The effect of positive and negative surprise on episodic memory

Enyedi, Ilona

Psychologie
Faculteit der Sociale Wetenschappen

Surprise and memory

The effect of positive and negative surprise on episodic memory

---

Name: Ilona Enyedi

Student number: s1986627

Date: 05/12/2022

Supervisor: David A. Vogelsang, PhD

Second reader:

Word count: 4830

Cognitive Psychology

Thesis Msci Applied Cognitive Psychology

Contents

Abstract

Previous research has suggested that reward prediction error, or surprise, can lead to enhanced episodic memory. It remains unclear however, how manipulating the strength and valence of the prediction error affects recall rates.

In the current study, we induced surprise by giving unexpected feedback to participants on their given tasks. The task participants had was to look through a set of images and later on recall which images were shown already and which ones were new. They were asked to indicate how confident they were in their answer and then they received feedback on whether their answer was correct or incorrect.

We looked at whether the surprise being negative – negative prediction error – or positive – positive prediction error – has a stronger effect on recall rates. Based on the analysis, we concluded that when participants were negatively surprised by the feedback, they remembered the image better than when the feedback was positively surprising. Images with negative emotional valence were also remembered better than images with positive emotional valence. Additionally, when participants encountered mild positive surprise, they were more likely to recall the image correctly than if they encountered strong positive surprise. We found the opposite to be the case with negative surprise: strong negative surprise led to higher recall rates than mild negative surprise.

The results from this study indicate that manipulating both the valence and strength of surprise, as well as the valence of the images shown can yield different recall rates. Future research could explore why the strength of the surprise yields different recall rates when interacting with negative compared to positive surprise.

The effect of positive and negative surprise on episodic memory

Surprise is one of the most basic and universal human emotions (Ekman, 1992), along with happiness, sadness, disgust, fear, and anger. This emotion can occur when our expectations are disconfirmed (Kissinger & Corkin, 2003). Surprise plays an important role in cognitive processes, such reasoning, persuasion, humor and memory (Maguire, Maguire, & Keane, 2011). We will focus on the role that surprise plays in memory.

Unexpected events are more likely to be remembered compared to predictable events (Axmacher et. al., 2010). According to Axmacher and colleagues, this is likely because surprise interrupts ongoing cognitive processes and focuses the attention on the surprising event. This is in line with the findings that heightened attentional state and an increase in arousal levels have been shown to enhance memory consolidation and recall in adults (McGAugh, 2004).

Studies done with nonhuman animals also show that surprise has an enhancing effect on memory. For example, Takeuchi and colleagues (2016) found that novelty creates better memory for otherwise trivial events. They observed that in mice, being surrounded by unfamiliar floor surfaces for 5 minutes prolonged spatial memory to 24 hours compared to the mice being in their usual environment. The researchers observed that neuronal firing in the locus coeruleus is particularly sensitive to environmental novelty. The firing in this region projects to the hippocampus, which is associated with memory (Scoville & Milner, 1957). When something unexpected happens, this process is activated, which enhances memory retention.

It seems plausible that simply finding something more interesting also leads to higher recall. A study by Schraw, Bruning, and Svoboda (1995) demonstrated that perceived interest is positively related to later recall. They arrived at this conclusion after presenting

participants with a short text and measuring their perceived interest in it. They found that the higher participants rated their interest in the text, the better they remembered that text later. As surprise is one of the main reasons that lead to feelings of interest, it is likely that encountering surprising stimuli also enhances memory (Berlyne 1966).

Another mechanism behind the enhanced learning through surprise is the reward prediction error. According to Shultz (2017), reward prediction error is the difference between a reward that is being received and the reward that is predicted to be received. Positive reward prediction error, when a reward is better than expected, leads to positive learning and enhances approach behavior. However, when the reward is worse than expected (negative prediction error), it leads to avoidant behavior and negative emotions. Dopamine is released by the locus coeruleus when there is a positive prediction error, and it is inhibited when encountering negative prediction error (Shultz, 2016). In either case, the change in dopamine induces learning.

Furthermore, a review by Kensinger (2007) seems to conclude that the emotional polarity of surprise may affect memory retention in different ways. For example, in 2003, Kennsinger and Corkin found in their experiment comparing the effects of negative and neutral words, that participants were more likely to remember details of the presentation of negative words, compared to neutral words. They thus concluded that memory is improved by emotional, not neutral, stimuli. Additionally, a study by Wang (2018) also shows that when presenting people pictures with positive, negative and neutral valance, the negative pictures are remembered better long-term (after two weeks). This is in line with the result of Kennsinger and her colleagues' study (2003, 2006) showing that experiencing negative emotion in enhancing both the vividness of a memory and also the likelihood that details of the event are remembered.

One of the primary reasons for why negative surprising events may be better remembered can be found in evolution. Negative events tend to be more salient, as it makes more sense to focus one's attention on potentially threatening information (Vaish, Grossmann & Woodward, 2008). Negative events are more associated with activity in the brain areas such as the orbitofrontal cortex and the amygdala than positive events. These regions of the brain are important for emotion-processing and the more activated these regions are, the more likely the event is remembered (Kensinger, 2009). The types of memories which are involved in emotion processing tend to be episodic memories. Episodic memory is a type of explicit memory, which refers to memory that we are able to consciously recall (Dickerson & Eichenbaum,2010). There are two types of explicit memory: semantic memory and episodic memory. Semantic memory refers to the storage of factual information, such as words, numbers and concepts. On the other hand, episodic memory consists of past personal experiences (Schacter, Gilbert & Wegner, 2009). In our paper, we will focus on episodic memories.

