Current Psychology (2024) 43:18242–18252
https://doi.org/10.1007/s12144-024-05657-7

The influence of state anxiety on event construction and elaboration during episodic future thinking

Bin Zhou[1,2] · Yajing Li[1,2] · Zhiguo Hu[1,2]

Accepted: 12 January 2024 / Published online: 22 January 2024

Abstract
Episodic future thinking (EFT) is a fundamental cognitive capacity that enables individuals to mentally simulate and prepare for possible future events. This capacity involves two distinct phases: construction and elaboration. How state anxiety affects the event construction and elaboration in EFT remains unclear. Therefore, the present study aims to address this issue by adopting a verbal cueing paradigm, taking into account familiarity and emotional valence. To induce state anxiety, our study employed a mental arithmetic task coupled with immediate feedback and the investigator's supervision. Cue words were associated with either high-familiar or low-familiar future events, as well as different emotional valences (positive, neutral or negative). In the cueing task, each participant was required to construct a specific episodic event and then elaborate on it based on the provided cues. Subsequently, subjective ratings of the imagined event were collected after each imagination. The results revealed that individuals experiencing state anxiety took longer to elaborate events compared to the control group. Notably, there were asymmetric results in high- and low-familiarity conditions when considering cue words with different emotional valence. Overall, this study suggests that the influence of state anxiety on EFT is constrained to the elaboration phase and does not extend to the construction phase.

Keywords State anxiety · Construction · Elaboration · Episodic future thinking · Familiarity

Introduction

Humans not only remember the past, but also imagine their future. This ability, called episodic future thinking (EFT), enables individuals to mentally project themselves into potential future scenarios (Schacter et al., 2017; Suddendorf & Corballis, 2007), allowing for the simulation and preparation of upcoming events. This has an important adaptive benefit to our mental health (Grysman et al., 2015). In addition, it is even considered to be unique to humans (Raby & Clayton, 2009). Over the past decade, EFT has emerged as a rapidly expanding field of research within psychology and cognitive neuroscience. As a crucial adaptive ability, extensive empirical evidences suggest that EFT is closely associated with other competencies, such as emotion regulation (Hallford & D'Argembeau, 2021; Moscovitch et al., 2018), decision-making (Thorstad & Wolff, 2018), and spatial navigation (Buckner & Carroll, 2007).

Anxiety, a prevalent negative emotion in our society, has been found to have a close relationship with EFT (Parodi et al., 2021; Wang et al., 2021). Individuals experiencing anxiety often exhibit avoidance, protracted hyperarousal, and persistent panic (Tovote et al., 2015). Specifically, anxiety is closely linked to the expectation of future threats, and "future-oriented" cognitive processes are even considered as a key feature of anxiety (Miloyan et al., 2014, 2016). Consequently, numerous studies have explored the impact of anxiety on EFT, highlighting the tendency of overgeneralized future imagination and increased negative expectations of the future (Brunette & Schacter, 2021; Miloyan et al., 2014, 2016; Moustafa et al., 2018).

It is worth noting that previous studies have mainly explored individuals diagnosed with anxiety disorders and have not investigated the influence of state anxiety experienced by ordinary individuals. In a recent study, Hallford and colleagues (Hallford et al., 2019) investigated the effect

✉ Zhiguo Hu
huzg@hznu.edu.cn

1 Center for Cognition and Brain Disorders, Affiliated Hospital of Hangzhou Normal University, Hangzhou 311121, China

2 Zhejiang Key Laboratory for Research in Assessment for Cognitive Impairments, Hangzhou 311121, China

of state anxiety on the specificity of autobiographical memory (AM) and future thoughts. They found significantly decreased AM specificity in the anxiety induction group compared to the control group. However, no significant effect was revealed on future thinking specificity in either group. Contrarily, a substantial body of literature has demonstrated that state anxiety disrupts cognitive processes, including executive functions that are involved in operating the content of EFT (D'Argembeau et al., 2010; Hill & Emery, 2013; Moran, 2016; Shields et al., 2016). Thus, it's rational to expect that increased state anxiety would affect the processing of EFT. The null findings in Hallford et al.'s study may be attributed to the insensitive measurements used. In their study, a word cueing paradigm (i.e., participants were required to verbalize their responses to the cue words) and coding methodology (i.e., the participants' responses were audio recorded and later coded as either specific or non-specific) was adopted.

