Encoding Method and Narrative Coherence Modulate the Effect of Emotion on Temporal Order Memory

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Abstract

Temporal order information, as one of the crucial associative elements between memory items, is vulnerable to emotional interference. The present study investigated whether and how encoding strategies and narrative coherence modulate emotional interference on temporal order memory through three experiments. Experiment 1 employed a 2 (encoding strategy: narrative encoding/discrete encoding) × 3 (emotion type: positive/negative/neutral) mixed factorial design, with encoding strategy as a between-subjects variable, to examine whether encoding strategy could modulate the interference of emotional information in picture materials on temporal order memory. Results demonstrated that in the discrete encoding group, temporal order memory accuracy under negative emotion conditions was significantly lower than in the other two conditions; conversely, in the narrative encoding group, no significant differences in temporal order memory were observed across the three emotion types. Experiment 2 utilized word stimuli with two emotion types (neutral and negative) to test whether the effect of encoding strategy on temporal order memory generalizes across materials. Experiment 3 manipulated the degree of narrative coherence between items to further investigate whether the aforementioned effect depends on the level of inter-item coherence. Results revealed that the aforementioned narrative encoding effect only emerged when items possessed high coherence. This study not only elucidates the mechanism by which narrative encoding preserves temporal information in emotional memory, but also underscores the importance of coherence level in the narrative encoding effect.

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Encoding Types and Narrative Coherence Modulate the Impact of Emotions on Temporal Order Memory

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Abstract

Temporal order information serves as a crucial binding element between memory items and is particularly susceptible to emotional interference. This study investigated whether and how encoding types and narrative coherence modulate the disruptive effects of emotion on temporal order memory through three experiments. Experiment 1 employed a mixed design with encoding type (narrative encoding vs. discrete encoding) as a between-subjects variable and emotional valence (positive, neutral, negative) as a within-subjects variable to examine whether encoding strategies could regulate emotional interference in temporal order memory for pictorial materials. Results demonstrated that in the discrete encoding group, temporal order memory accuracy was significantly lower under negative emotional conditions compared to the other two conditions. Conversely, in the narrative encoding group, no significant differences emerged across the three emotional conditions. Experiment 2 utilized emotional word stimuli (neutral and negative) to test whether the encoding effect generalized across materials. Experiment 3 further manipulated narrative coherence between items to investigate whether the observed effects depended on the degree of inter-item coherence. The findings revealed that the narrative encoding effect only manifested when items possessed high coherence. This study not only identifies the mechanisms through which narrative encoding preserves temporal information in emotional memory but also highlights the critical importance of coherence degree in narrative encoding effects.

Keywords: emotion, narrative encoding, temporal memory, episodic memory, narrative coherence

Introduction

In daily life, we can effortlessly recall memories associated with intense emotions, such as the joy of graduation or the scene of a car accident. Laboratory research has also identified the emotional enhancement of memory (EEM) effect, whereby individuals remember emotional content more deeply than neutral content [**?**, **?**, **?**]. On one hand, emotion enhances memory for core event content; on the other hand, it impairs memory for peripheral information and associations between information [?, ?, ?, ?], a phenomenon known as emotion-induced memory trade-off effects. Nevertheless, existing research on emotional memory has primarily focused on memory for items themselves, their spatial locations, or associative relationships between items [?, ?], with temporal information receiving scant attention [?, ?, ?].

As a defining feature of episodic memory [?], how is temporal information (such as the sequential order of events) affected by emotion? Based on the trade-off effect in emotional memory, temporal order information, as a type of contextual background information, should be vulnerable to negative emotional influences. Several studies support this hypothesis, demonstrating that emotion has detrimental effects on temporal order memory [?, ?, ?]. In one study by Huntjens et al. (2015), participants encoded sequences of high-arousal and low-arousal positive and negative pictures, with each sequence containing eight pictures of identical valence and arousal categories. After encoding each sequence, participants completed recognition memory and temporal reconstruction tasks. Results showed that compared to low-arousal pictures, high-arousal pictures yielded better recognition memory but poorer temporal reconstruction performance. In another study, participants encoded the presentation order of pleasant, unpleasant, and neutral words, followed by a temporal memory test. Findings indicated that temporal memory for unpleasant words was worse than for pleasant and neutral words [?]. A free recall study by Talmi et al. (2019) similarly showed that emotional words disrupted participants' tendency to recall words according to their learning sequence. These studies suggest that while recognition memory or free recall for emotional items is enhanced, this enhancement often comes at the cost of impairing memory for "peripheral" contextual information such as temporal order.

Conversely, other research has found that negative emotion positively enhances temporal order memory [?, ?] or that emotion has no effect on temporal order memory [?]. In Schmidt et al. (2011), participants familiarized themselves with different scenes during encoding, each consisting of a neutral background (e.g., a forest) plus three emotional objects (e.g., various forest creatures). Participants sequentially integrated object pictures into the neutral background until all three objects were incorporated. After the encoding phase, participants completed a cued recall test using the background as a cue to recall object names, followed by a temporal reconstruction task for the three objects in each scene. Results revealed that temporal memory for high-arousal object images was better than for low-arousal object images. In Dev et al. (2022), participants viewed edited video combinations of emotional scenes from the film *Pihu* during encoding, then completed a temporal reconstruction task using screenshots from the film clips. Findings showed that temporal order memory was better under negative high-arousal conditions compared to positive low-arousal conditions. Differing from these experimental manipulations, another study examined the relationship between emotional experience and temporal order memory from an individual differences perspective. Researchers recruited participants who had watched *Avengers: Age of Ultron* and asked them to arrange verbal descriptions of ten important movie scenes in the correct order. No correlation was found between emotional experience during viewing (derived from mean scores of emotional valence, intensity, and frequency) and temporal order memory for movie details [?]. These studies typically used stimulus valence or arousal to measure emotion and examine its impact on temporal order memory, yielding inconsistent results. However, experimental paradigms using materials with storylines or narrative structures are less likely to disrupt temporal order memory and may even enhance it [?, ?].

Narrative constitutes an indispensable component of episodic memory, with various theories emphasizing its critical role [?]. Rubin's (2006) basic-systems model of episodic memory posits that episodic memory comprises various forms of information—visual, auditory, olfactory, spatial, linguistic, affective, and narrative—each operating in independent systems with unique neural substrates. Among these interacting systems, narrative serves as a core component by imposing temporal and causal structure on information. From a social interactionist perspective, Nelson and Fivush (2004) propose that autobiographical memory emerges and develops through narrative construction during early childhood collaborative interactions with adults. Bauer (2015) further notes that narrative not only facilitates communication of event information but also aids in encoding, storing, consolidating, and retrieving different aspects of past events, thereby producing durable memories. Cohn-Sheehy et al. (2022) demonstrated that episodic memory exhibits a narrative-level organizational structure, such that temporally distant events can be linked if they form a coherent narrative.