When comparing negative and positive unexpected stimuli, studies show that we pay more attention to negative stimuli. In an experiment measuring reaction time, participants showed longer reaction times for negative than positive unexpected pictures (Schützwohl & Borgstedt, 2005). In the article about this experiment, the authors state that unpleasant stimuli engaging more attentive resources than pleasant stimuli are likely because of the threat detection system of surprise. The purpose of this system is to search for threat-related stimuli, which is also the reason people look at threatening stimuli longer and more attentively than at pleasant stimuli.

Therefore, I expect that when comparing people who are negatively surprised by the feedback on their performance to when they are positively surprised by the feedback, they will remember the negatively surprising feedback better. In our study we will define negative

surprise as receiving feedback that the answer was incorrect and positive surprise as receiving feedback that the answer was correct.

Research objectives and implications

The goal of our experiment is to find what conditions work best for enhancing episodic memory. The novel aspect of the study is that we will examine the effects of surprise and emotion together. The way in which we will do this is by altering the feedback participants will receive during the experiment in order to induce (positive or negative) surprise. We will also use images with positive and negative emotional valence and examine what effect that has on memory. Having such knowledge could help in understanding the mechanisms underlying human memory. This knowledge could also potentially allow people to enhance their memory by using scientifically tested methods and have insight into the impact positive and negative surprise has on remembering information. Overall, by having such experiments, we can address memories of events more appropriately.

Hypotheses:

Hypothesis 1: Surprise enhances episodic memory.

There are three main reasons why surprise is likely to enhance episodic memory. Firstly, as surprising events tend to catch our attention, and attention influences recall, these events are likely to be more memorable (Axmacher et al., 2019). Secondly, perceived interest and novelty is shown to be positively related to later recall (Shraw et al., 1995 & Takeuchi et al., 2016). Thirdly, change in dopamine induces learning, and since both positive prediction error and negative prediction error change dopamine levels, it is likely that in either case learning will be induced (Shultz, 2016), so the recall rates will be higher.

Hypothesis 2**:** Negative surprise is remembered better than positive surprise.

According to the study by Schützwohl and Borgstedttudies (2005), people pay more attention to negative surprising stimuli than positive surprising stimuli. In line with this finding and evolutionary theory stating that it is more useful to pay attention to negative than positive unexpected events (Vaish, Grossmann & Woodward, 2008), I expect that negatively surprising feedback will also be better remembered than positively surprising feedback.
Hypothesis 3: Images with negative emotional valence are more memorable than those with positive emotional valence.

According to Kennsinger and colleagues (2003, 2006) negative emotion tends to enhance the vividness of a memory and increases the likelihood that details of the event are remembered, compared to positive emotion. Therefore, I expect this to be the case in our study as well.

Methods

Participants

Twenty-eight participants were recruited through SONA, a participant management tool used by Leiden University and through personal contacts. As the experiment was in English, one of our inclusion criteria was to be fluent in English. The other inclusion criteria was to be between the ages of 18 and 35. There were also two exclusion criteria. Firstly, using any psychoactive medication or drugs and secondly, being diagnosed with any neurological or psychological disorders.

The calculation of the appropriate sample size took into account prior studies that focused on manipulating surprise. One such study by Fazio and Marsh (2009), who used a sample size of 46 in their first experiment. We used the G*Power Version 3.1.9.2 software (Faul, Erdfelder, Buchner, & Lang, 2009) to acquire an a priori estimate of the sample size.

With a power of .95 and an alpha of .05, we calculated that a sample size of 19 would be sufficient. We computed the effect size to be .88 with an effect size calculator spreadsheet by Lakens (2013).

Out of the 28 recruited participants who completed the experiment, we were able to use the results of 25. This is due to having to exclude three participants who showed response bias based on our a priori criteria. We set as criteria to not include participants who score more than two standard deviations below chance level on the tasks. The participants who completed the experiment were awarded 2 university credits if they were university students at Leiden, otherwise they agreed to participate without compensation. This study was approved by the ethical committee of psychology by Leiden University (CEP).

Design

The experiment used a within subject repeated measures design to test the effect of the independent variables: direction of surprise (positive/negative), type of picture (positive/negative), and strength of the surprise (slight/high) on the dependent variable: memorability.

Materials

We used a set of pictures for this experiment taken from the Open Affective Standardized Image Set (Kurdi et al; 2017). We preselected what images to use from this set, including the pictures with the highest emotional valence, both positive and negative. We took out some extremely negative pictures that could be too disturbing or inappropriate.