Furthermore, it is important to notice that EFT can be divided into two distinct stages, *construction* and *elaboration.* During the construction phase, a specific event (i.e., specific people, time, place) is created; while in the elaboration phase, supplementary details are added to enhance the vividness of the event (Addis et al., 2007; Ernst et al., 2015). The two phases have been found to engage different cognitive processes and correspond to different brain mechanisms (Addis et al., 2007; Ernst et al., 2015; Hill & Emery, 2013). However, to the best of our knowledge, no study has yet investigated the influence of state anxiety on the separate two phases (event construction and elaboration) in EFT. Therefore, the present study aims to fill this gap by utilizing more sensitive measures with a behavioral paradigm.

According to *the Constructive Episodic Simulation Hypothesis*, the ability to generate detailed episodes of imagined future events relies on accessing episodic memory (Addis & Schacter, 2008; Schacter et al., 2017). The number of episodic details retrieved during EFT is influenced by the familiarity and emotional valence of the imagined event (Salgado & Berntsen, 2020; Wang et al., 2016). The hypothesis suggests that familiarity has a significant role in the vividness of imagined events (D'Argembeau & Van der Linden, 2012; Wang et al., 2016). Hence, the present study differentiates future events into high- and low-familiarity events. Additionally, future events can be categorized into positive, neutral, or negative valence. Consistent with the optimism bias toward the future in human beings (Salgado & Berntsen, 2020), positive future events are imagined more frequently than negative and neutral, and they are often characterized by greater vividness and specificity. Overall, in this study, we will investigate the effects of state anxiety on EFT, concerning these two important factors: familiarity and emotional valence.

In summary, the present study aims to investigate the influence of state anxiety on the event construction and elaboration phases of episodic future thinking. A verbal cueing paradigm was employed to assess the simulation of future events with cue words manipulated in terms of familiarity (high/low) and emotional valences (positive/neutral/negative). The study measured the processing time for the event construction and elaboration phases during EFT and collected subjective ratings of the imagined events (Duffy & Cole, 2021; Noël et al., 2022). Based on the negative effect of anxiety on EFT and the impairment of executive function during anxiety (Du et al., 2022a; Miloyan et al., 2014, 2016; Salgado & Berntsen, 2020), we posit that the processing time of both event construction and elaboration phases will be longer under the state anxiety condition compared to the control state. Furthermore, the processing time and subjective rating scores in different levels of familiarity and emotional valence will differ between state anxiety and the control state.

Method

Participants

A priori sample size estimate was calculated using G*power 3.1. When using an alpha level of 0.05 and statistical power of 0.80 with a small-to-moderate sized main effect ($f^2 = 0.20$), a total sample size of 28 participants were required. The selection of these parameters was based on a prior study (Hallford et al., 2019), which addressed a similar research question (i.e., the influence of state anxiety on autobiographical memory specificity and future thinking) to the present study. For the present study, fifty adults (40 females, M_{age} = 20.2 years) from Hangzhou Normal University were recruited with monetary compensation. Participants who had no history of psychiatric disorders and did not experience intense events in a month which would substantially affect their mood were included in this study. The participants were randomly assigned into the state-anxiety group (26 participants, including 20 females) and the control group (24 participants, including 20 females). Written informed consent was obtained from each participant following a research protocol approved by the Institutional Review Board of the Affiliated Hospital of Hangzhou Normal University.