Narrative coherence in memory research typically refers to the logical sequence of information presentation, contextual relevance, and consistency of storytelling. In real life, recall of encoded episodes does not always follow the presentation order. Research shows that when individuals recall real-world events, they invariably construct recall along causal relationships [?], semantic relations [?], and connections between events [?]. Tulving's (1972) concept of episodic memory also emphasizes the importance of contextual coherence in individual experience. A series of studies indicate that narrative coherence helps individuals construct connected and logical event streams, facilitating the formation and consolidation of temporal order memory. In a study by Bellana et al. (2022), word sequences with different coherence levels (word, sentence, and story levels) were used to explore the role of narrative coherence. Results showed that compared to materials with low coherence, the gist and details of complete stories remained in consciousness for several minutes after reading, and this process was unconscious. In complex or emotional contexts, emotional stories with high narrative coherence produce better memory effects than other types of memory [?]. These studies provide important perspectives on how narrative coherence influences temporal memory, yet questions remain regarding how to measure coherence degree, how different types of coherence (e.g., emotional coherence, narrative coherence) independently or jointly affect memory, and how coherence influences temporal information in memory processes.

The object-based framework of emotional memory proposes that memory binding for "within-object" features (such as color, location) is positively affected by emotion, whereas memory binding for "between-object" features (such as sequential order between items, connections between items and contextual details) is negatively affected by emotion \cite{Mather2007, Mather2011. Reviewing studies on emotion impairing temporal order memory reveals that the sequential stimuli in these studies share characteristics of being discrete and unrelated, causing attentional resources to focus more on emotional stimuli themselves [?] rather than contextual information such as time and space, thereby disrupting temporal continuity in memory [?]. However, coherence between contexts in naturalistic materials (e.g., film clips) facilitates the formation of complete temporal order memory and reduces or offsets the negative impact of negative emotion [?].

Compared to traditional sequential learning and encoding of individual items, narrative encoding and its high coherence help transform connections between items and between items and contextual information into "within-object" binding [?], directing more attention to these connections and thereby reducing the impact of negative emotion. For example, Kensinger et al. (2005) examined how encoding type and age influence item-context memory. During encoding, participants viewed a series of pictures and performed different tasks. In the incidental encoding condition, participants decided whether to approach or avoid each picture; in the intentional encoding condition, participants were explicitly informed that memory for each component would be tested later. During the test phase, participants completed recognition judgments for item context. Results showed that in the incidental encoding condition, both younger and older adults had significantly lower accuracy for negative item contexts compared to neutral item contexts. In the intentional encoding condition, older adults showed the same pattern, whereas younger adults showed no significant difference in context memory accuracy between negative and neutral items, suggesting that intentional encoding can influence or even eliminate the negative impact of emotion on background information memory.

However, whether narrative encoding can reduce or offset the disruptive effects of negative emotion on temporal order memory remains unclear. To further investigate this issue, it is necessary to incorporate coherence and emotional variables into experimental designs to explore their influence on memory processes. This will help understand the protective effects of narrative coherence on temporal order memory under emotional influence [?].

In summary, this study systematically investigated whether and how encoding types and coherence degree modulate the influence of emotion on the temporal organization of memory through three experiments. By manipulating emotional information, we created three emotional types: positive, neutral, and negative. Relative to neutral conditions, positive emotional conditions used materials that could induce pleasant and relaxed emotions (i.e., high valence, low arousal), while negative emotional conditions used materials that could induce tension and anxiety (i.e., low valence, high arousal). The experiments included two encoding types: discrete encoding and narrative encoding. Discrete encoding required participants to encode emotional items sequentially according to presentation order, whereas narrative encoding required participants to encode emotional items by creating stories that connected them. In Experiment 1, participants were randomly assigned to two groups that used different encoding methods (narrative encoding vs. discrete encoding) to encode three types of emotional pictures (positive, neutral, negative), followed by a relative recency judgment task to test temporal order memory. We hypothesized that narrative encoding would show an advantage effect, that negative emotion would impair temporal order memory, and that a significant interaction between encoding type and emotional valence would emerge. Specifically, in the discrete encoding group, temporal order memory performance under negative emotional conditions would be worse than under positive and neutral conditions, while narrative encoding would offset or reduce the impairing effect of negative emotion on temporal order memory. Experiment 2 used emotional words as stimuli to test the robustness of these effects. Building on Experiment 2, Experiment 3 manipulated narrative coherence between words (high vs. low coherence) for narrative encoding under neutral and negative emotional conditions to investigate whether the narrative encoding effect depended on inter-item coherence. We hypothesized that high coherence would facilitate temporal order memory formation, thereby offsetting or reducing the impairing effect of negative emotion on temporal order memory compared to low coherence.

Experiment 1

Experiment 1 established two distinct encoding methods (discrete encoding and narrative encoding) and used three types of emotional pictures (positive, neutral, and negative) as stimuli to investigate whether encoding type could modulate the impact of emotion on temporal order memory.

2.1.1 Participants

Sample size was estimated using G*Power 3.1.9.7 software, setting a medium effect size of f = 0.20 and statistical power of 1-β = 0.90, yielding a planned sample size of 56 participants. To account for potential invalid data, 65 university students were actually recruited (mean age = 19.68 years, SD = 1.56; 17 males). The narrative encoding group comprised 31 participants, and the discrete encoding group comprised 34 participants. All participants had normal or corrected-to-normal vision and no color vision deficiencies. Before the experiment began, the experimenter provided detailed instructions about the experimental content, procedures, and precautions. All participants indicated full understanding and provided written informed consent. Participants received compensation after completing the experiment. The study was approved by the university ethics committee (No. ZSRT2023167).

2.1.2 Materials

Picture selection initially involved 420 images drawn from the Affective Image Database (AID; [?]), the International Affective Picture System (IAPS; [?]), and online picture libraries. Seventeen participants rated all pictures on valence (1 = "very unpleasant" to 7 = "very pleasant") and arousal (1 = "very calm/relaxed" to 7 = "very excited/tense") using 7-point scales. Based on these ratings, 120 pictures each of positive, neutral, and negative valence were selected. Analysis of the selected materials revealed significant differences in emotional valence among the three picture types, $F(2, 238) = 3803.17$, $p < 0.001$, $^2p = 0.97$, and significant differences in arousal levels, $F(2, 238) = 1289.84$, $p < 0.001$, $^2p = 0.91$. These three emotional types represent the most common materials in daily life, and their selection and naming conventions are consistent with previous research [?]. Detailed information is presented in Table 1 .

Selected pictures were further combined into 30 sets of four pictures each for each emotional condition. Ten participants who did not participate in the formal experiment rated the coherence of these 90 picture sets on a 1-10 scale (1 = "very incoherent," 10 = "very coherent"). After rating, 18 sets were selected for each emotional condition. The coherence ratings for picture sets across the three emotional conditions did not differ significantly, $F(2, 34) = 0.26$, $p = 0.774$, $^2p = 0.02$. Detailed information is presented in Table 1.