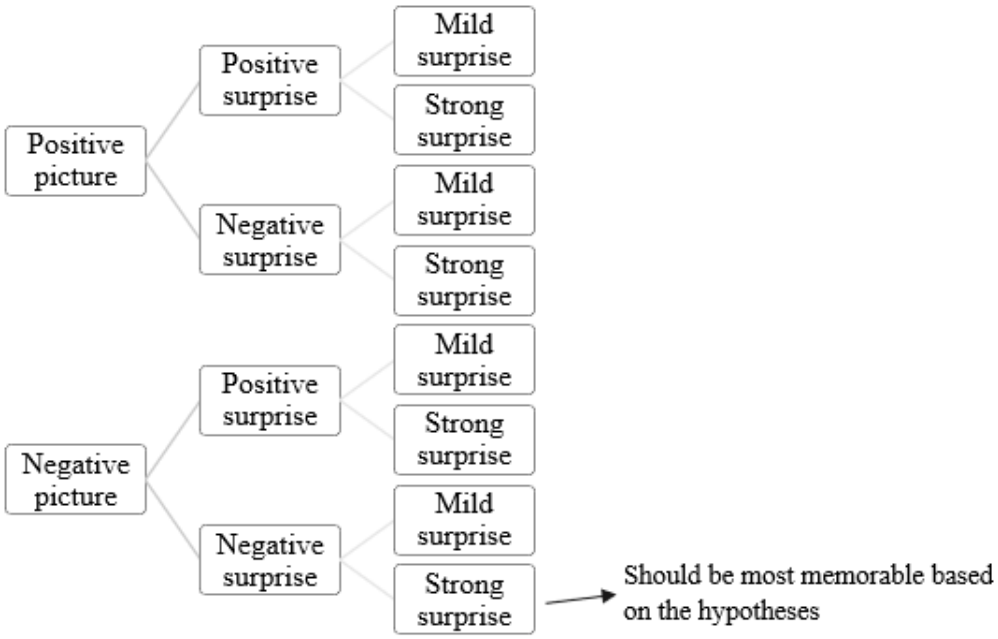
To take part in this study, participants were given a link to Pavlovia, a platform that hosted our experiment (https://pavlovia.org/). The experiment was created using Psychopy, an open-source software package made for behavioral science experiments (Peirce et al., 2019). The introduction, informed consent and debriefing were created in the research platform Qualtrics (https://www.qualtrics.com).

Procedure

The study took approximately 40 minutes to complete. Participants performed a practice block to familiarize themselves with the experiment. After this practice block, participants proceeded with the main experiment. (see also: Figure 1).

Figure 1

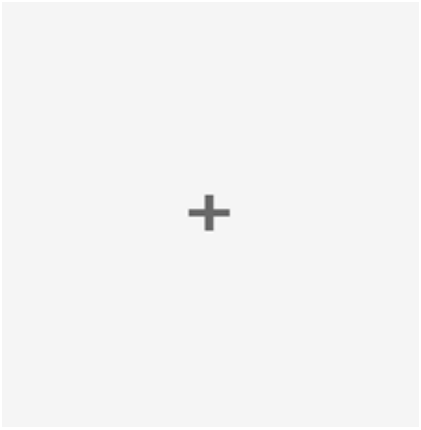
Possible combinations



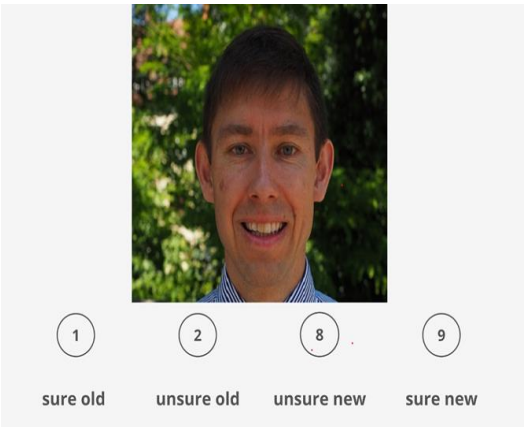
In Phase 1, we asked participants to look through a set of pictures. Each picture was shown for 2 seconds, with a fixation cross of 1 second in between each picture). In Phase 2, participants performed an old/new recognition memory task in which they were asked whether the presented picture on the screen was old (i.e. seen in phase 1) or new (see Figure 2).

Figure 2

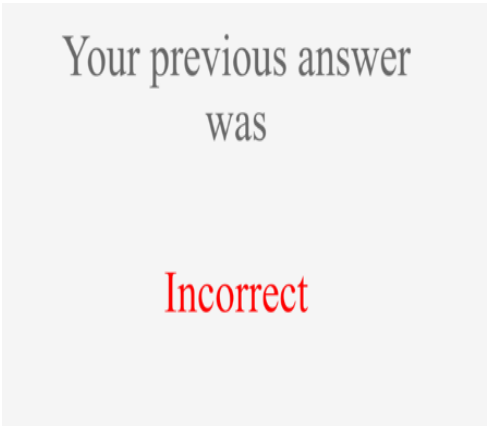
What a sequence looks like in Phase 2 or Phase 3



Fixation cross



Presenting picture and testing recognition



Feedback

Participants provided their answer by selecting one of the following options: “sure old”, “unsure old”, “sure new”, “unsure new”. Afterwards, they received feedback on their answer, which was either “your previous answer was correct” or “your previous answer was incorrect”, which was shown for 2 seconds. The feedback participants received was manipulated, so even if they remembered accurately, the feedback may not have stated that they were correct. This manipulation allowed for feelings of surprise to arise when participants received their feedback. A positively surprising feedback would be when participants were unsure of their answer and their feedback said they were correct, while a negatively surprising feedback would be when the answer of the participants yield an “incorrect” feedback response. Finally, participants performed a second old/new recognition memory test etc. etc. Phase 3 also involved an old/new memory recognition test, which included all old and new words from Phase 2. All three phrases are described and illustrated in Table 1.

