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The Effect of Reward and Positive Affect on Memory and Decision-Making

by

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Abstract

Memory and Decision-making are two highly interrelated cognitive processes. Several studies have demonstrated that reward on the one hand and positive affect on the other bias both memory and decision-making. However, these effects have largely been studied separately and no study has directly compared the effect of reward versus positive affect on both processes. Therefore, this study aims to compare the effect of positive affect and reward on memory and decision-making within a single design. In the study, participants learned to associate reward and positive affect with novel neutral stimuli (Tibetan characters) through an incidental learning task. Positive affect was induced through viewing pleasant images while reward was provided in the form of points. Participants' preference for reward- and positive affect-associated stimuli were measured through a choice task between pairs of Tibetan characters. Participants' memory was tested using a standard memory recognition test. The results revealed no differences between positive affect and reward's influence on memory and decision-making. Based on the result, reward and positive affect may have a similar effect on both memory and decision making, supporting an intricate link between memory and decision making. Future studies may look at individual differences in susceptibility to reward versus positive affect in modulating memory and decision-making.

The Effect of Reward and Positive Affect on Memory and Decision-Making

Background

Memory and decision-making are two cognitive processes that are closely related. Many past studies have suggested that memory plays a critical role in the value-based decision-making process. For example, retrieval of episodic memories of past choices strongly influences current decisions. Reminders of past choices can influence the next decision (Bornstein et al., 2017), and even retrieving the context of previous choices can bias current choices (Bornstein & Norman, 2017). In addition, memory encoding interacts with preference change in many different task paradigms. In the free-choice paradigm, among pairs of neutral items, for example, pictures of food, participants increase their preference rating for the food item they chose and decrease the rating for the food item they rejected, despite the two items being rated equally before the choice. This well-known effect of choice-induced preference change only occurs when the chosen item is remembered (Chammat et al., 2017). In the cue-approach training paradigm, participants are trained to perform a speeded motor response for items paired with a neutral cue ("Go item") and do nothing for items without a cue ("No-Go items"). For example, when participants see a red candy (Go item) on the screen, they would always hear a sound that indicated that they need to press a key immediately (speeded motor response). Whereas when they see a yellow candy (No-Go item), there is no sound so they do not need to do anything. Under this task paradigm, memory for the trained Go items (e.g. red candy) is enhanced and thus leading to an increased preference for the Go items than the No-Go item (yellow candy, Botvinik-Nezer et al., 2021). Additionally, neural evidence suggests that brain regions implicated in memory and decision-making overlap. The ventromedial prefrontal cortex (vmPFC) and hippocampus are associated with both episodic memory and decision-making, for example (Euston et al., 2012; Weilbächer & Gluth, 2017).

How does the connection between memory and decision-making form? A recent review article argues that the hippocampus, which is a brain structure that has long been known to be essential for forming long-term memories, is also critical for value-based decision-making. The researchers propose that the hippocampus allows for the formation of links between elements of memories, even when those elements are not experienced together at the same time or in the same place, and helps guide flexible value-based decision-making through generalization across contexts, decomposition of novel choice options into familiar components, and memory-guided deliberation (Biderman et al., 2020). Broadly, this view advocates a crucial role for a relational memory system, which critically relies on the hippocampus, in value construction to guide decision-making.

Two types of values that are frequently studied in psychology research are positive affective value—value driven by the experience of positive emotion and expression—and reward value—monetary reward or value driven by the experience of goal-attainment. Both positive affect and reward have been shown to have a beneficial influence on memory as well as decision-making (Euston et al., 2012; Hebscher et al., 2016; Juvina et al., 2018).

Positive affect has been shown to benefit all types of memory in past studies. In the long term, positive affect is associated with less memory decline in a longitudinal study (Hittner et al., 2020); in the short term, it improves working memory (Yang et al., 2013). For episodic memory, emotional enhancement of memory (EMM), the phenomenon that emotional arousal enhances past episodic memory, is demonstrated by many past studies (Buchanan, 2007; LaBar & Cabeza, 2006). One fMRI study that includes more than 500 participants demonstrated that EMM is related to the strengthening functional connectivity between the hippocampus and amygdala during encoding of emotional stimuli (Fastenrath et al., 2014). In addition, positive emotion has shown an enhancement effect on consolidation of memory of single items, (Wang & Sun, 2017), and memory of association of words in the word-pair recall paradigm, where the recall rate is highest when both target and probe words are positive (Madan et al., 2019). Reward also shows a beneficial effect on memory. Initially neutral stimuli that are associated with high reward values are remembered better than other neutral stimuli that are associated with low reward values (Adcock et al., 2006; Madan & Spetch, 2012; Wittmann et al., 2005), and the effect is constant for both younger and older populations (Spaniol et al., 2014). Past studies also demonstrated that the interaction of positive affect and reward intensity enhances memory. (Gable & Harmon-Jones, 2010)

In addition, positive affect and reward have a beneficial effect on decision-making. Imagining future positive events strongly reduces the delay-discounting effect (devaluing future reward, Palombo & Madan, 2021). Originally, participants tend to reduce the value of a reward if it's available in the future instead of immediately. However, when participants are prompted to imagine positive events happening in the future, they tend to devalue the future reward less. In addition, when instructed to focus on their feelings of each attribute of cars, participants select the cars with most positive attributes more often than when they are instructed to focus on the details of each attribute (Dijksterhuis et al., 2006; Mikels et al., 2011)**.** Furthermore, participants show a preference for positive affect-associated stimuli over neutral affect-associated stimuli that they tended to choose a neutral stimulus (e.g. blue square) that returned more positive images as feedback over a neutral stimulus (e.g. Green square) that returned more neutral images as feedback (Katahira et al., 2011). Reward-associated stimuli are also chosen over unrewarded neutral stimuli. Participants prefer stimuli that give reward value more often than stimuli that yield no reward value during the decision-making process (O'Doherty et al., 2017).

