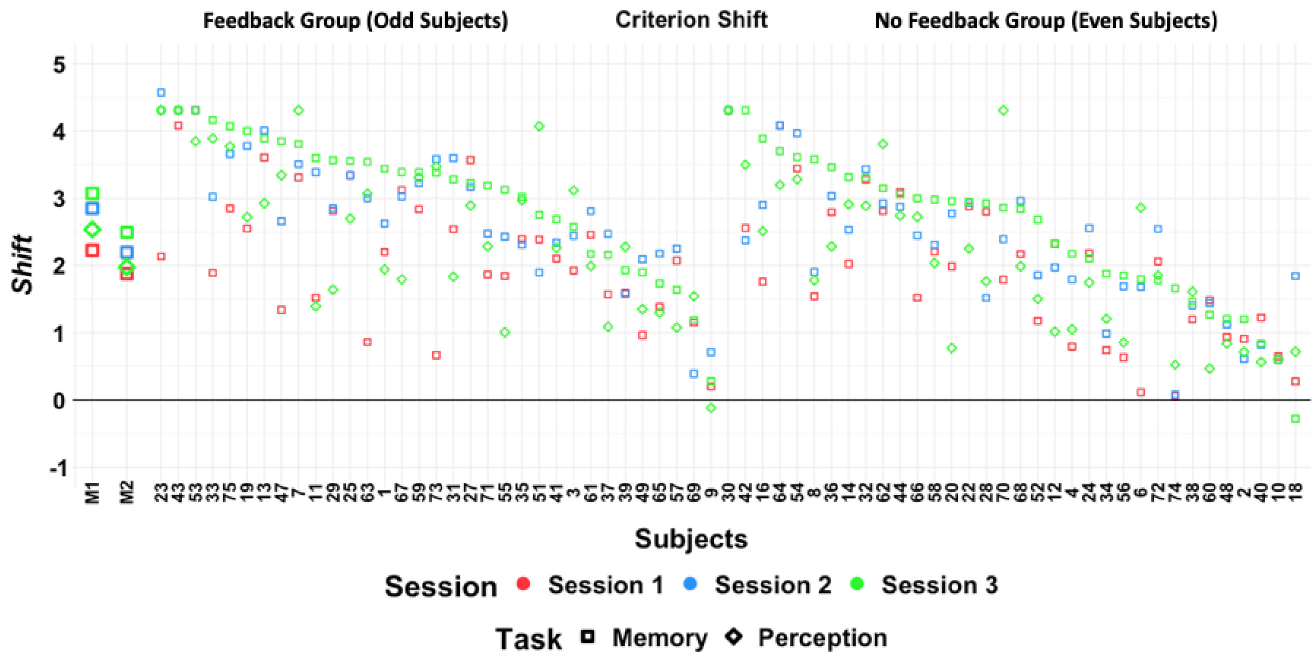

Figure 2. Data from Study 2 illustrating the extent to which participants shifted criteria on each of the three sessions with and without feedback in the recognition vs. visual detection (Perception) tasks. Participants are ordered from left to right based on who shifted criteria the most during session 3 of the recognition memory task. The mean *C* values for the group who received feedback (M1) versus not (M2) are shown on the left side of the graph.

Discussion

The purpose of this study is to see whether trial-by-trial feedback during recognition memory tests can increase the extent of criterion shifting and whether or not these effects can persist across another testing session in both the same task and a novel visual detection task. This was done in order to see if feedback is a possible mechanism in improving decisional outcomes by increasing the extent of criterion shifting. Feedback effectively improved the extent of criterion shift in Study 1, but not very much in Study 2. Participants in Study 1 were likely less motivated to shift overall during the task, since they were not getting paid and their performance had no real world consequences. This may have resulted in relatively little criterion shifting in session 1, with feedback subsequently boosting shifting substantially in session 2. On the other hand, Study 2 participants shifted criteria quite extensively on average in session 1, which likely resulted from an increased motivation to shift since doing so affected their total payment. However, feedback didn't seem to substantially increase criterion shifting in session 2, relative to a group who did not receive feedback. Specifically, feedback only seems to work when people do not shift much to begin with and there appears to be a limit to how much feedback can actually increase criterion shifting (i.e. if people shift a decent amount already, the effect of feedback on criterion shifting is diminished). Motivation could be a possible mechanism for these results such that participants are more likely to be motivated to perform well on a study that compensates with payment rather than research credits, but trial-by-trial feedback encouraging the optimal response could serve as a motivator to shift in the latter case. This is only speculation, however, as more research should explore the role motivation plays in decision-making.

On the other hand, across both studies there wasn't a significant difference between session 2 and 3 regardless if feedback was given, and saw fairly stable shifting across these sessions. Participants seemed to be able to transfer the extent to which they criterion shift on the session 3 memory task, but less so on the session 3 visual detection task. This was expected, as participants were more accustomed to the recognition memory task than the visual detection task.

In order for criterion shifting to be able to transfer other cognitive tasks, such as visual detection, more research needs to be conducted that investigates ways in which shifting can be reliably induced as well as strategies that can produce more shifting.

Because participants for the most part had a larger *C* value on the session 3 memory task than the session 3 visual detection perception task, feedback did not seem to be able to persist to a novel visual detection task from a recognition memory task to increase criterion shifting. However, it should be noted that feedback did help some individuals shift more in the visual detection task, thus there are individual differences in how feedback can affect cross-task performance (helps some shift but not others).

The data for both studies show extreme individual variability in the way participants were able to shift throughout all three sessions and whether or not feedback helped alter their decision criteria. Participants were remarkably stable in their criterion shifting tendencies where some participants shifted every single session, while others chose to keep a stable criterion regardless if feedback was given or not. This data is intriguing as more research needs to address the nature of the feedback as well as which individuals may be more susceptible to feedback (*Figure 1, Figure 2)*.