Table 1

What participants had to do in each phase

Phase 1	Old/new recognition memory test (Phase 2)	Old/new recognition memory test (Phase 3)
Look through a set of 80 images (one by one, 2 seconds per picture)	Look though a set of 160 images (80 old 80 new) Attempt to recall which pictures were present in Phase 1 Determine confidence level of answer being correct Get feedback whether the answer was correct	Look through a set of 320 images Attempt to recall which pictures were present before Determine confidence level of answer being correct

After Phase 3, participants were presented with a debriefing form, informing them that some of the feedback they received was false: we set the study to give feedback that participants' answer was correct 50% of the time and incorrect the other 50% of the time. At this time they were also presented with the question: did you suspect the feedback to be manipulated?

Analysis

In Phase 2, we compared whether pictures with a positive emotional valence were more or less accurately remembered than pictures with a negative emotional valence. We did this using a paired samples t-test comparing the mean correct responses of positive and mean correct responses of negative pictures.

In Phase 3, we compared whether positive feedback is better remembered than negative feedback. We did this by using a repeated measures ANOVA with the factors of

direction of surprise (positive/negative) and strength of surprise (mild/strong) first for pictures that were used in Phase 2 already and then also for pictures that were only used in Phase 3.

While examining the data we examined an interesting pattern of results related to the strength of the surprise. Despite the fact that this was not part of our main hypotheses, we decided to investigate this effect using an exploratory analysis. We compared whether there is a difference between receiving highly surprising positive feedback compared to receiving slightly surprising positive feedback and the difference between highly surprising negative feedback compared to a slightly surprising negative feedback.

Results

Hypothesis 1 and Hypothesis 2: Surprise enhances memory and negative surprise is remembered better than positive surprise.

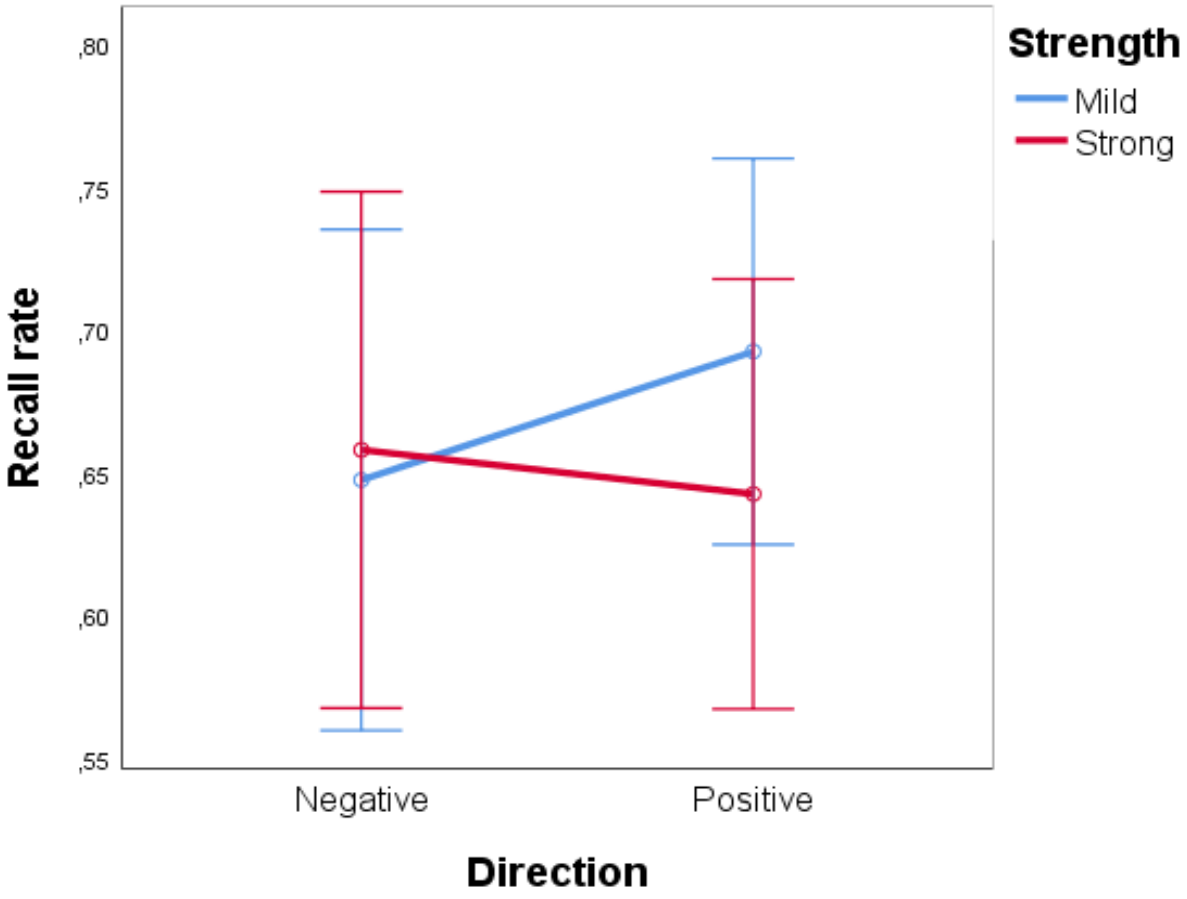
To test these hypotheses, we looked at how participants reacted to the feedback they received, which was either strongly surprising or mildly surprising and either positively surprising or negatively surprising. We used the results of Phase 3 and first looked at foil pictures (which have been introduced in Phase 2) and tested the effect of the strength and direction of surprise on memory (see: Figure 3). In the Repeated measures ANOVA with the factors direction of surprise (positive vs negative) and strength of surprise (mild vs strong), we found no significant effect for either strength of surprise: $F(1, 24)= .304$, $p=.586$, $\eta^2=.013$, nor direction of surprise: $F(1, 24)= .155$, $p=.698$, $\eta^2= .007$. This is not in line with the hypothesis that negative surprise is remembered better than positive surprise, or that the more surprising something is, the better remembered it is.