Although many past studies have demonstrated the effect of reward on memory and decisions, and the effect of positive affect on memory and decisions separately, no study has contrasted these effects directly within a single design. Is memory for reward-associated stimuli better than memory for positive affect-associated stimuli? Will positive affect-associated stimuli be chosen over reward-associated stimuli? To address these questions, the current thesis project aims to compare the effect of positive affect and reward on memory and decision-making.

First, we must address whether positive affect and reward are separable. Intuitively, people will feel some level of positivity when experiencing a stimulus that induces positive affect and when receiving a reward. Thus, it is important to disentangle positive affect processing from reward processing. Chiew and Braver's work suggests that positive affect and reward can be separated; that positive affect is more related to general mood or feeling positive whereas reward is related to task completion or goal achievement (Chiew & Braver, 2011). The different states induced by reward and positive affect render possible the investigation of their differential effect on memory and decision-making.

Hypothesis

Speer and colleagues demonstrated that participants choose to reminisce about positive autobiographical memories instead of receiving tangible rewards (Speer et al., 2014). This study implies that people may prefer positive affect to reward. As participants choose to experience positive affect through recalling positive autobiographical memories over receiving the monetary reward, positive affect may be prioritized over reward during the deliberation of a decision. Therefore, I predict that initially neutral stimuli that are associated with positive affect may be preferred over initially neutral stimuli that are associated with reward. In addition, based on Biderman and colleagues' hypothesis, memory should be influenced the same way as decision-making; I predict that positive affect-associated items will be remembered better than reward-associated items.

Methods

Participants

Participants were recruited online through MTurk, an Amazon platform to recruit paid participants to conduct online studies. Participants were between the age of eighteen and thirty-five years old and lived in the United States at the time of participation. For better data quality, only participants who passed attention and engagement measures by CloudResearch, a platform for filtering MTurk participants, and completed more than 100 MTurk studies and had a 95% approval rate were recruited. Each participant was compensated $7.5 and received a $3 bonus if they completed both sessions. At the beginning of the study, participants were tested on their understanding of the task instructions with 5 quiz questions. If they did not correctly answer all questions within 2 attempts, they were rejected from participating in the study. To make sure all responses come from participants who were paying attention during the tasks, participants were excluded post hoc if the total number of times that they did not respond within the designated times or selected the wrong characters (see description below in learning phases) was more than fifthteen for the first session or more than ten for the second session. They were also excluded if their response time was lower than 300 ms for more than fifthteen responses for the first session or more than ten responses for the second session. In addition, participants were excluded if they exhausted the image set during the rating phase, which led to incomplete trials for the learning phases. The detailed exclusion procedure is described in the analysis section.

Fifty-five participants were recruited for the first session of the study and forty-one remained after all exclusion criteria were applied (mean age = 28.78 years, SD = 3.87, range 20–34; 21 female, 20 male). Only participants who passed the exclusion criteria were invited for a second session of the study and twenty-seven participants came back for the second session. One participant was excluded from the second session for triggering too many attention checks, resulting in twenty-six participants remaining (mean age = 28.77 years, SD = 3.65, range 20–34; 13 female, 13 male).

Material

The images used in the study were selected from OASIS (Open Affective Standardized Image Set, Kurdi et al., 2017). One hundred and sixty neutral images, ninety positive images, and sixteen negative images were selected for the study. The images were selected according to the normative rating of valence and arousal that were provided by OASIS. The positive images were those that have the highest valence and arousal ratings, the neutral images were those with ratings closest to the mean, and the negative images were those that had the lowest valence ratings. Images that were too similar to distinguish from one another were excluded from the final stimulus set and negative images that were too disturbing were also excluded.

Procedure

Rating Phase

The study started with a rating phase in which participants rated a series of images on how negative, neutral, or positive the images made them feel. Participants were asked to rate the feeling that the image induced on a scale of 1 (very negative) to 7 (very positive). Images rated 3, 4, or 5 were classified as neutral images. Images rated 6 or 7 were classified as positive images. The neutral images and positive images were used in the following phases. The rating phase ended, unbeknownst to the participant when they rated 30 images as positive (6 or 7) and 90 images as neutral (3, 4, or 5). Participants had 7 seconds per trial to rate an image. If they failed to rate an image within 7 seconds, an attention check would appear and after they passed the check, the same image would reappear. The attention check instructed participants to press the key of a randomly selected alphabet that appeared on the screen.

Learning Phases

In the second phase of the experiment, participants learned to associate four Tibetan characters with positive affect, neutral affect, reward, and no reward separately through an incidental learning task. Positive affect was induced by presenting participants with positive images (according to the participants' subjective ratings stated during the *Rating phase,* see above). Reward was given in the form of points. Participants took part in two blocks of learning. In the positive-affect learning block, participants learned to associate a certain Tibetan character with positive affect (viewing images that were rated as positive in the rating phase), and another character with neutral affect (viewing images that were rated neutral in the rating phase). In the reward learning block, participants learned to associate a character with reward (10 or 20 points), and another character (e.g., orange) with no reward (0 points). The order of the affect block and the reward block was counterbalanced across participants.