Table 1 Rating results of experimental materials

Valence (M±SD)	Arousal (M±SD)	Coherence Rating (M±SD)
1.71$±0.38	3.93±0.43	5.55±0.36
2.92±0.33	4.95±0.37	5.70±0.39
3.97±0.4 [illegible]	[illegible]	[illegible]

2.1.3 Design

The experiment employed a 2 (encoding type: narrative encoding/discrete encoding) × 3 (emotional type: positive/neutral/negative) mixed design, with encoding type as a between-subjects variable and emotional type as a within-subjects variable. Temporal order memory accuracy served as the dependent variable.

2.1.4 Procedure

The experiment was programmed using PsychoPy 2021.2.3 [?] and conducted individually in quiet, distraction-free psychology laboratories. Before the experiment began, the experimenter explained the instructions, after which participants entered a practice phase. After confirming complete understanding of the task rules, participants proceeded to the formal experiment. The formal experiment required participants to first complete the Chinese version of the Positive and Negative Affect Scale (PANAS) [?] to establish baseline levels of positive and negative affect. Participants then completed tasks in each block. Each block consisted of: (1) an encoding phase (picture encoding and pleasantness rating task), (2) a self-report phase, and (3) a test phase (temporal order memory test). Each emotional condition comprised three blocks. After completing each emotional condition, participants filled out the PANAS again. The experimental procedure is illustrated in Figure 1 [Figure 1: see original paper]A.

(1) PANAS Administration: Eighteen items (nine negative and nine positive) were presented sequentially on the screen. Participants read each item carefully and responded based on their current feelings. Each item included five response options: A. very slightly or not at all, B. a little, C. moderately, D. quite a bit, and E. extremely. Participants selected the option that best matched their current feelings by clicking on a rating bar below each item with the mouse.

(2) Encoding Phase: Picture encoding and pleasantness rating (Figure 1B): In the narrative encoding condition, participants were instructed to encode subsequent pictures by creating a story that connected them. In the discrete encoding condition, participants were instructed to memorize subsequent pictures in sequential order. Each trial began with a 0.5-second fixation point, followed by picture presentation for 3 seconds. During this 3-second window, participants rated the pleasantness of each picture by clicking on a 7-point rating bar below the picture (higher ratings indicated greater pleasantness). Four pictures were presented sequentially, with participants rating each picture's pleasantness. After encoding each picture set, participants answered one question. The narrative encoding group rated "To what extent can these pictures be connected into a story?" on a 1-10 scale. The discrete encoding group rated "To what degree can you remember this set of pictures?" on a 1-10 scale.

(3) Self-Report Phase: After completing the encoding phase, participants answered three questions using 7-point scales by clicking on rating bars.

Question 1: "How fast did you feel time passed during the picture encoding process?" Response options ranged from 1 (very slowly) to 7 (very quickly).

Question 2: "How pleasant do you feel right now?" Higher ratings indicated greater pleasantness.

Question 3: "How excited do you feel right now?" Higher ratings indicated greater excitement, while lower ratings indicated greater calmness.

(4) Memory Test Phase: Temporal order memory test (Figure 1C): Two pictures from the encoding phase were presented simultaneously. Participants judged which picture appeared earlier during encoding, pressing the left key to indicate the left picture appeared first and the right key to indicate the right picture appeared first. For each picture set, the middle two pictures were used to test temporal order memory.

2.1.5 Data Analysis

Experimental data were analyzed using a 2 (encoding type) × 3 (emotional type) mixed-design ANOVA. Three participants in the discrete encoding group reported using narrative strategies during encoding, and two participants had temporal order memory accuracy scores beyond $±$2 standard deviations. These five participants were excluded from data analysis.

2.2.1 Manipulation Check of Emotional Types

The effectiveness of emotional type manipulation was assessed through picture pleasantness ratings and PANAS results. First, we examined the effects of encoding type and emotional type on picture pleasantness ratings. ANOVA of pleasantness ratings (Figure 2 [Figure 2: see original paper]A) revealed a significant main effect of emotional type, $F(2, 57) = 566.92$, $p < 0.001$, ^{2}p = 0.91. Specifically, pleasantness ratings for positive pictures were significantly higher than for negative pictures ($p < 0.001$, Cohen's d = 5.50) and neutral pictures ($p < 0.001$, Cohen's d = 2.62), and neutral picture ratings were significantly higher than negative picture ratings ($p < 0.001$, Cohen's d = 4.23). Neither the main effect of encoding type nor the interaction between encoding type and emotional type was significant, ps > 0.05.

PANAS scores for each emotional condition were obtained by subtracting baseline values to derive increases in positive and negative affect. Analysis of these increases revealed that for positive affect increase (Figure 2B), the main effect of emotional type was significant, $F(2, 57) = 82.62$, $p < 0.001$, ^{2}p = 0.59. Positive affect increase was significantly higher in the positive condition than in the neutral ($p < 0.001$, Cohen's d = 0.82) and negative conditions ($p < 0.001$, Cohen's d = 1.82), and higher in the neutral condition than in the negative condition ($p < 0.001$, Cohen's d = 1.08). Neither the main effect of encoding type nor the interaction was significant, ps > 0.05.

For negative affect increase (Figure 2C), the main effect of emotional type was significant, $F(2, 57) = 108.21$, $p < 0.001$, ^{2}p = 0.65. Multiple comparisons revealed that negative affect increase was significantly higher in the negative condition than in the positive ($p < 0.001$, Cohen's d = 1.68) and neutral conditions ($p < 0.001$, Cohen's d = 1.53), and higher in the neutral condition than in the positive condition ($p = 0.029$, Cohen's d = 0.20). Neither the main effect of encoding type nor the interaction was significant, ps > 0.05. In summary, the manipulation of emotional variables in Experiment 1 was effective.

Figure 2 Results of emotional type manipulation check in Experiment 1. Note: A. Picture pleasantness ratings; B. Positive affect increase; C. Negative affect increase. *p < 0.05,* ***p < 0.01,*** p < 0.001. Error bars represent standard errors.

2.2.2 Temporal Order Memory Test

We examined the effects of encoding type and emotional type on temporal order memory accuracy (Figure 3 [Figure 3: see original paper]). Results showed a significant main effect of emotional type, $F(2, 57) = 4.70$, $p = 0.001$, ^{2}p = 0.10. Temporal order memory accuracy was significantly higher in the positive condition (M_{positive} = 0.82) than in the negative condition (M_{negative}

= 0.78, p = 0.017, Cohen's d = 0.19), and higher in the neutral condition (M_{neutral} = 0.85) than in the negative condition (M_{negative} = 0.78, p = 0.001, Cohen's d = 0.52). The main effect of encoding type was also significant, $F(1, 58) = 24.50$, $p < 0.001$, $^2p = 0.30$, with the narrative group (M_{narrative} = 0.86) showing significantly higher accuracy than the discrete group (M_{discrete} = 0.77, $p < 0.001$, Cohen's d = 6.86).