Hypothesis 3: Images with negative emotional valence are more memorable than those with positive emotional valence

In order to test this hypothesis, we used the results from Phase 2, and ran a paired samples t-test, comparing the correct responses for images with a positive valence and images with a negative valence. The mean correct response for negative images was 78% (.780) while the mean correct response for positive images was 73.5% (.735). The difference between these two variables was significant, with M=.046, SD=.068 and t(24)=3.419, p=.002, with a Cohen's d of .684.

Figure 3

Analysis of foil images: results of the effect of the strength and direction of surprise on memory.



Note: We used +/- 2 SE error bars

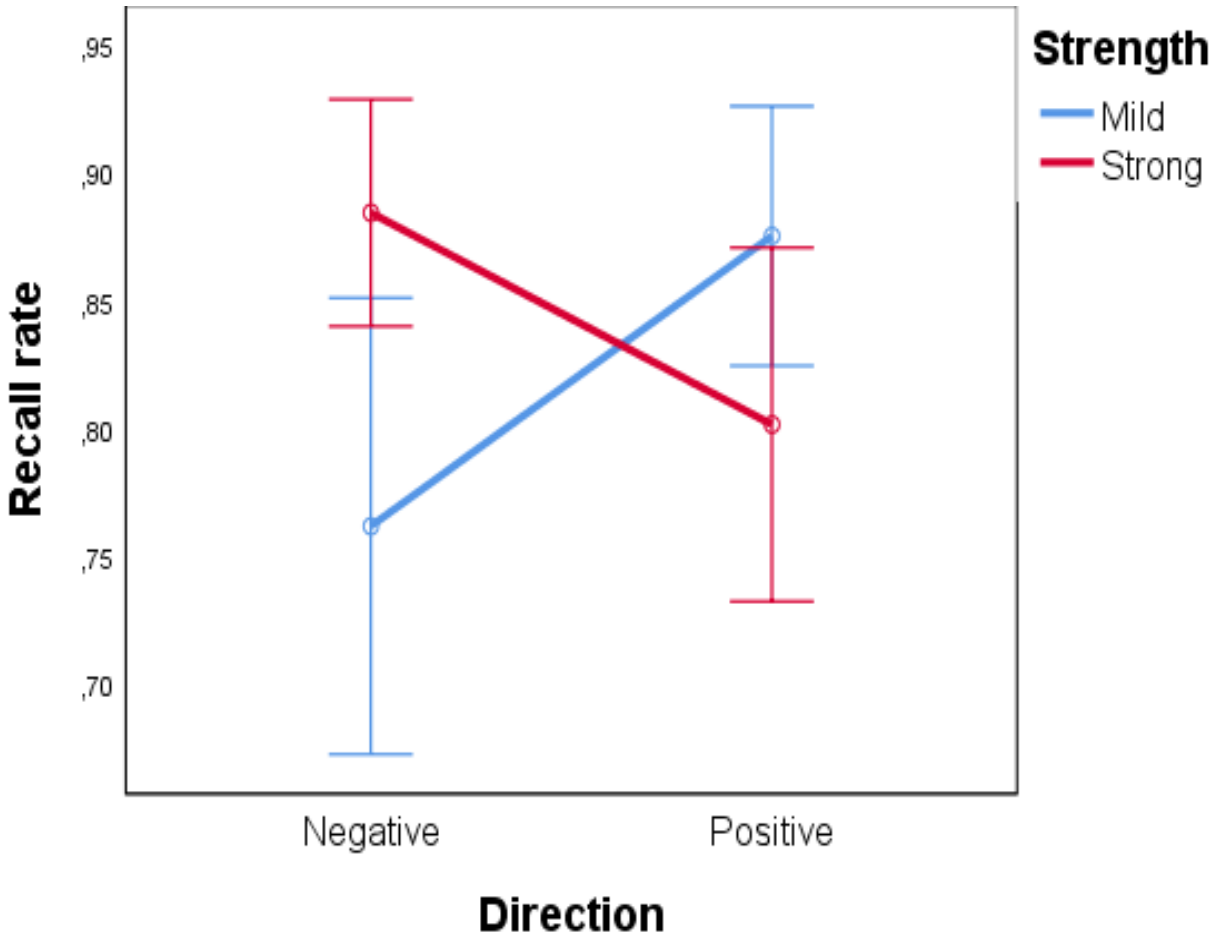
Exploratory analysis result

We also looked at old pictures (images introduced in Phase 1) and the effect of the strength and direction of the surprise (see Figure 4). Also in this RMANOVA with the factors of direction (positive/negative) and strength (mild/strong) of surprise, we found no significant effect for strength: F (1.24)=.945, p=.341, η^2=.038, nor direction of surprise: F(1, 24)= .389, p=.539, η^2= .086. We did, however, find a significant interaction effect between strength and direction of surprise: F (1, 24) = 11.809, p=.02, η^2 =.330. The interaction effect showed that mild positive surprises are better remembered than strong positive surprises, while mild negative surprises are not remembered as well as strong negative surprises.

To explore this interaction further, we performed a follow-up paired samples t-test to compare mild negative surprise and strong negative surprise, which was significant: M=-.123, SD=. 195, t (24) =-3.151, p=.004, Cohen's d: 0.695 and we compared mild positive surprise to strong positive surprise, which was not as significant: M= .074, SD= .186, t (24) = 1.986, p=.059, Cohen's d: 1.516.

Figure 4

Analysis of old images: results of the effect of the strength and direction of surprise on memory.



Note: We used +/- 2 SE error bars

In addition to the results from the analysis of hypotheses, it is also relevant to mention the findings from the debriefing phase. When we asked participants whether they suspected the feedback we gave them to be manipulated, 75% of the respondents said that they indeed suspected this.

Discussion

Hypotheses

The present study explored the effects of surprise on episodic memory. We had three hypotheses, of which two were confirmed. The first hypothesis stated: surprise enhances memory. When only looking at the effect of the strength of surprise (mild and strong) on the recall rates, we found no significant effect, so this hypothesis is not confirmed. On the other

hand, our second hypothesis, stating that negative surprise is remembered more than positive surprise, was confirmed. We found that negative surprise does indeed lead to higher recognition memory compared to positive surprise. These findings indicate that surprise in general may not be enough to elicit higher recall rates, but negative surprise in specific is likely to enhance memory. Our third hypothesis, stating that images with negative emotional valence are remembered better than images with positive emotional valence, was also confirmed.

Why are images with negative emotional valence recalled better?