Each block consisted of 60 trials including 30 positive trials and 30 neutral trials, which made up to 120 trials for the learning phase. On each trial, two of the same Tibetan characters appeared on the screen: one in red, and one in black. Participants were asked to choose the red character on every trial. If they chose the wrong color, they would be prompted and the trial would repeat. Four different Tibetan characters appeared in four conditions: positive-affect, neutral-affect, reward, and no-reward. For the affect block, on positive trials, participants saw a positive image after they selected the red character; on neutral trials, they saw a neutral image. For the reward block, on positive trials, participants selected the red character and then saw a neutral image followed by the number of points they gained; in neutral trials, they saw a neutral image followed by an indicator that they gained 0 points as feedback. The neutral images in the reward block were used to test participants' memory in later phases. Each trial in the learning phase lasted for a maximum of 3 seconds. If participants failed to respond within 3 seconds, an attention check would appear and after they pass the check, the same trial would reappear.

Decision-making Phase

After completing the learning phase, participants took part in a decision-making phase. Participants' choice preferences for the four different Tibetan characters were assessed to measure preferences for positive affect- and reward-associated stimuli. There were 6 trials in the decision-making phase consisting of all unique pair combinations of the four characters previously seen in the different training conditions: positive-affect vs reward, positive-affect vs neutral-affect, positive-affect vs no-reward, reward vs no-reward, reward vs neutral-affect, and no-reward vs neutral-affect. The trial of interest was one that pitted a positive affect- vs a reward-associated character. The remaining pairs served as sanity checks: people who learned the association should choose characters associated with positive conditions (either positive affect or reward) over characters associated with neutral conditions (neutral affect, no reward). Participants had 3 seconds to make the choice and if they failed to do so, an attention check would appear. After they passed the check, the same pair of characters would reappear. After they made a choice, they rated their level of confidence (0% certain to 100% certain) of the choice.

Memory Recognition Phase

In the last phase of the experiment, participants' memory for images that appeared in the learning phase was measured using an old/new memory recognition paradigm. The first memory recognition test was presented immediately after participants completed the decision-making phase and read the instructions for the memory task. The task consisted of 90 trials with half of the 120 old images along with 30 new images (foils). On each trial, participants were asked to judge whether the image was old or new and rate their level of confidence (0% certain to 100% certain). A second session memory recognition test was conducted 2 days after the first session, employing the same task but with different images. The second unseen half of the old images and 30 new foils were tested in the second memory recognition test. On each trial, participants had 3 seconds to make the judgment and if they failed to do so, an attention check would appear. After they passed the check, the same image would reappear.