The interaction between emotional type and encoding type was significant, $F(2, 57) = 3.61$, $p = 0.030$, $^2p = 0.06$. Simple effects analysis revealed that in the discrete encoding group, $F(2, 67) = 8.06$, $p = 0.001$, $^2p = 0.22$, temporal order memory accuracy was significantly higher in the positive condition (M_{positive} = 0.78) than in the negative condition (M_{negative} = 0.70, p = 0.004, Cohen's d = 0.70), and higher in the neutral condition (M_{neutral} = 0.82) than in the negative condition (M_{negative} = 0.70, $p < 0.001$, Cohen's d = 0.88). No other comparisons were significant, $ps > 0.05$.

Figure 3 Temporal order memory accuracy in Experiment 1

2.3 Discussion

Experiment 1 compared the effects of positive, neutral, and negative emotional pictures on temporal order memory performance under different encoding conditions. Results demonstrated an advantage effect for narrative encoding, with the narrative encoding group showing better temporal order memory performance than the discrete encoding group. This structured encoding approach facilitates establishing connections between items and between items and contextual information. When retrieving temporal order information between items, individuals rely on these inter-item connections; stronger connections make temporal information easier to retrieve [**?**]. In this experiment, narrative encoding group participants connected pictures into a story during encoding, whereas discrete encoding group participants could only encode items individually as they were presented.

Temporal order memory performance was worse under negative emotional conditions compared to positive and neutral conditions. Additionally, PANAS results showed that negative emotional pictures induced greater emotional fluctuations than the other two picture types. Processing emotional information is a stimulus-driven, bottom-up automatic process. Compared to non-emotional stimuli, emotionally meaningful stimuli attract more attention or occupy more attentional resources [**?**], leaving fewer resources for connections between neutral items and other peripheral contextual information, thereby weakening memory for background information [**?**]. The negative pictures used in this experiment contained strong emotional information that elicited emotional responses in participants. As temporal order information constitutes a type of contextual background information, it was weakened by negative emotional stimuli. Previous studies have similarly found this phenomenon; for example, Maddock and Frein (2009) found that temporal order memory for unpleasant words was worse than for pleasant and neutral words.

The impact of emotion on temporal order memory differed across encoding types. Specifically, in the discrete encoding group, temporal order memory performance under negative emotional conditions was worse than under positive and neutral conditions. In contrast, in the narrative encoding group, no significant differences emerged across the three emotional conditions. According to the object-based framework of emotional memory, under discrete encoding conditions, each item is an independent object. Negative emotional items attract more attention, reducing attentional resources allocated to temporal order information between items and consequently impairing temporal order memory. Narrative encoding, however, can give discrete items certain connections, integrating them into a story through a shared narrative framework. This directs more attention to connections between items, thereby offsetting or reducing the impact of negative emotion [**?**].

Experiment 2

Experiment 1 used picture stimuli and found that narrative encoding could modulate the impairing effect of negative emotion on temporal order memory. Experiment 2 used emotional word stimuli to test whether the effect of encoding type on temporal order memory generalized across materials. Observing similar results with both picture and word conditions would provide stronger evidence for the mechanisms underlying emotion's influence on temporal order memory and enhance the external validity of the findings. Pictures, as complex visual materials, can directly evoke emotions and memories without linguistic mediation. In contrast, emotional words involve linguistic processing and semantic comprehension, placing different demands on cognitive systems and activating different brain regions \cite{Kensinger2006. Comparing these two stimulus types allows deeper understanding of the advantage effect of narrative encoding on temporal order memory and whether this effect varies by material type.

This study primarily focused on how narrative encoding modulates the negative impact of negative emotion on temporal order memory. Experiment 1 found that temporal order memory performance under negative emotional conditions was significantly worse than under positive and neutral conditions, with no significant difference between positive and neutral conditions. Therefore, Experiment 2 only used negative and neutral emotional words as stimuli.

3.1.1 Participants

Sample size was estimated using G*Power 3.1.9.7 software. Based on effect size calculations from Experiment 1 (f = 0.21) and statistical power of 1-β = 0.90, the planned sample size was 62 participants. This experiment actually recruited 66 university students (mean age = 19.38 years, SD = 1.75; 21 males). All participants had normal or corrected-to-normal vision and no color vision deficiencies. Before the experiment began, the experimenter provided detailed instructions about the experimental content, procedures, and precautions. All participants indicated full understanding and provided written informed consent. Participants received compensation after completing the experiment.

3.1.2 Materials

Word selection involved 352 two-character words from the Chinese Affective Words System (CAWS) [?], including 180 negative words and 172 neutral words. These words were paired to form 45 sets for the negative condition and 43 sets for the neutral condition, with each set containing four words. Ten participants who did not participate in the formal experiment rated the story coherence of these 88 word sets on a 1-10 scale (1 = "very incoherent," 10 = "very coherent"). After rating, 18 word sets each were selected for neutral and negative conditions. Coherence ratings did not differ significantly between neutral and negative word sets, $F(1, 17) = 0.54$, $p = 0.474$, $^2p = 0.03$. Detailed information is presented in Table 1.

3.1.3 Design

The experiment used a 2 (encoding type: narrative/discrete) × 2 (emotional type: neutral/negative) mixed design, with encoding type as a between-subjects variable and emotional type as a within-subjects variable. Temporal order memory accuracy served as the dependent variable.

3.1.4 Procedure

The procedure was identical to Experiment 1, except that word stimuli replaced picture stimuli.

3.1.5 Data Analysis

Data from each phase were analyzed using 2 (encoding type) × 2 (emotional type) ANOVAs. Three participants in the discrete encoding group reported using narrative strategies during encoding, and one participant had temporal order memory accuracy scores beyond $±$2 standard deviations. These four participants were excluded from data analysis.

3.2.1 Manipulation Check of Emotional Types

Emotional type manipulation effectiveness was assessed through word pleasantness ratings and PANAS results. First, we examined the effects of encoding type and emotional type on word pleasantness ratings. Two-way mixed-design ANOVA of pleasantness ratings (Figure 4 [Figure 4: see original paper]A) revealed a significant main effect of emotional type, $F(1, 60) = 912.41$, $p < 0.001$, $^2p = 0.94$. Specifically, neutral words received significantly higher pleasantness ratings than negative words ($p < 0.001$, Cohen's $d = 38.65$). Neither the main effect of encoding type nor the interaction was significant, $ps > 0.05$.

Second, we examined the effects of encoding type and emotional type on positive and negative affect increases in PANAS results. For positive affect increase (Figure 4B), the main effect of emotional type was significant, $F(1, 60) = 7.88$, $p < 0.001$, $^2p = 0.34$. Positive affect increase was significantly higher in the neutral condition than in the negative condition ($p < 0.001$, Cohen's $d = 5.82$). Neither the main effect of encoding type nor the interaction was significant, ps > 0.05.