Negative emotions in general tend to enhance both the vividness of a memory and also the likelihood that details of the event are remembered (Kensinger & Corkin 2003). The reason individuals are prone to elaborate on stimuli with negative emotional valence more is likely because evolutionarily, the failure to detect and process unexpected threatening information had more negative consequences than not recognizing unexpected benefits (Reisenzein et.al., 2019). Therefore, the negative emotions associated with negative surprise may be responsible for the heightened recall rates in comparison to positive surprise in our study.

Why are negative surprises recalled better?

Our findings are in line with the literature on stimuli with emotional valence, such as that by Kensinger and Corkin (2003), who found in their study that participants remember the content and the color of words more if the word is negative rather than neutral. Stimuli with emotional valence are more likely to activate semantic or autobiographical information in individuals which could lead to an enhancement in the ability to vividly recollect these stimuli. Wang (2018) also tested whether this effect holds true when comparing pictures with negative valence, neutral valence and positive valence. In line with our findings, Wang also found that people tend to remember images with negative valence more than images with

neutral valence and positive valence. However, one key difference between our study the studies by Wang (2018) and Kensinger and Corkin (2003) is that they distinguished two different components underlying recognition, which may be differently affected by emotional valence.

Recognition memory is composed of recollection and familiarity (Jacoby, 1991 as cited in Wang, 2018). During recollection, details associated with an encoding episode are consciously recalled, while experiencing familiarity involves the automatic identification of an event as having occurred. Wang uses the study by Kensinger and Corkin (2003) as an example to showcase the difference in the influence of emotional valence on memory. Although Kennsinger and Corkin found higher recollection for negative words than for neutral words; they did not find significant difference between familiarity for negative and neutral words. In order to find the distinguished effects of familiarity and recollection, participants were asked to make "remember/ know" judgements (remember referring to recollection and know referring to familiarity) if words were identified as "old". The results of our study concerning the impact of negatively valanced pictures seems to indicate that participants used more on recollection than familiarity, but this question could be analyzed in future studies by adding the "remember/know/guess" component to the study ("guess" being the addition Wang proposed to filter out guesses).

Why is strong positive surprise not remembered as well as mild positive surprise?

As a result of our exploratory analysis, we also found that strong negative surprise leads to higher recall compared to mild negative surprise, yet strong positive surprise leads to lower recall than mild positive surprise. This result conflicts with previous research that found that increased surprise leads to better recall (McGuire et al; 2014).