Materials

Cue words

The study adopted a verbal cueing paradigm using emotional words (positive, neutral, negative) to induce participants to imagine corresponding episodic events. The selection of these words involved two steps: a prior interview and an evaluation process. In the prior interview, we provided a form to three undergraduate students (who did not participate in the formal experiment) and asked them to write as many two-character words as possible in six categories (i.e., positive high-familiarity, neutral high-familiarity, negative high-familiarity, positive low-familiarity, neutral low-familiarity, negative low-familiarity). Each word could refer to an event that may happen in the future. Here high-familiarity future events refer to those events that occurred frequently in the past and are likely to occur in the future, while low-familiarity future events refer to those events that appeared rarely in the past and are less likely to occur in the future. To assess the emotional valence and familiarity of these words, an additional group of 30 college students (who did not take part in the formal experiment), were recruited to rate the words based on 7-point Likert scales (For emotional valence: 1 = very negative, 7 = very positive; For familiarity: 1 = not familiar at all, 7 = very familiar). Ultimately, thirty words were obtained with each category consisting of five words: positive high-familiarity (e.g., "过节" (guo4jie2, meaning 'celebrating festival')), positive low-familiarity (e.g., "结婚" (jie2hun1, meaning 'getting married'), neutral high-familiarity (e.g., "上课" (shang4ke4, meaning 'attending classes')), neutral low-familiarity (e.g., "种菜" (zong4cai4, meaning 'growing vegetables'),) negative high-familiarity (e.g., "熬夜" (ao2ye4, meaning 'staying up late')), negative low-familiarity (e.g., "酗酒" (xu4jiu3, meaning 'excessive drinking')). As expected, the familiarity score of high-familiarity cue words was significantly higher than that of low-familiarity cues ($F(1,29) = 70.865$, $p < 0.001$, $\eta^2_p = 0.710$). The familiarity score of neutral words was significantly higher ($F(2,58) = 14.917$, $p < 0.001$, $\eta^2_p = 0.550$) than that of the positive and negative words (which didn't show a significant difference from each other). Regarding the emotional valence, the high-familiarity words were more positive than the low-familiarity words ($F(1,29) = 33.773$, $p < 0.001$, $\eta^2_p = 0.538$). The positive/neutral/negative words have significantly different emotional valence from each other ($F(2,58) = 115.635$, $p < 0.001$, $\eta^2_p = 0.799$). See Table 1 for the details.

Table 1 The score of the familiarity and emotional valence of different types of cue words ($M \pm SD$)

	Positive	Neutral	Negative
The score of familiarity			
High-familiarity	5.16 ± 1.44	5.53 ± 1.62	5.02 ± 1.44
Low-familiarity	2.76 ± 0.78	3.19 ± 1.23	2.17 ± 0.95
The score of emotional valence			
High-familiarity	5.84 ± 1.39	3.88 ± 0.89	3.29 ± 0.90
Low-familiarity	5.04 ± 1.23	3.41 ± 0.60	2.60 ± 0.61

Questionnaire

The present study used the Chinese version of State-Trait Anxiety Inventory (STAI) to measure the participants' anxiety (Wang et al., 1999). The STAI consists of two subscales: the State Anxiety Inventory (STAI-S) and the Trait Anxiety Inventory (STAI-T), each comprising 20 items. The STAI-S assesses the intensity of how much anxiety a person feels "right now, at this moment", while the STAI-T measures the frequency of how a person "generally feels" anxious. The total score of each subscale is obtained by summing the scores of each item in the subscale, with a higher score indicating a higher level of anxiety. The STAI scale has been demonstrated to have high reliability and validity in China in previous studies (Du et al., 2022b; Shek, 1993). In this study, the STAI-S was employed to evaluate state anxiety following the state-anxiety induction, while the STAI-T was used to assess the trait anxiety of the participants in the two groups in their daily lives.