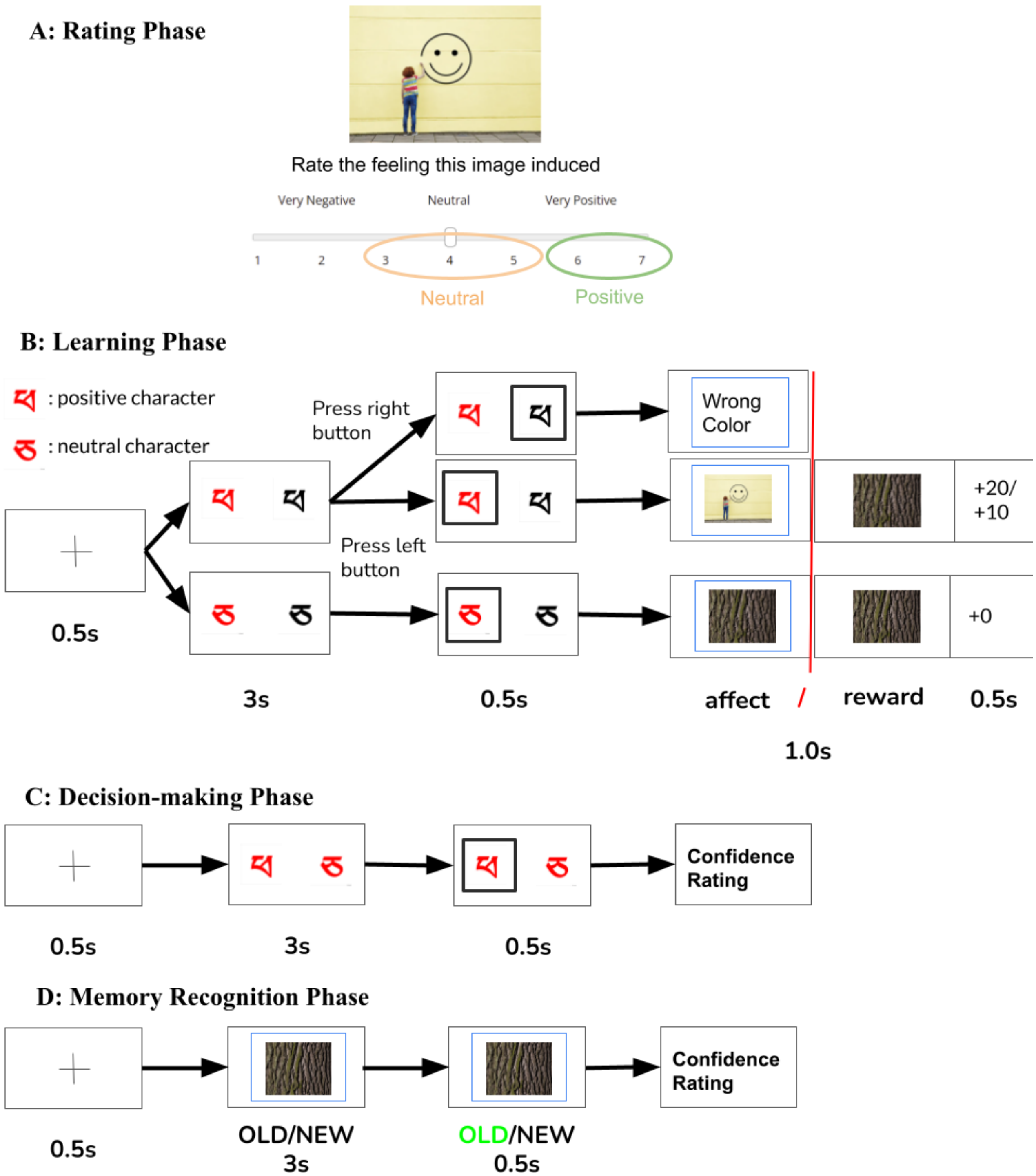

Figure 1. Task diagram. The task is made up of four phases. (**A**) Rating Phase: one image along with a scale from 1 (very negative) to 7 (very positive) appeared on the screen. The participant was instructed to rate how the image on the screen made them feel. If the participant rated the image 3, 4, or 5, it was classified as a neutral image. If it was rated 6 or 7, it was classified as a positive image. (**B**) Learning Phase: a cross appeared in the center of the screen for 0.5 seconds and then one Tibetan character in red and the same character in black appeared on the screen for a maximum of 3 seconds. The participant was instructed to select the red character. If the participant selected the black character, they received feedback

that they chose the wrong color. If they correctly chose the red character, the trial progressed as follows: 1) for positive feedback trials, the participant saw a positive image in the affect block, or a neutral image followed by the number of points they gained in the reward block; 2) for neutral feedback trials, the participant saw a neutral image for the affect block, or a neutral image followed by an indicator that they gained 0 points for the reward block. Different feedback trials were randomly ordered and the position of black and red characters was also randomly placed. The character that represented each condition was randomly selected for each participant. (**C**) Decision-making Phase: The participant chose between pairs of red characters from different learning phase conditions and then rated their level of confidence in their choice. ("From 0% certain to 100% certain, How confident are you in your choice?") (**D**) Memory Recognition Phase: The participant was asked to indicate whether the image on the screen was old and they remember seeing it before or if it was new and they haven't seen it before. They then rated their level of confidence in their memory decision.

Analysis

Exclusion Criteria

Data were first filtered by exclusion criteria to remove participants that were not paying attention during the study. Participants triggered an attention check in the study if they failed to respond within the designated time for each trial. Participants also triggered an alert if they selected the wrong color during the learning phase. The total number of attention checks and alerts was calculated for each participant and people who triggered more than fifthteen of those were excluded from the analysis. In addition, participants who rated more than two hundred and forty images during the rating phases were also excluded since they exhausted the image sets. Fourteen participants were excluded from the first session of the study and one participant was excluded from the second session based on the above criteria. The final sample included forty-one participants for the first session of the study and twenty-six participants for the second session of the study.

Decision-making Phase

The decision-making task results were aggregated per choice pair. The number of participants who chose each character per pair was calculated for all pairs. The statistical significance was determined using a one-sample t-test compared with chance level (50%). The aggregated result was plotted with Python Matplotlib barplot methods in Figure 2. The average confidence rating for each choice in each choice pair was calculated and the statistical significance was determined using independent sample t-tests.

Memory Phase

The corrected Hit Rate was calculated for four conditions (positive-affect, neutral-affect, reward, and no-reward) for both session 1 and session 2 memory tests. First, Hit Rate was calculated with the number of correctly identified old images divided by the total number of old images within each condition for each participant. Then False Alarm Rate was calculated as the percentage of new images that were misidentified as old images in each condition. For positive affect, the False Alarm Rate was calculated from recognition results of positive foils (new images that were classified as positive based on ratings from OASIS). For the rest three conditions, neutral foils were randomly sampled and assigned 10000 times into each condition and the average False Alarm Rate was calculated.

Corrected Hit Rate was calculated by subtracting False Alarm Rate from Hit Rate for each participant for each condition. The statistical significance of the difference in Corrected Hit Rate between conditions was assessed through repeated measures ANOVA to compare the four conditions. The Corrected Hit Rate for each condition was plotted with Python Matplotlib boxplot methods in Figure 3. The average confidence rating for correctly identified old images was aggregated and the statistical significance was determined using repeated measures ANOVA that included the four conditions.

Results

Decision-making Task

For all four pairs of sanity checks (a character associated with a positive condition versus a character associated with a neutral condition), 50.61% of participants selected the character associated with positive conditions over the character associated with neutral conditions (t(40)=0.15, p=0.88) (Figure 2A). Broken down into the four pair types: 53.66% of participants chose the character associated with positive affect over the character associated with neutral affect (t(40)=0.46, p=0.65); 51.22% of participants chose the character associated with reward over the character associated with no reward (t(40)=0.15, p=0.88); 43.90% of participants chose the character associated with reward over the character associated with neutral affect (t(40)=-0.78, p=0.44); and 53.66% of participants chose the character associated with positive affect over the character associated with no reward (t(40)=0.46, p=0.65). These results suggest that pairing positive affect or reward with neutral stimuli in an incidental learning design during the learning phase did not increase preferences for those stimuli.