As concluded by Shultz (2016), and as supported by prior experiments (McGuire et. al., 2014), both negative and positive reward prediction error should lead to higher recall. The

method McGuire and colleagues used to induce surprise was different from ours. They used a video game setting in which participants had to predict the optimal location for a bucket to be placed to catch money that fell from a helicopter. Surprise was induced by the helicopter appearing in an unexpected location (not above the bucket) or by having a higher-than-expected reward (more money) appear in the bucket. The positive surprise in this scenario may have yielded a higher intensity of surprise than what we considered strong positive surprise in our setting. In our experiment, when the participant indicated that they believe to have seen an image before and their answer ended up being correct was what we considered a positive prediction error. Strong positive surprise meant that the participant was not sure of their answer but still chose correctly (according to the feedback), while mild positive surprise meant that participants were sure of their answer and the feedback confirmed that their answer was correct. Overall, having such different methods of inducing surprise is likely the cause of the different results, but it's also possible our prediction error manipulation did not work as well as we expected in inducing surprise.

Another explanation for mild positive surprise being remembered better is because confidence and accuracy are strongly related (Wixted & Wells, 2017). The more confident we are in our answer, the less surprising it is if the answer is correct. According to confirmation bias, we tend to recall information in a way that confirms or supports our prior beliefs (Raymond, 1998), therefore we may remember our stronger beliefs better. When experiencing strong positive surprise, participants indicated they were not confident about their answer at first, which perhaps this translated into remembering the lack of confidence or confusion upon seeing the picture again, but not necessarily remembering the correct answer. On the other hand, when initially being confident of their answer, they may remember the high level of confidence and the answer. This phenomenon could also be explained by selective perception (Messad et al., 1979). In case the participants felt it's more important to

pay attention to how the task makes them feel (e.g.: confident), rather than what information they are given as feedback, it is possible that they were able to recall easier that they felt very sure of their answer instead of remembering the feedback.

Limitations and future studies

The main potential drawback of our study is that most participants did suspect that the feedback was manipulated. This might be due to them still getting feedback on their choice even when they didn't react by clicking on something or pressing a key on the keyboard. If participants discovered that they receive feedback even if they don't do the tasks, they may not take the study seriously or lose focus. However, even if participants did react every time, there is still a chance they would suspect the answers to be pre-programmed eventually. Therefore, this element of the study should be changed in a future, for example by programming the task so that the feedback is always genuine, and no feedback is given when there is no response.

In future studies, it could also be useful to explore different ways of inducing positive surprise, such as giving a physical reward that the participant rates at a higher value than the expected reward. This change would allow us to see whether different ways of inducing positive surprise yield different results. Additionally, it would be informative to know whether personality type affects how surprising events are remembered. As an example from our findings, it is possible that people who need more self-affirmation would remember events better when they were sure of themselves compared to being unsure, while those who need less self-affirmation might remember events when they were unsure more, as this information could potentially be more useful to them. Self-affirmations tend to be more needed for those who want to manage their stress or feel that their perceived adequacy or integrity is threatened (Steele, 1988). Therefore, it would be informative to measure levels of

stress and self-assuredness before the experiment to find out whether this has an effect on how confident participants are in their answers.

It would be also insightful to distinguish between familiarity and recollection in future studies, by adding a "remember/know/guess" selection option at the recall phase of the experiment. Having this additional information could be useful in understanding how emotions impact our memory and examining whether there's distinctions between familiarity and recollection would advance our knowledge on dual-process and single-process theories on memory (Yonelinas, 2002).

A final suggestion for future studies would be to have the experiment done in a more controlled lab environment, using equipment to measure brain activity, such as fMRI (as did McGuire and colleagues in 2014). Studies on surprise looking for brain activation, make use of fMRIs for example to detect activation levels in the medial temporal lobe structures implicated in novelty detection (Schroeder et. al., 2004). Therefore, using brain imaging techniques could assists in answering questions related to the intensity of surprise more precisely.

Conclusion

In conclusion, our research added to the existing knowledge on memory by exploring the effect surprise and emotional valence has on recall. Although one of our hypotheses was that increased surprise leads to higher recall, we found this to be the case only if the surprise was negative, rather than positive. The main possible explanation for this could be found in confirmation bias: perhaps participants recalled what they remember to have chosen before as an answer, especially if they were highly confident in their first answer (Raymond, 1998). In the case of negative surprise, increased surprise led to higher recall possibly because evolutionarily, paying more attention to negative surprise, especially when highly unexpected, aided our survival more than paying attention to positive surprise (Reisenzein

et.al., 2019). This evolutionary explanation may also be the reason why our results showed that negative images tend to be remembered better. Future studies could take into account the feedback that we got for our study, namely that most participants were aware that the feedback they got was manipulated. Additionally, to have more precise results, this study could be recreated with the aid of equipment to measure brain activity and a remember/know/guess selection option to measure whether recollection or familiarity is more effected by our independent variables (strength and valence of surprise). Overall, researching the effect of surprise on memory is important for understanding when and what we are able to recall most, for assessing the accuracy of eye-witness testimonies, and for understanding cognitive processes better in general.

References

Axmacher, N., Cohen, M. X., Fell, J., Haupt, S., Dümpelmann, M., Elger, C. E., Schlaepfer, T. E., Lenartz, D., Sturm, V., & Ranganath, C. (2010). Intracranial EEG correlates of expectancy and memory formation in the human hippocampus and nucleus accumbens. Neuron, 65(4), 541–549. https://doi.org/10.1016/j.neuron.2010.02.006

Burgoon, J. K.; Jones, S. B. (1976). "Toward a Theory of Personal Space Expectations and Their Violations". Human Communication Research. 2 (2): 131–146. doi:10.1111/j.1468-2958.1976.tb00706.x.