Procedure

The experimental procedure consisted of four steps: Step (1) was the administration of the questionnaires; step (2) was the induction of state anxiety or the control manipulation; step (3) was the state-anxiety measurement; and step (4) was the imagination stage. Steps 1 and 3 were completed using pencil and paper, while steps 2 and 4 were conducted using E-prime 2.0 software (Psychology Software Tools, Inc., Pittsburgh, PA, USA).

At the beginning of the experiment, participants completed the STAI-T. Subsequently, participants underwent state anxiety induction. To this end, we adopted a program derived from the Montreal Imaging Stress Task (MIST), which has been proposed to be a tool for investigating the effects of perceiving and processing psychosocial stress (Dedovic et al., 2005). During this step, participants were required to answer a series of mental arithmetic questions (i.e., addition, subtraction, multiplication, and division with two digits). The questions were categorized into five difficulty levels, and each level had 12 questions. From level 1 (e.g., $8 + 9$) to level 5 (e.g., $41 \times 3 + 2$), the questions became more and more challenging (Luo et al., 2018). Participants in the state-anxiety group had a time limit of only three seconds to answer each question, and received feedback after each response (i.e., "right" or "wrong"). Additionally, an experimenter stood behind the participant during the whole task to create environmental pressures. Thus, this task consists of not only a series of mental arithmetic challenges, but also social evaluative threat components in the program or exerted by the investigator. In contrast, the participants in the control group answered the questions without a time limit and received no feedback or supervision from the experimenter. After the induction step, STAI-S was administrated to measure the participants' state anxiety.

Participants then engaged in the future imagination task. In each trial, the participants were initially presented with a cue word and then instructed to engage in episodic future thinking. Specific requirements were emphasized as follows: (1) the imagination must pertain the future, involving a specific time, place, and person; (2) the imagined event could last for a few minutes or hours, but not more than 24 h; (3) the event is likely to happen within five years. If a specific event appeared in their mind, they were instructed to press the spacebar to indicate the beginning of the imagination. Then they were to supplement as many details as they could into the imagined event. If they were not able to add any more details, they should press the spacebar again to indicate the completion of the event imagination. It should be noted that, during the imagination, participants were instructed to think covertly without verbal expression (cf., Ansuini et al., 2016; D'Argembeau & Van der Linden, 2004; D'Argembeau & Mathy, 2011; Vito et al., 2014). In each trial, a given cue word was displayed on the computer screen for no more than one minute. According to previous studies addressing future imagining (e.g., Abram et al., 2014; Kleim et al., 2013; Miloyan & McFarlane, 2019), one minute would allow participants to complete imagining a specific event (including both event construction and elaboration). If the participants complete the event imagination in one minute, the cue will disappear immediately. If the participants did not press the spacebar within one minute, the cue would disappear automatically.

After the imagination phrase, participants completed a subjective rating section. This section consisted of six subjective ratings based on 7-point Likert scales to evaluate the previously imagined future events: (1) The subjective rating of the sensory details of the event (including visual, auditory, and other sensory details) (1 = not at all, 7 = a lot); (2) the subjective rating of the clarity of the location, object, person, and time associated with the event (1 = not at all clear, 7 = extremely clear); (3) the subjective rating of the feeling of pre-experiencing the event (1 = not at all, 7 = totally); (4) the subjective rating of the occurrence likelihood of the event (1 = impossible, 7 = definitely); (5) the subjective rating of the difficulty of imagining the event (1 = very difficult, 7 = very easy); (6) the subjective rating of the affective feeling when imagining the event (1 = very negative, 7 = very positive) (cf., D'Argembeau & Van der Linden, 2012; De Brigard et al., 2013; Madore et al., 2014).

After the evaluation, participants were requested to verbally summarize the imagined event using about 20 words. This was done to confirm if they have imagined as desired, as well as to draw the participants' attention to the current imagination tasks. The completion of the summary signified the conclusion of one trial. A total of 30 trials were included in the experiment, with each trial featuring a randomly selected cue word from a pool of the 30 words. A 5-second interval was inserted between consecutive trials. When participants completed the experiment, they were provided with a period of relaxation (e.g., listening to some relaxing music) to alleviate induced anxiety before leaving the laboratory.