For negative affect increase (Figure 4C), the main effect of emotional type was significant, $F(1, 60) = 29.59$, $p < 0.001$, $^2p = 0.33$. Negative affect increase was significantly higher in the negative condition than in the neutral condition ($p < 0.001$, Cohen's $d = 6.40$). Neither the main effect of encoding type nor the interaction was significant, ps > 0.05. In summary, the emotional type variable was effectively manipulated in this experiment.

Figure 4 Results of emotional type manipulation check in Experiment 2

3.2.2 Temporal Order Memory Test

We examined the effects of encoding type and emotional type on temporal order memory accuracy (Figure 5 [Figure 5: see original paper]). Results showed no significant main effect of emotional type, $F(1, 60) = 2.31$, $p = 0.134$, $^2p = 0.04$. Temporal order memory accuracy did not differ significantly between neutral (M_{neutral} = 0.78) and negative conditions (M_{negative} = 0.75, $p = 0.134$, Cohen's $d = 1.85$). The main effect of encoding type was significant, $F(1, 60) = 3914.77$, $p < 0.001$, $^2p = 0.99$, with narrative encoding (M_{narrative} = 0.81) showing significantly higher accuracy than discrete encoding (M_{discrete} = 0.72, $p < 0.001$, Cohen's $d = 5.66$).

The interaction between emotional type and encoding type was significant, $F(1, 60) = 7.19$, $p = 0.009$, $^2p = 0.11$. Simple effects analysis revealed that in the discrete encoding condition, $F(1, 60) = 9.85$, $p = 0.005$, $^2p = 0.13$, temporal order memory accuracy was significantly higher in the neutral condition (M_{neutral} = 0.76) than in the negative condition (M_{negative} = 0.67, $p = 0.005$, Cohen's $d = 0.66$). No other comparisons were significant, ps > 0.05.

Figure 5 Temporal order memory accuracy in Experiment 2

3.3 Discussion

Experiment 2 used words as stimuli to compare differences in temporal order memory between negative and neutral emotions in narrative and discrete groups. Results showed an advantage effect for narrative encoding, with the narrative group demonstrating better temporal order memory performance than the discrete group, consistent with Experiment 1. Within Paivio's (1991) theoretical framework for processing differences between visual and linguistic information, mental imagery (generated from pictures) and linguistic symbols (such as words) are processed through different channels in the brain. Although these two types of information can eventually be converted and complemented in cognitive processes, they show clear differences in directness and encoding efficiency at the primary processing level. For instance, visual information requires more levels of processing and transformation when being converted into semantic information for narrative encoding \cite{Zacks2001. Compared to picture materials requiring further processing and transformation, directly obtaining relevant semantic information from word materials involves shorter processing time \cite{Fang2009. Research on memory construction and future imagination also suggests that the directness of linguistic materials in promoting abstract thinking and conceptual integration may make the narrative encoding process more straightforward \cite{Schacter2007.

Temporal order memory performance did not differ significantly between negative and neutral emotional conditions, inconsistent with Experiment 1's results. Previous research has found that emotional effects are weaker for emotional words than for emotional pictures \cite{Hinojosa2009, Rellecke2011, which may explain why no impairing effect of negative emotion was observed in this study. Although both emotional images and emotional words are important components of daily social interaction, they produce different emotional effects \cite{Frühholz2011, Hinojosa2009, Rellecke2011, Wang2019. First, emotional meaning in pictures can be obtained directly through perceptual features, whereas emotion in words requires semantic processing. For example, Frühholz et al. (2011) compared the time course of processing emotional faces and emotional words, finding similar effects in later processing stages but differences in early stages, with emotional faces showing earlier effects than emotional words. Second, numerous studies have found that emotional words typically produce weaker emotional effects than emotional pictures \cite{Hinojosa2009, Rellecke2011.

Significant differences emerged in how emotion affected temporal order memory across encoding types. In the discrete encoding condition, negative emotion significantly impaired temporal order memory performance compared to the neutral condition. However, under narrative encoding, no significant difference existed between negative and neutral emotions' impact on temporal order memory. This finding aligns with Experiment 1's results. Previous research on emotion and memory indicates that although intense emotional experiences can deepen memory impressions, effective memory integration and recall still require appropriate encoding strategies \cite{Zacks2007. By organizing discrete information into logically connected narratives, narrative encoding establishes tighter connections between memory contents, providing a protective mechanism against negative emotional interference. We therefore infer that enhanced inter-item coherence facilitates smoother narrative encoding processes, preventing the negative impact of negative emotion on temporal order memory.

Experiment 3

Experiments 1 and 2 explored the effects of emotion and encoding type on temporal order memory using picture and word stimuli, consistently finding a narrative encoding effect: negative emotion impaired temporal order memory under discrete encoding conditions, while narrative encoding protected inter-item temporal information from negative emotion's impairing effects. Experiment 3 further investigated whether this narrative encoding effect depended on inter-item coherence by manipulating narrative coherence.

Additionally, compared to pictures, word materials allow coherence to be measured using natural language processing methods (such as semantic similarity). In addition to using subjective coherence ratings from pre-test participants, we supplemented the design with natural language processing methods to match coherence levels between materials. This not only increased experimental rigor and objectivity but also provided possibilities for quantitative measurement of material coherence, helping us explore more precisely the important role of coherence degree in temporal order memory.

4.1.1 Participants

Sample size was estimated using G*Power 3.1.9.7 software, setting a medium effect size of f = 0.25 and statistical power of 1-β = 0.90, yielding a planned sample size of 30 participants. This experiment actually recruited 32 university students (mean age = 19.59 years, SD = 2.09; 7 males). All participants had normal or corrected-to-normal vision and no color vision deficiencies. Before the experiment began, the experimenter provided detailed instructions about the experimental content, procedures, and precautions. All participants indicated full understanding and provided written informed consent. Participants received compensation after completing the experiment.

4.1.2 Materials

Word selection involved 352 two-character words from the Chinese Affective Words System (CAWS) [?], including 180 negative words and 172 neutral words. These words were combined to form 45 sets for the negative condition and 43 sets for the neutral condition, with each set containing four words. Ten participants who did not participate in the formal experiment rated the coherence of these 88 word sets on a 1-10 scale (1 = "very incoherent," 10 = "very coherent"). After rating, word sets with mean scores above 8.5 were selected as high-coherence sets, and those below 5 as low-coherence sets. Ultimately, 18 high-coherence and 18 low-coherence word sets were selected for each emotional condition for the formal experiment. Coherence ratings differed significantly between high- and low-coherence conditions, $F(1, 17) = 4311.12$, $p < 0.001$, ^{2}p = 1.00, with high-coherence sets (M_{high} = 9.22) receiving significantly higher ratings than low-coherence sets (M_{low} = 2.98, $p < 0.001$, Cohen's d = 0.70). Coherence ratings did not differ significantly between neutral and negative emotional conditions, F(1, 17) = 0.54, p = 0.474, ^{2}p = 0.03. Detailed information is presented in Table 2 .