In a study that addressed criterion shifting in response to feedback, Hans & Dobbins (2008) investigated whether or not participants were actively aware they were shifting their criteria based on the feedback. That is, they believed participants were responding implicitly, or they were unaware they were shifting their criteria. This brings along new avenues of research about explicit versus implicit criterion shifting, and if there are mechanisms that induce one over the other in response to different forms of feedback. Responding differently with or without feedback has broad implications for why individuals choose to shift or not to shift. Although it is unclear from the current study whether feedback induced greater criterion shifts implicitly or explicitly, future studies should more closely examine the extent to which the participants are aware they are shifting, which can bring more light to how participants may or may not change their decision strategies.

Overall, this study gained more insight into the many nuances to how feedback impacts criterion shifting performance on subsequent testing sessions with both the same task and novel task with a different decision domain. Specifically, feedback seems to help participants who do not initially shift a lot, but there appears to be a limit to how much it can actually improve. That is, a ceiling effect seems to exist where feedback may not help those already shifting a good amount. The effects of feedback on criterion shifting seem to generally last to another testing session, particularly when participants did not shift much to begin with, but there appears to be individual differences in the degree to which feedback affects criterion shifting on a separate day and decision task (it seems to work for some more so than others). Even so, across both studies criterion shifting tendencies among the participants were generally stable across all testing sessions and task domains.

Teasing apart individual differences that influence criterion shifting tendencies is difficult because there are a myriad of factors that may impact a person's memory and decision-making. While this may be a barrier to investigating the underlying decision-making mechanisms of our memories, it also serves to be beneficial in that it will open up additional areas of research that focus on how one's memory accuracy can be maximized through making better decisions.

This study can impact several real-world issues that rely on memories and decision-making. One of these problems is the reliability of eyewitness testimony. Eyewitness testimony has been an important part of our criminal justice system, and it has been controversial over the years because of its reliability. Eyewitness testimony essentially relies on one person's memory, so it's essential that the memory is reliable and accurate. In an issue this important, it's crucial to make as few critical errors as possible and avoid problems such as wrongly convicting someone of a crime. Memories often carry uncertainty, which means an appropriately biased criteria is essential to avoiding critical errors. When consequences are low (e.g. a person's testimony will lead to additional questioning of a suspect), a more liberal criterion should be used. When consequences are high (e.g. a person's testimony will send a suspect to jail), a conservative criterion should be used. This research can affect the way eyewitness testimony is taken as evidence, as an individual's criterion shifting tendencies should be specifically assessed to see the impact providing feedback for the optimal response as opposed to the correct response has on promoting better decisional outcomes.

To add, appropriately adapting a decision criteria is quite important for military personnel to avoid detrimental consequences. At a security checkpoint, people should have a more liberal criterion, questioning anyone who raises suspicion, whereas in the battle field a more conservative criterion should be used to ensure you've identified an enemy rather than a civilian. The importance of our decisions should not be taken lightly, as they have widespread implications in many parts of our lives.

Conclusion

The current study investigated whether trial-by-trial feedback can improve the extent of criterion shifting across time and decision domains as well as whether shifting can be “learned” from previous recognition memory tasks and be applied to a novel visual detection task. Feedback seemed to help, particularly for those who didn’t shift as much to begin with, yet there seemed to be a ceiling effect to how much feedback could actually help. That is, those already shifting a lot to begin with were less impacted by the feedback. The feedback appeared to transfer well to another session of the same task, but was less effective for a different task domain. However, individual differences suggest that some people do adapt criteria well to the novel visual detection task whereas others do not.

References

Aminoff, E. M., Clewett, D., Freeman, S., Frithsen, A., Tipper, C., Johnson, A., ... & Miller, M. B. (2012). Individual differences in shifting decision criterion: A recognition memory study. *Memory & Cognition, 40*(7), 1016-1030.

Brainard, D. H. (1997). The psychophysics toolbox. *Spatial vision, 10(4)*, 433-436.

Franks, B. A., & Hicks, J. L. (2016). The reliability of criterion shifting in recognition memory is task dependent. *Memory & cognition*, *44*(8), 1215-1227.

Frithsen, A., Kantner, J., Lopez, B. A., & Miller, M. B. (2018). Cross-task and cross-manipulation stability in shifting the decision criterion. *Memory*, *26*(5), 653-663.

Han, S., & Dobbins, I. G. (2008). Examining recognition criterion rigidity during testing using a biased-feedback technique: Evidence for adaptive criterion learning. *Memory & Cognition*, *36*(4), 703-715.

Kantner, J., Vettel, J. M., & Miller, M. B. (2015). Dubious decision evidence and criterion flexibility in recognition memory. *Frontiers in psychology*, *6*, 1320.

Macmillan, N. A., & Creelman, C. D. (2004). *Detection theory: A user's guide*. Psychology press.

Rhodes, M. G., & Jacoby, L. L. (2007). On the dynamic nature of response criterion in recognition memory: Effects of base rate, awareness, and feedback. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *33*(2), 305.

Singer, M. (2009). Strength-based criterion shifts in recognition memory. *Memory & Cognition*, *37*(7), 976-984.

Starns, J. J., & Olchowski, J. E. (2015). Shifting the criterion is not the difficult part of trial-by-trial criterion shifts in recognition memory. *Memory & Cognition*, *43*(1), 49-59.

Stretch, V., & Wixted, J. T. (1998). On the difference between strength-based and frequency-based mirror effects in recognition memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *24*(6), 1379.