Data analysis

The data obtained from the study were analyzed using SPSS 21 software (IBM Corp., Armonk, NY, USA). The dependent variables in the analysis included questionnaire results, imagination time, and subjective assessment scores. The scores of questionnaires were compared between groups by independent samples t-test, while the imagination time (i.e., event construction and elaboration) and subjective scores were analyzed using a mixed-model ANOVA with factors of group (2 levels: state-anxiety group, control group), familiarity (2 levels: high, low) and emotional valence (3 levels: positive, neutral, negative).

For the construction phase, the time interval was measured from the presentation of the cue to 1000 ms prior to the button press indicating the initiation of the event elaboration. With respect to the elaboration phase, the response time was obtained from 1000 ms before the start of the elaboration phase to the completion of the event imagination. According to the electrophysiological evidences in previous studies (Addis et al., 2007; Addis & Schacter, 2008; Conway et al., 2001), the neural changes associated with the formation of autobiographical memory usually start 800–1000 ms before the manual response, thus we calculated the response time of elaboration phase from 1000 ms before the corresponding button press.

The subjective rating of sensory details for each event was obtained by averaging the scores of the three modalities (visual, auditory, and other sensory details). Similarly, the subjective rating of the clarity for each event was obtained by averaging the scores of the four aspects (location, object, person, and time).

Results

Questionnaire results

In the present study, Cronbach's alpha coefficients for STAI-S and STAI-T were 0.862 and 0.955, respectively. An independent samples t-test was conducted to compare the scores of STAI-T between the state-anxiety group and the control group. The result revealed no significant difference between the two groups (State-anxiety group: 41.38 ± 7.50; Control group, 38.17 ± 7.14; $t(48) = 1.551$, $p = 0.128$). In contrast, a significant difference was observed in the scores of the STAI-S between the two groups (State-anxiety group: 51.04 ± 9.69; Control group: 33.00 ± 8.72; $t(48) = 6.899$, $p < 0.001$, Hedges' $g = 1.922$). The findings indicate that the state anxiety induction procedure in the present study was successful.

Results of imagination time

The average duration of the construction and elaboration phases is presented in Table 2.

A 2 (group: state-anxiety group, control group) × 2 (familiarity: high, low) × 3 (emotional valence: positive, neutral, negative) ANOVA on reaction time during the construction phase revealed a significant main effect of familiarity ($F(1,48) = 14.832$, $p < 0.001$, $\eta^2_p = 0.236$). However, there were no significant main effects of group ($F(1,48) = 0.128$, $p = 0.722$) and emotional valence ($F(2,96) = 0.527$, $p = 0.592$). Furthermore, the interaction between familiarity and emotional valence was significant ($F(2,96) = 15.333$, $p < 0.001$, $\eta^2_p = 0.242$). Simple effect analysis revealed that the high-familiarity negative/neutral words were associated with faster construction of future imagination than the low-familiarity negative/neutral words (ps < 0.05). For positive cues, there was no significant difference in reaction time of constructing a future event between the words with high and low familiarity ($p = 0.623$). Additionally, when cues with high familiarity were presented, the construction time for positive cues was longer compared to negative cues ($p = 0.001$), whereas the construction time for positive cues was shorter compared to negative cues when the cues' familiarity was low ($p = 0.006$). No other significant interaction was found (all ps > 0.05). Please refer to Fig. 1 for a visual representation of these findings.