Table 2 Coherence ratings and semantic similarity of word sets
| Coherence Rating (M±SD) | Semantic Similarity (M±SD) | |———————————-|——————————————-| | 9.21$±0.41|3.11±0.80||9.23±0.34|0.47±0.07||0.31±0.06|0.37±0.07||2.85±0.84|0.27±$0
|

Semantic similarity was calculated based on word co-occurrence frequencies in natural language texts, extracting weight vectors of co-occurring words to compute semantic distances between words. Specifically, this study utilized the widely used open-source corpus, the Tencent AI Lab Embedding Corpus (https://ai.tencent.com/ailab/nlp/zh/index.html), which provides 200-dimensional vector spaces for over 8 million Chinese words, capturing semantic meanings of Chinese words and phrases. First, word vector coordinates were obtained from the Tencent corpus, then the gensim toolkit in Python was used to calculate semantic distances between word vectors. Cosine similarity was computed for adjacent words in the 72 selected word sets to derive mean semantic similarity for each set. The cosine similarity algorithm measures differences between two vectors based on the cosine of the angle between them in vector space; cosine values approaching 1 indicate greater similarity, while values approaching 0 indicate greater dissimilarity.

A two-way repeated-measures ANOVA on semantic similarity revealed a significant main effect of emotional type, F(1, 17) = 28.05, p < 0.001, ^{2}p = 0.62. Post-hoc tests showed that semantic similarity was significantly higher for negative word sets (M_{negative} = 0.39) than for neutral word sets (M_{neutral} = 0.32, p < 0.001, Cohen's d = 0.73). The main effect of coherence was also significant, F(1, 17) = 83.71, p < 0.001, ^{2}p = 0.83, with high-coherence sets (M_{high} = 0.42) showing significantly higher similarity than low-coherence sets (M_{low} = 0.29, p < 0.001, Cohen's d = 1.83). No other effects were significant, ps > 0.05.

4.1.3 Design

The experiment used a 2 (coherence: high/low) × 2 (emotional type: neutral/negative) within-subjects design, with temporal order memory accuracy as the dependent variable.

4.1.4 Procedure

The procedure was identical to the narrative encoding condition in Experiment 2, with the addition that participants encoded both high- and low-coherence word sets.

4.1.5 Data Analysis

Data from each phase were analyzed using 2 (coherence) × 2 (emotional type) repeated-measures ANOVAs.

4.2.1 Manipulation Check of Emotional Types

Emotional type manipulation effectiveness was assessed through word pleasantness ratings and PANAS results. First, we examined the effects of coherence and emotional type on word pleasantness ratings. Two-way repeated-measures ANOVA of pleasantness ratings (Figure 6 [Figure 6: see original paper]A) revealed a significant main effect of emotional type, $F(1, 29) = 283.60$, $p < 0.001$, $^2p = 0.91$, with neutral words receiving significantly higher ratings than negative words ($p < 0.001$, Cohen's $d = 24.10$). The interaction between coherence and emotional type was significant, $F(1, 29) = 6.33$, $p = 0.018$, $^2p = 0.20$. Simple effects analysis showed that neutral words received significantly higher pleasantness ratings than negative words in both high-coherence ($p < 0.001$, Cohen's $d = 4.32$) and low-coherence conditions ($p < 0.001$, Cohen's $d = 4.06$). No other effects were significant, $ps > 0.05$.

Second, we examined the effects of coherence and emotional type on positive and negative affect increases in PANAS results. For positive affect increase (Figure 6B), the main effect of emotional type was significant, $F(1, 29) = 11.18$, $p = 0.002$, $^2p = 0.28$, with positive affect increase significantly higher in the neutral condition than in the negative condition ($p = 0.002$, Cohen's $d = 3.74$). The main effect of coherence was also significant, $F(1, 29) = 6.69$, $p = 0.015$, $^2p = 0.19$, with positive affect increase significantly higher in the high-coherence condition than in the low-coherence condition ($p = 0.015$, Cohen's $d = 2.43$). No other effects were significant, $ps > 0.05$.

For negative affect increase (Figure 6C), the main effect of emotional type was significant, $F(1, 29) = 15.34$, $p = 0.001$, $^2p = 0.35$, with negative affect increase significantly higher in the negative condition than in the neutral condition ($p = 0.001$, Cohen's $d = 4.01$). The main effect of coherence was also significant, $F(1, 29) = 6.69$, $p = 0.015$, $^2p = 0.19$, with negative affect increase significantly lower in the high-coherence condition than in the low-coherence condition ($p = 0.015$, Cohen's $d = 1.55$). No other effects were significant, $ps > 0.05$. In summary, the emotional type variable was effectively manipulated in this experiment.

Figure 6 Results of emotional type manipulation check in Experiment 3

4.2.2 Encoding Coherence Level

A two-way repeated-measures ANOVA on encoding coherence levels (Figure 7 [Figure 7: see original paper]) revealed a significant main effect of emotional type, $F(1, 29) = 9.39$, $p = 0.005$, $^2p = 0.25$, with neutral word sets (M_{neutral} = 5.74) showing significantly lower coherence than negative word sets (M_{negative} = 6.23, $p = 0.005$, Cohen's $d = 2.54$). The main effect of coherence was significant, $F(1, 29) = 916.83$, $p < 0.001$, $^{2}p = 0.92$, with high-coherence sets ($M_{high} = 8.75$) receiving significantly higher coherence ratings than low-coherence sets ($M_{low} = 3.22$, $p < 0.001$, Cohen's $d = 23.43$). No other effects were significant, ps > 0.05. These results indicate that the coherence variable was effectively manipulated.

Figure 7 Encoding coherence levels in Experiment 3

To examine the consistency between pre-experiment coherence ratings (high/low) and coherence levels during encoding, Experiment 3 used point-biserial correlations to calculate correlation coefficients between pre-ratings and encoding coherence levels for neutral and negative conditions separately. These correlation coefficients were then transformed to z-scores and compared to 0 using one-sample t-tests. Results showed that z-scores were significantly higher than 0 for both neutral ($t(31) = 15.77$, $p < 0.001$, Cohen's $d = 2.79$) and negative conditions ($t(31) = 11.27$, $p < 0.001$, Cohen's $d = 1.99$). These results indicate that although pre-test and Experiment 3 participants were different, pre-experiment material ratings accurately reflected differences in encoding coherence levels during the experiment.