Creswell, J. D., Dutcher, J. M., Klein, W. M. P., Harris, P. R., & Levine, J. M. (2013). Self-affirmation improves problem-solving under stress. *PloS One*, *8*(5), e62593–e62593. https://doi.org/10.1371/journal.pone.0062593

Dickerson, B. C., & Eichenbaum, H. (2010). The episodic memory system: neurocircuitry and disorders. Neuropsychopharmacology: official publication of the American College of Neuropsychopharmacology, 35(1), 86–104. https://doi.org/10.1038/npp.2009.126

Ekman, P. (1992b). Are there basic emotions? *Psychological Review,* 99, 550–553. doi: 10.1037/0033- 295X.99.3.550

Kensinger, E., & Corkin, S. (2003). Memory enhancement for emotional words: Are emotional words more vividly remembered than neutral words? *Memory & Cognition, 31*, 1169-1180.

Kensinger, E. A. (2007). Negative Emotion Enhances Memory Accuracy: Behavioral and Neuroimaging Evidence. *Current Directions in Psychological Science*, 16(4), 213–218. https://doi.org/10.1111/j.1467-8721.2007.00506.x

Kensinger E. A. (2009). Remembering the Details: Effects of Emotion. Emotion review:

journal of the International Society for Research on Emotion, 1(2), 99–113. https://doi.org/10.1177/1754073908100432

Kurdi, B., Lozano, S., & Banaji, M. R. (2016). Introducing the Open Affective Standardized Image Set (OASIS). Behavior Research Methods, 49(2), 457–470. https://doi.org/10.3758/s13428-016-0715-3

Lakens, D. (2013). Calculating and reporting effect sizes to facilitate cumulative science : a practical primer for t-tests and ANOVAs. Frontiers in Psychology, 4, 1–12. https://doi.org/10.3389/fpsyg.2013.00863

Massad, C. M., Hubbard, M., & Newtson, D. (1979). Selective perception of events. Journal of Experimental Social Psychology, 15(6), 513-532.

McGuire, J. T., Nassar, M. R., Gold, J. I., & Kable, J. W. (2014). Functionally dissociable influences on learning rate in a dynamic environment. Neuron, 84(4), 870–881.

Nickerson, R. S. (1998). Confirmation Bias: A Ubiquitous Phenomenon in Many Guises. Review of General Psychology, 2(2), 175–220. https://doi.org/10.1037/1089-2680.2.2.175

Pavlovia. https://pavlovia.org/ (accessed in June 2021)

Peirce, J. W., Gray, J. R., Simpson, S., MacAskill, M. R., Höchenberger, R., Sogo, H., Kastman, E., Lindeløv, J. (2019). PsychoPy2: experiments in behavior made easy. Behavior Research Methods. 10.3758/s13428-018-01193-y

Reisenzein, R., Horstmann, G., & Schützwohl, A. (2019). The Cognitive-Evolutionary Model of Surprise: A Review of the Evidence. *Topics in Cognitive Science*, 11(1), 50–74. https://doi.org/10.1111/tops.12292

Schacter DL, Gilbert DT, Wegner DM (2009). "Semantic and episodic memory". Psychology. pp. 185–6. ISBN 9780716752158.

Schultz W. (2016). Dopamine reward prediction error coding. *Dialogues in clinical neuroscience,* 18(1), 23–32. https://doi.org/10.31887/DCNS.2016.18.1/wschultz

Schultz, W. (2017). Reward prediction error. *Current Biology*, 27(10), R369-R371.

Steele, C. M. (1988). The psychology of self-affirmation: Sustaining the integrity of the self. *Advances in Experimental Social Psychology*, 261–302. https://doi.org/10.1016/s0065-2601(08)60229-4

Schroeder, U., Hennenlotter, A., Erhard, P., Haslinger, B., Stahl, R., Lange, K. W., & Ceballos-Baumann, A. O. (2004). Functional neuroanatomy of perceiving surprised faces. *Human brain mapping*, 23(4), 181–187. https://doi.org/10.1002/hbm.20057

Scoville, W. B., & Milner, B. (1957). Loss of recent memory after bilateral hippocampal lesions. *Journal of neurology, neurosurgery, and psychiatry*, 20(1), 11.

Takeuchi, T., Duszkiewicz, A., Sonneborn, A. et al. Locus coeruleus and dopaminergic consolidation of everyday memory. *Nature* 537, 357–362 (2016). https://doi.org/10.1038/nature19325

Teigen, K. H., & Keren, G. (2003). Surprises: Low probabilities or high contrasts? *Cognition, 87*(2), 55–71. https://doi.org/10.1016/s0010-0277(02)00201-9

Vaish, A., Grossmann, T., & Woodward, A. (2008). Not all emotions are created equal: the negativity bias in social-emotional development. *Psychological bulletin*, 134(3), 383–403. https://doi.org/10.1037/0033-2909.134.3.383

Wang, B. (2018). Retention interval modulates the effect of negative arousing pictures on recognition memory. *Memory*, 26(8), 1105-1116.

Yonelinas, A. P. (2002). The nature of recollection and familiarity: A review of 30 years of research. *Journal of memory and language, 46*(3), 441-517.