No significant difference was found for preference toward positive affect- or reward-associated stimulus. In choices between Tibetan characters associated with positive affect and those associated with reward, 60.98% of participants chose the character associated with reward over the character associated with positive affect (t(40)=1.42, p=0.16) (Figure 2A). However, participants who preferred the positive affect- over reward-associated stimulus showed higher confidence in their choices. In choices between Tibetan characters associated with positive affect and those associated with reward, participants who chose the character associated with positive affect (M=65.75% certainty, SD=20.50%) had significantly higher confidence in their choice than participants who chose the character associated with reward (M=48.64%

certainty, SD= 24.70%; t(40)=2.31, p<0.05) (Figure 2B). This result suggests that compared to neutral stimuli paired with reward, participants did not show a preference toward neutral stimuli paired with positive affect.

Participants who chose the character associated with reward over no reward had significantly higher confidence (M=66.86% certainty, SD=24.88%) in their choice compared to participants who chose the character associated with no reward (M=48.53% certainty, SD= 29.68%; t(40)=2.17, p<0.05). For the rest of the choice pairs, no significant differences were found in the confidence ratings. In choices between Tibetan characters associated with positive affect and those associated with no reward, on average, participants were 60.55% certain in their choice of the character associated with positive affect (SD=20.33%), and participants were 53.95% certain in their choice of the character associated with no reward (SD=29.10%, t(40)=0.85, p=0.40). In choices between Tibetan characters associated with positive affect and those associated with neutral affect, on average, participants were 50.77% certain in their choice of the character associated with positive affect (SD=31.68%) and participants were 59.42% certain in their choice of the character associated with neutral affect (SD=20.84%, t(40)=-1.01, p=0.32). In choices between Tibetan characters associated with positive reward and those associated with neutral affect, on average, participants were 64.44% certain in their choice of the character associated with positive affect (SD=24.37%) and participants were 56.83% certain in their choice of the character associated with neutral affect (SD=27.16%, t(40)=0.93, p=0.36). These results suggest that participants who prefer neutral stimuli paired with positive affect over neutral stimuli paired with reward were more certain in their choice compared to participants who choose neutral stimuli paired with reward.

In addition, participants who selected positive affect-associated stimuli over reward-associated stimuli also have a significantly higher confidence rating across all of their choices (M=66.16%, SD=21.28%) than participants who selected reward-associated stimuli(M=51.69%, SD=26.83%, t(39)=4.46, p=1.26e-05). Participants who selected positive affect-associated stimuli also selected characters associated with positive conditions more often in the four sanity-check pairs (M_affect=62.5%, M_reward=43%, t(39)=2.47, p=0.01). Higher confidence in their choices plus higher preference toward overall positive conditions imply that participants who selected positive affect-associated stimulus over reward-associated stimulus learned the association better than participants who selected reward-associated stimulus.