A similar mixed-designed ANOVA was conducted on the processing time during the elaboration stage. The results showed significant main effects of group ($F(1,48) = 5.919$, $p = 0.019$, $\eta^2_p = 0.110$) and familiarity ($F(1,48) = 7.690$, $p = 0.008$, $\eta^2_p = 0.138$). Specifically, individuals experiencing state anxiety spent more time in the elaboration phase. Furthermore, a significant interaction effect was found between familiarity and emotional valence ($F(2,96) = 5.344$, $p = 0.006$, $\eta^2_p = 0.100$). Simple effect analysis revealed that the high-familiarity negative/neutral words were associated with shorter elaboration time compared to low-familiarity negative/neutral words (ps < 0.01). Meanwhile, for positive cues, there was no significant difference in elaboration time between the words with high and low familiarity ($p = 0.321$). Under both high and low familiarity conditions, there were no significant differences among the three different emotional valences (all ps > 0.05). No other significant main or interaction effects were found (all ps > 0.05). See Fig. 1 for details.

Results of subjective evaluations of the imagined events

The mean rating scores of the different dimensions of the imagined events are presented in Table 3.

For the rating scores of the sensory details, an interaction effect between familiarity and emotional valence was observed ($F(2,96) = 8.204$, $p = 0.001$, $\eta^2_p = 0.146$). The simple effect analysis revealed that imagined events with high-familiarity neutral cues contained more details compared to those with low-familiarity neutral cues ($p = 0.001$). In addition, there were more sensory details associated with neutral cues than negative cues ($p = 0.007$) under the high-familiarity condition. While fewer sensory details were associated with neutral cues than positive cues under the low-familiarity condition ($p = 0.004$). For more information, please refer to Figure S1 and Text S1.

The results of the clarity rating scores of the events showed a similar pattern. An interaction effect between familiarity and emotional valence was found to be significant ($F(2,96) = 14.762$, $p < 0.001$, $\eta^2_p = 0.235$). Further details can be found in Figure S2 and Text S2.

Table 2 The mean reaction time of the construction and elaboration phase under distinct conditions ($M \pm SD$)

		State-anxiety group		Control group	
		Construction	Elaboration	Construction	Elaboration
High-familiarity	positive	10.16 ± 4.99	17.92 ± 11.73	10.32 ± 6.13	10.93 ± 6.90
	neutral	9.70 ± 5.15	16.11 ± 9.31	8.84 ± 5.80	9.91 ± 6.65
	negative	7.89 ± 3.76	16.10 ± 12.23	8.06 ± 3.10	11.09 ± 8.46
Low-familiarity	positive	9.88 ± 5.82	16.55 ± 8.45	9.90 ± 5.98	10.91 ± 6.87
	neutral	10.65 ± 5.52	17.29 ± 10.63	10.98 ± 6.23	12.83 ± 7.91
	negative	11.62 ± 3.10	19.50 ± 12.78	14.71 ± 10.72	13.04 ± 7.03