4.2.3 Temporal Order Memory Test

First, we examined the effects of coherence and emotional type on temporal order memory accuracy. For temporal order memory accuracy (Figure 8 [Figure 8: see original paper]A), the main effect of emotional type was significant, $F(1, 29) = 5.36$, $p = 0.028$, $^{2}p = 0.16$, with accuracy significantly higher in the neutral condition ($M_{neutral} = 0.78$) than in the negative condition ($M_{negative} = 0.73$, $p = 0.028$, Cohen's $d = 2.93$). The main effect of coherence was significant, $F(1, 29) = 118.96$, $p < 0.001$, $^{2}p = 0.80$, with accuracy significantly higher in the high-coherence condition ($M_{high} = 0.85$) than in the low-coherence condition ($M_{low} = 0.67$, $p < 0.001$, Cohen's $d = 12.49$). The interaction between emotional type and coherence was significant, $F(1, 29) = 4.93$, $p = 0.034$, $^{2}p = 0.15$. Simple effects analysis revealed that in the low-coherence condition, $F(1, 29) = 9.85$, $p = 0.004$, $^{2}p = 0.25$, temporal order memory accuracy was significantly higher in the neutral condition ($M_{neutral} = 0.70$) than in the negative condition ($M_{negative} = 0.63$, $p = 0.004$, Cohen's $d = 3.80$). In the high-coherence condition, no significant difference emerged between emotional types, ps > 0.05.

To further explore memory gains from coherence across different emotional types, Experiment 3 used relative temporal order memory accuracy—the difference between high- and low-coherence memory performance during narrative encoding (Figure 8B)—as an index. Paired-samples t-tests compared differences between neutral and negative emotional types. Results showed that relative temporal order memory accuracy was significantly higher in the negative condition ($M_{negative} = 0.21$, $SD_{negative} = 0.12$) than in the neutral condition ($M_{neutral} = 0.15$, $SD_{neutral} = 0.12$), $t(29) = 2.22$, $p = 0.034$, Cohen's d = 0.41. This indicates that temporal order memory gains from narrative coherence were greater under negative emotion compared to neutral emotion.

To further investigate whether these memory gains were related to differences in encoding coherence levels, Experiment 3 calculated correlations between high-low coherence differences during encoding and memory gains for each emotional condition. Results showed no significant correlation for neutral stimuli ($r = 0.22$, $p = 0.24$; Figure 9 [Figure 9: see original paper]A), but a significant positive correlation for negative stimuli ($r = 0.38$, $p = 0.039$; Figure 9B), indicating that larger differences in coherence levels during encoding under negative conditions were associated with greater memory gains during testing. Further analysis using the Cocor package in R software revealed no significant difference between these two correlation coefficients, $z = -0.62$, $p = 0.53$, 95% CI [-0.61, 0.32].

Figure 8 Temporal order memory and relative temporal order memory results in Experiment 3

Figure 9 Correlations between encoding coherence differences and memory gains in Experiment 3

4.3 Discussion

In Experiments 1 and 2, we observed that narrative encoding conferred some advantage by providing connections between items, forming a meaningful story framework. Experiment 3 therefore examined whether narrative encoding remained effective when inter-item coherence varied. Results showed that materials with higher coherence produced better temporal order memory than less coherent materials, indicating that temporal order memory is closely related to inter-item coherence. Furthermore, we found that narrative encoding's facilitative effect on temporal order memory significantly depended on material coherence: specifically, under low-coherence conditions, negative emotion still significantly impaired temporal order memory despite narrative encoding; whereas under high-coherence conditions, negative emotion did not significantly affect temporal order memory. Moreover, temporal order memory gains from coherence were greater under negative emotion than under neutral emotion. Previous research has found that higher semantic integration between items leads to better memory performance in recognition tasks \cite{Lu2015, and that retrieval of temporal order information depends on the availability of inter-item associations \cite{DuBrow2013. Although participants were instructed to use narrative encoding for both high- and low-coherence materials, low-coherence materials were difficult to integrate into complete stories, revealing that narrative encoding effects are constrained by material coherence levels.

Under negative emotional conditions, there was a significant positive correlation between coherence differences during encoding and temporal memory gains, whereas no such correlation was found under neutral conditions. Emotional content is believed to enhance related memory encoding and consolidation \cite{Kensinger2003. In this context, negative emotion may increase sensitivity to coherence differences by motivating higher levels of cognitive resource investment in processing negative emotion-related information \cite{Kensinger2009. Therefore, feedback on coherence differences during encoding under negative conditions is more likely to be strengthened and transformed into performance gains during memory retrieval. Correlation analysis showed no significant difference between correlation coefficients for neutral and negative conditions, though future research should examine the direct relationship between coherence encoding strategy changes and memory performance across emotional states using larger samples.

General Discussion

Temporal order information, as a crucial binding element between memory items, is vulnerable to emotional interference. This study investigated whether and how encoding types and coherence degree modulate emotional interference with temporal order memory through three experiments. Experiment 1 found that encoding type modulated the negative impact of emotion on picture temporal order memory: in the discrete encoding group, temporal order memory accuracy under negative emotional conditions was significantly lower than in the other two conditions; conversely, in the narrative encoding group, no significant differences emerged across the three emotional types. Experiment 2 replicated these main findings using word stimuli. Experiment 3 further revealed that narrative encoding's protective effect depended on inter-item coherence strength, manifesting only when items possessed strong coherence.

5.1 Negative Emotion's Impairing Effect on Temporal Order Memory

This study found that negative emotion impairs temporal order memory. Previous research indicates that emotion produces trade-off effects on memory: emotional information (especially negative emotion) can enhance memory for core emotional content while interfering with memory for inter-stimulus associative information and emotional contextual information \cite{Bisby2013, Madan2012, Madan2017. For example, in Kensinger et al. (2007), participants encoded scene pictures composed of either negative or neutral objects, followed by memory tests for objects and scenes. Results showed better recognition memory for negative objects than neutral objects, but worse scene recognition memory for scenes containing negative objects, indicating a memory trade-off between central emotional elements and peripheral non-emotional elements. In this study, temporal order information as a type of associative information was similarly affected by negative emotion, manifested as impaired memory performance. This impairing effect can be explained by attentional narrowing theory: under conditions of limited attentional resources, intense negative emotional items capture attentional narrowing, concentrating individual attentional resources on the negative item's emotional information \cite{Easterbrook1959, Todd2012, resulting in reduced attentional resources for associative information between items (such as sequential information) and consequently interfering with memory for this content \cite{Bisby2013, Bisby2016, Madan2017.

Neurophysiological mechanisms underlying emotion's influence on memory indicate that the amygdala participates in emotion-related memory processes \cite{Phelps2004, while the hippocampus is involved in forming coherent episodic memories, where partial cues can trigger consolidation and recovery of various memory aspects \cite{Bisby2020. Research shows that when negative items are presented, amygdala activity increases while hippocampal activity decreases, accompanied by impaired binding memory between items and context \cite{Bisby2016. The amygdala may thus modulate or directly inhibit hippocampal activity \cite{Dolleman-VanDerWeel1997. When episodic memory is emotion-related, emotion can weaken episodic memory coherence by activating the amygdala, thereby impairing inter-item connections and memory for inter-item relationships \cite{Bisby2017, Brewin2010. Specifically, presenting negative stimuli increases amygdala activation, which inhibits hippocampal activity. Consequently, strong connections cannot be established between negative stimuli in memory, leading to unclear retrieval of adjacent items during testing and resulting in lower temporal order memory accuracy for negative emotional stimuli compared to neutral stimuli.