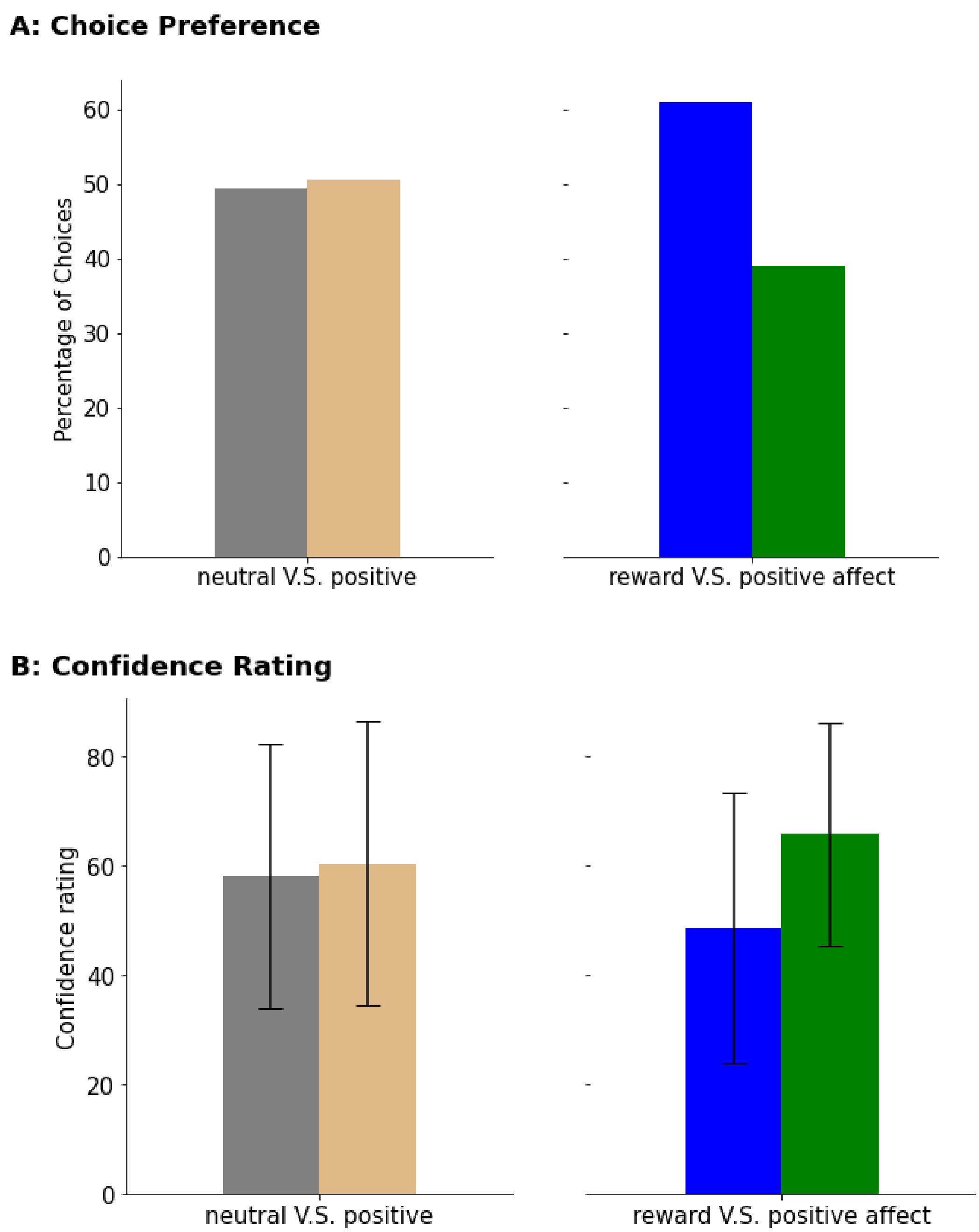

Figure 2. Decision-making phase results. (**A**) Participants chose stimuli in the neutral conditions (collapsed across neutral affect and no reward) as often as they chose stimuli in the positive conditions (collapsed across positive affect and reward) when pitted against one another, left. In a choice between a stimulus associated with reward and one associated with positive affect, roughly the same number of participants chose either, right. (**B**) The average confidence level for choosing the neutral conditions (collapsed across neutral affect and no reward) was the same as the average confidence level for choosing stimuli in the positive conditions (collapsed across positive affect and reward conditions) when pitted against one another, left. Participants who chose stimulus associated with positive affect had significantly higher confidence level than participants who chose stimulus associated with reward, right. The error bars in the plot are standard deviations of each condition.

Memory recognition Task

For the memory recognition task in session 1, there were no significant differences in corrected hit rates between the four conditions (positive affect: M=65.60%, SD=22.75%; reward: M=68.48%, SD=25.63%; neutral affect: M=69.92%, SD=20.53%; no reward: M=67.99%, SD=23.69%; $F(3,40) = 0.79$, $p=0.50$) (Figure 3A). For confidence ratings in the memory task, there were no significant differences in confidence ratings for correctly identified old images across all four conditions (positive affect: M=89.06%, SD=17.23%; reward: M=88.67%, SD=16.79%; neutral affect: M=90.21%, SD=15.37%; no reward: M=90.62%, SD=14.95%; $F(3,40) = 2.37$, $p=0.07$)

For the memory recognition task in session 2, there were no significant differences in corrected hit rates between the four conditions (positive affect: M=33.66%, SD=25.72%; reward: M=37.59%, SD=19.60%; neutral affect: M=31.23%, SD=24.22%; no reward: M=31.76%, SD=20.97%; $F(3,25) =0.87$, $p=0.46$) (Figure 3B). For confidence ratings in the memory task, there were no significant differences in confidence ratings for correctly identified old images between the four conditions (positive affect: M=69.05%, SD=26.98%; reward: M=73.13%, SD=25.95%; neutral affect: M=73.38%, SD=24.70%; no reward: M=72.37%, SD=26.96%; $F(3,40) = 1.49$, $p=0.22$).