5.2 Narrative Encoding's Protective Effect

Both Experiment 1 and Experiment 2 found that narrative encoding has certain advantage effects, specifically that narrative encoding can improve temporal order memory performance and protect temporal order memory from negative emotional interference. During memory processes, people segment continuous experiences into meaningful events and use these structures to summarize and organize memory \cite{Franklin2020. During encoding, narrative encoding can promote the formation of meaningful structures, thereby integrating a series of discrete items into a single representation \cite{Palombo2024. Research has found that memory for event narrative order (encoding order) is influenced by event occurrence order, with higher accuracy when encoding order matches event occurrence order \cite{Grall2023, Xu2019. When using narrative encoding, participants connect pictures into a story according to presentation order, making encoding order consistent with story occurrence order, thereby demonstrating narrative encoding advantages. Integrated encoding strategies can similarly protect against negative emotion's negative impact on inter-item associative memory \cite{Han2018, Murray2012. Narrative encoding focuses on organizing information in story form, strengthening memory by connecting information into logical narrative frameworks. Integrated encoding, however, focuses on integrating and abstracting information across different levels, not limited to processing sequential or linear information but attempting to process information from multiple perspectives to form high-level integrated cognition.

Compared to discrete encoding, narrative encoding can mitigate the impairing effect of negative emotion on temporal order memory. A recent study examining the relationship between emotion and temporal memory \cite{McClay2023 required participants to listen to emotional music while viewing sequentially presented pictures and form mental narratives to facilitate temporal information processing. This result aligns with predictions from the object-based framework of emotional memory: if episodic memory is organized into discrete events, information from multiple events interferes with each other when retrieved simultaneously \cite{Brown2005. Conversely, narrative can shape individuals' thinking patterns and promote item integration \cite{Palombo2024. If information from different events can be integrated into a broader unit, this inter-event competition can be resolved \cite{Cohn-Sheehy2022. Milivojevic et al. (2015) used fMRI to analyze hippocampal activity patterns evoked by temporally adjacent events. Results showed that although two events were initially unrelated, when participants followed instructions to use narrative encoding to make events interrelated, hippocampal activity patterns became more similar. This indicates that when events are encoded through narrative, hippocampal activity patterns change to support the formation of tightly connected narrative structures, which benefits recall of temporal order information.

5.3 Narrative Encoding's Protective Effect Depends on Inter-Item Coherence

Narrative encoding provides connections between items, forming a meaningful story. When inter-item coherence is stronger, the narrative encoding process proceeds more easily. Research in text comprehension has found that coherence between textual materials is an important factor affecting readers' understanding \cite{Graesser1994. Coherent text refers to information in adjacent sentences that can be easily integrated (local coherence) and understood according to an overall theme (global coherence). Event segmentation theory posits that event boundaries segment continuous experiences into independent event units \cite{Kurby2008, Pu2022, Wen2022, Zacks2007. Changes in emotional context cause situational changes \cite{Palombo2020, and different emotional states form event boundaries in continuously unfolding experiences, which weaken encoding of temporal order in experiences \cite{Clewett2019, McClay2023. In this study, encoded items were independent objects, each capable of evoking individual emotional responses and forming inter-item boundaries, particularly under negative emotional conditions. However, when individuals encode highly coherent items using narrative methods, items' gist and details remain continuously available in consciousness, promoting item integration \cite{Bellana2022 and stringing discrete items into a whole. Event boundaries become blurred, forming a larger emotional narrative segment that facilitates temporal order memory.

Neurophysiological mechanism research similarly indicates that the hippocampus can integrate discrete events into coherent memories \cite{Bellmund2022. Cohn-Sheehy et al. (2021) used the Sideplot coherence paradigm, presenting participants with fictional stories composed of multiple events, where half formed coherent narratives about one character and half formed incoherent narratives about another character. Results showed better memory for coherent than incoherent narratives. fMRI results indicated that narrative coherence influenced hippocampal memory integration, with higher pattern similarity during encoding of coherent narrative materials compared to unrelated materials. After 24 hours, the hippocampus preferentially supported detailed recall of coherent narratives by reactivating encoding activity patterns \cite{Cohn-Sheehy2021. Wu et al. (2022) found in an EEG study that under coherent story scene conditions, neural activity during encoding and early event offset showed increased representational similarity, a phenomenon absent when scenes lacked coherence. This similarity was significantly correlated with subsequent memory outcomes, indicating that rapid post-event recall of encoded items only occurred under coherent conditions, thereby promoting memory. The prefrontal cortex (particularly the anterior cingulate cortex and dorsolateral prefrontal cortex) plays key roles in emotion regulation, cognitive control, and executive function. These regions are involved in inhibiting interfering information, attentional control, and memory strategy use when processing complex narrative encoding tasks \cite{Eichenbaum2017. Therefore, high-level cognitive control during narrative encoding may involve prefrontal regulatory mechanisms that help the memory system prioritize and integrate narrative-related information when facing emotional interference.

5.4 Limitations and Future Directions

First, this study selected stimuli to form sequences with certain coherence and used subjective ratings to assess material coherence. Future research could further manipulate semantic coherence using natural language processing methods. This study manipulated emotional information to form different emotional types to examine emotion's impact on temporal order memory; future research could further investigate different emotional states such as anxiety, passion, and stress to determine whether they produce different effects on temporal order memory.

Second, this study primarily examined the effects of common positive, neutral, and negative emotions on temporal order memory. Future research could further explore different dimensions of emotion, comprehensively considering arousal and valence, individuals' own depression and anxiety levels, and how emotional dynamic continuity affects temporal information memory. For example, compared to healthy controls, depressed patients often omit temporal descriptions (e.g., "now," "later") in their narratives and tend to recall autobiographical memories in non-linear ways \cite{Habermas2008. Additionally, although this study found that negative emotion impairs temporal order memory, whether specific types of negative emotion (e.g., disgust, fear) have different effects requires further investigation \cite{Lohnas2024.

Finally, this study used a relative recency judgment task to quantify temporal order memory, which may involve both sequential order information and specific temporal information. Recent research has found that temporal order information and temporal moment information are independent \cite{Naim2021.

Future research could consider using more refined paradigms to differentiate dimensions of temporal memory \cite{Coull2022, Palombo2021 to separately examine how emotion affects different aspects of temporal memory.

Conclusion

This study investigated whether and how narrative encoding modulates emotional interference with temporal order memory through three experiments. Results indicate that temporal order information, as a binding element between items, is affected by negative emotion. However, narrative encoding strategies can offset or reduce the impact of negative emotion on temporal order memory through inter-item coherence, providing new perspectives for understanding the complex relationships between emotion, narrative encoding, and temporal order memory.

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Note: Figure translations are in progress. See original paper for figures.