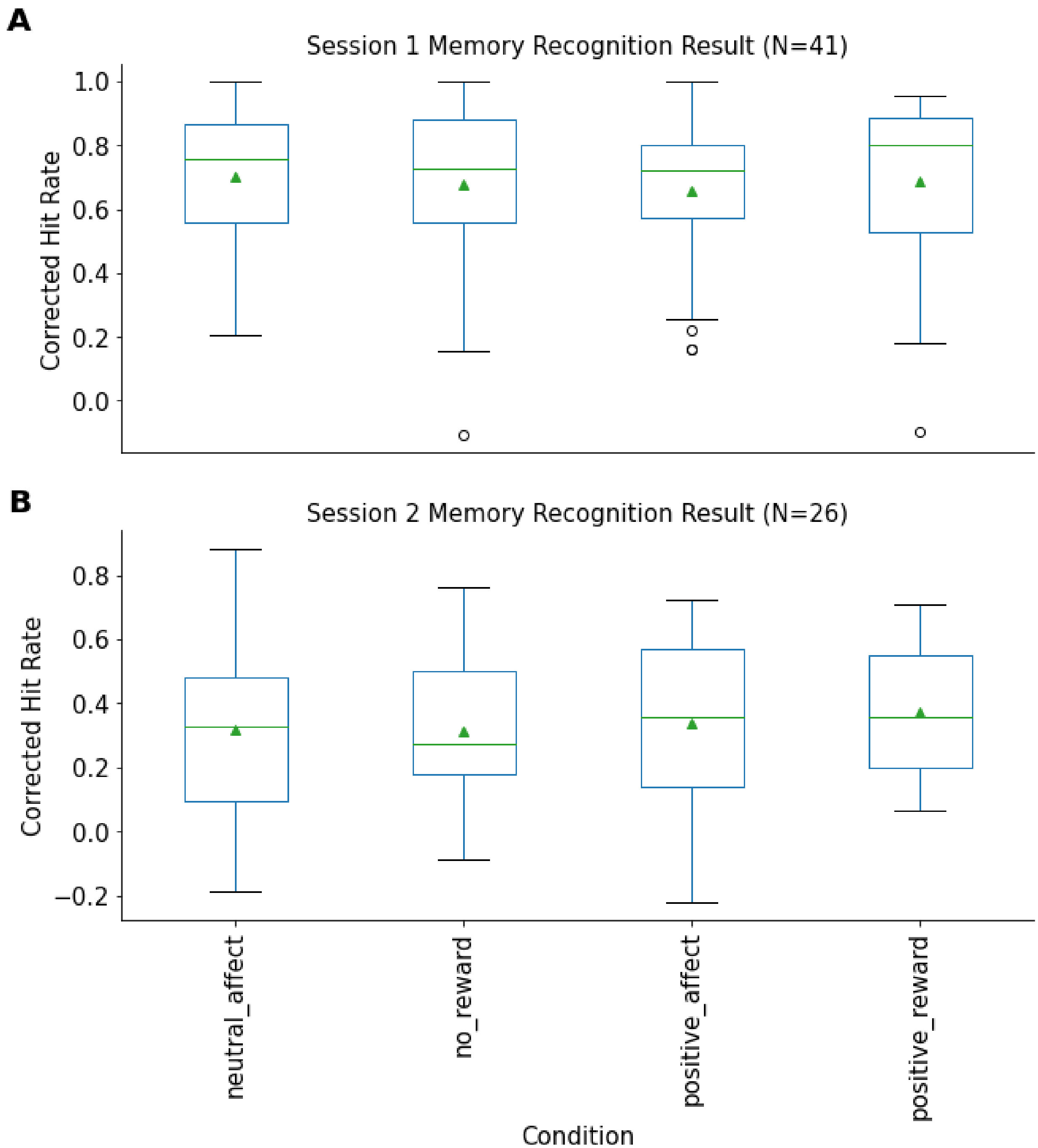

Figure 3. Memory Recognition Results. Corrected hit rates per condition are plotted in box plots. The line in each bar is the median value and the triangles in the graph indicate the mean value of each condition across participants. (**A**) Memory Recognition Result for session 1. (**B**) Memory Recognition Result for session 2.

Discussion

Memory is essential for optimal decision-making as it allows past experiences to guide adaptive behavior. It has long been known that different forms of value—in particular positive affective value and reward value—modulate both memory and choice (Euston et al., 2012; Hebscher et al., 2016; Juvina et al., 2018). To our knowledge, the present study is the first to put these two forms of value in competition to investigate the link between memory and decision making. Our results indicate that positive affective value and reward value modulate memory and decision-making equally well. This is surprising as we expected, based on previous research, that positive affective value, at least in the short term, would exert a more pronounced influence on both memory and decision making.

Although our findings do not support our hypothesis that affective value may be a more potent driver of memory and preferences, they do support the hypothesis that memory and decision-making are intricately linked. Both memory and decision-making performance showed no difference between positive affect and reward processing, suggesting that memory and decision-making processes are related. In addition, we observed a numerical difference between positive affect and reward's influence on memory and decision making. Numerically, more people chose the neutral stimulus—a Tibetan character—associated with reward than the neutral stimulus associated with positive affect when the two were pitted against each other. Similarly, memory performance—the average corrected hit rate—for images in the reward condition was numerically higher than positive affect images in the delayed memory recognition test. Additionally, the average confidence level for correctly remembering reward images was numerically higher than confidence levels for remembering positive affect images. These numerical differences may suggest an effect of choice on memory consolidation. During decision-making, people retrieve myriad information related to the choice options under consideration (O'Doherty et al., 2017). Since more participants selected reward-associated stimuli during the decision-making phase, the action of choosing a reward-associated stimulus might also trigger more retrieval of information related to the chosen character. This spontaneous associative retrieval may then help enhance memory for reward images. The effect of retrieving information incidentally learned along with receipt of reward during decision-making can be further studied, especially on how it influences the memory consolidation process.

Although no group-level differences are found for affective or reward value's influence on memory and decision-making, there may be individual differences in memory and decision-making processes that lead to some individuals having better positive affect processing while others having better reward processing. Past studies demonstrate that individuals may respond to the same reward cue differently (Berridge, 2007; Robinson et al., 2014)**,** thus leading to different learning rates and different valuations for the same reward cue. Furthermore, a review article lays out how genetic differences are associated with individual differences in emotional memory enhancement (Todd et al., 2011). These individual differences may average out group-level results in our study, manifesting as a lack of significant difference in memory recognition performance and choices of stimuli from positive affect and reward conditions. Unfortunately, the sample in the current study is not large enough to investigate these individual differences in memory and decision-making processes. Future studies might investigate individual differences in susceptibility to reward or positive affect during incidental learning leading, and to biases in decision-making and memory with a larger sample size.

Shared neural activity when processing positive affect stimuli and reward stimuli may also be at the root of similar group-level results in the memory and decision-making tasks in this study. Indeed, the enhancement of positive affect memory is shaped by amygdala activity during memory encoding and retrieval, which is also involved in reward processing (Dolan et al., 2000; S. B. Hamann et al., 1999). The amygdala also modulates decision-making processes when reward is received (Bechara et al., 2000; Gupta et al., 2011). Shared neural activity during the processing of positive affect stimuli and reward stimuli may be at the root of a shared effect of both positive affect and reward on memory encoding and choice. However, evidence on whether affect and reward's influence on memory and decision-making are modulated by the same neural system is complex. Recent findings suggest that amygdala is activated when affective or rewarding stimuli are perceived during memory and decision-making tasks (S. Hamann, 2001; Murray, 2007), but the overlap in this activation is not perfect. For example, damage to the amygdala leads to impairment in decision-making performance in a gambling task and a lack of skin conductance response when receiving reward (Bechara et al., 1999). But studies on patients with amygdala lesions showed no impairment in emotional enhancement of memory for positive affect stimuli (Phelps et al., 1997, 1998). The differential influence of amygdala damage indicates that differences still exist in neural processing for reward and positive affect which leaves room to contrast their differential influence on memory and decision-making. Given the overlap in processing of affect and reward, we were careful to avoid confounding the two in our study. We avoid mixing positive affect with reward stimuli through removing any goal-attainment element in the positive affect condition. As discussed in the introduction, an important separation between positive affect and reward stimuli is that reward is related to feeling good about a specific task completion whereas positive affect is associated with more generally feeling positive.

Although the study design avoids the confounds of mixing reward and positive affect, several limitations should be noted. As an incidental learning task, this study might not be long enough for participants to learn the association between the neutral stimuli—Tibetan characters—and different affect and reward outcomes. Due to stimulus set limitations, the current study is made up of only one hundred and twenty training trials, while similar incidental learning tasks typically require hundreds of trials. For example, a study that had a similar design and found a preference toward positive affect stimuli over neutral ones was made up of sixty hundred trials in total (Katahira et al., 2011). The results of the decision-making task also suggest the possibility that participants did not establish a strong association between neutral stimuli and different affect and reward states. On average, participants did not prefer the character in the positive condition (either positive affect or reward) over the character in the neutral condition (Figure 2A). As past studies have shown that people showed preferences for stimuli associated with positive affect or reward over neutral stimuli, if participants successfully learned the associations, they should demonstrate a preference for characters associated with positive conditions over the neutral conditions. In addition, in the piloting run of this experiment, participants were given a clear goal in the learning task to find the neutral stimuli associated with positive affect or reward. In that version, most of the participants passed the decision-making phase sanity checks (they chose characters associated with positive conditions over characters associated with neutral conditions) and showed a significant preference toward the stimulus associated with reward over the stimulus associated with positive affect, which might suggest differential effects for positive affect and reward on decision-making when participants are provided a clear goal to pursue reward or positive affect during training. This version of the task was changed to remove the goal-directed component in the positive affect condition and better isolate it from reward processing. It is clear that participants can learn much better when they are given a goal, but the interpretation of the results becomes tenuous given the confound between the processing of reward and affect when a goal is provided. Future studies can improve the study design to either create a longer incidental learning task or provide clear instruction to help participants learn associations without introducing a goal in the positive affect condition.

The issue of participants not learning the associations between different value states and neutral stimuli may also cause differences in confidence rating in choice. Although numerically fewer participants selected positive affect-associated stimuli over reward-associated stimuli, participants who selected positive affect-associated stimuli had significantly higher confidence in their choice. In addition, participants who selected positive affect-associated stimuli have a higher confidence rating across all of their choices and selected characters associated with positive conditions more often over characters associated with neutral conditions. These results imply that participants who selected positive affect-associated stimuli over reward-associated stimuli learned the association between Tibentan characters and value states better than participants who selected reward-associated stimuli. The disparity in learning shown in these two groups of participants may be caused by the mismatch in the task design. In the current task design, it is easier for participants to learn the association in reward conditions since there is a separate indication for reward value—points received. Whereas for the positive affect condition, the affective value is embedded in the context of images which is not as obvious as the reward value. Therefore, participants who did not learn the associations well would tend to choose reward-associated stimuli over positive affect-associated stimuli as it’s relatively easier to pick up. Future studies can improve the study design to induce two forms of values more equally in terms of ease of learning.

Conclusion

Surprisingly, we did not find any difference in positive affective value and reward value modulation of memory and decision-making. The results suggest that perhaps the influence of reward and positive affect is equally strong across participants on both memory and decision-making. It also supports the hypothesis that memory and decision-making are highly related processes as a null effect on both was observed.

The current study is significant as it is the first study, to our knowledge, to directly contrast positive affect and reward's influence on memory and decision-making. Many past studies investigating mechanisms of memory and decision-making use the idea of positive affect and reward interchangeably. Usually, the induction of positive affect was done through giving a monetary reward or food incentive which makes it impossible to distinguish the influence of affect from reward. The tendency of mixing reward and positive affect seems to originate in animal lesion studies that investigate the neural basis of memory and decision-making (Baxter & Murray, 2002; Murray, 2007). This is due to the fact that there are hardly any other ways to induce positive affect in non-human animals without giving food incentives.

However, for humans, it is important to understand how reward and positive affect have different influences as we react to reward and positive affect stimuli differently and it has significance in many areas. For example, understanding the different influences of rewards and positive affect on decision-making can benefit the marketing industry; advertisements with different ratios of affect and reward cues might lead to different consumer purchase outcomes.

In addition, the current study also points to potential individual differences in positive affect and reward processing in memory and decision-making. The study of individual differences in susceptibility to reward and affect can benefit education and the mental-health industry. For example, motivating students with different preferences for reward and positive affect accordingly may improve their learning and memory of the knowledge through tailored instruction. Targeting patients with mental health disorders like depression with different treatment plans according to their sensitivity to reward and affect cues may benefit their treatment. Therefore, it is important for future studies with a significantly larger sample size to investigate more carefully individual differences in the influence of positive affect and reward on memory and decision-making.

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