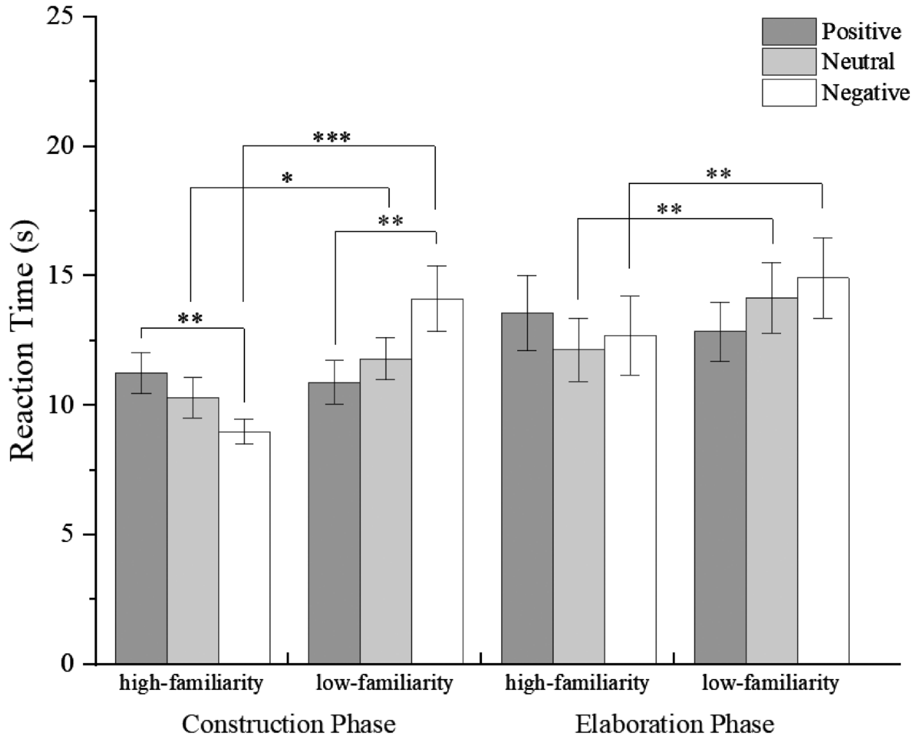

Fig. 1 The reaction time for the construction phase and the elaboration phase during the imagination when given different types of cue words. Error bars show standard errors. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Similarly, the ANOVA analysis for the rating score of the feeling of pre-experiencing the events also revealed a significant interaction between familiarity and emotional valence ($F(2,96) = 18.885$, $p < 0.001$, $\eta^2_p = 0.282$). Simple effect analysis yielded a greater feeling of pre-experience with the high-familiarity compared to the low-familiarity cues in positive, neutral, and negative conditions (ps < 0.001). Under the high-familiarity condition, neutral cues induced a stronger feeling of pre-experience than positive and negative words (ps < 0.005). Conversely, under the low-familiarity condition, the feeling of pre-experience decreased with the decreasing emotional valence (i.e., positive > neutral > negative, ps < 0.01). Additional details can be found in Figure S3 and Text S3.

The likelihood of event occurrence and the difficulty of imagining the events showed similar result patterns as the feeling of pre-experience, see the details in Figure S4/Text S4, and Figure S5/Text S5.

In terms of the affective feeling, the ANOVA analysis revealed significant main effects of familiarity ($F(1,48) = 34.004$, $p < 0.001$, $\eta^2_p = 0.415$) and emotional valence ($F(2,96) = 288.169$, $p < 0.001$, $\eta^2_p = 0.857$). Specifically, events with high-familiarity cues were associated with more positive feeling compared to events with low-familiarity cues. Additionally, the post hoc analysis showed that the affective feelings during the imagination of future events declined with decreasing valence (i.e., positive > neutral > negative, ps < 0.001). No other main or interaction effects were observed (all ps > 0.05). See the details in Figure S6.

Discussion

The objective of this study was to explore the impact of state anxiety on event construction and elaboration during EFT. A verbal cueing paradigm was employed using high- or low-familiar emotional cue words. The results indicated that participants in the state anxiety group tended to spend more time to elaborate the events compared to the control group. However, there was no significant difference in reaction time between the two groups during the construction phase. Interestingly, asymmetric results were observed across different levels of familiarity.

The study revealed significant findings regarding the processing time during the construction phase of EFT, with positive and negative cue words exhibiting a reverse pattern in high-familiarity and low-familiarity conditions. Specifically, in the high-familiarity condition, the construction time was longer for positive cue words compared to negative cue words. In contrast, in the low-familiarity condition, the construction time was shorter for positive cues than that for negative cue words. These results may be explained by the inherent positive bias toward the future in normal individuals (Salgado & Berntsen, 2020). Future-oriented imagery is a prevalent cognitive process in our daily lives, and the content of such future imagination tends to be positive

Table 3 The subjective rating results of the imagined events ($M \pm SD$)

		State-anxiety group						Control group					
		Sensory detail	Clarity	Pre-experience	Likelihood	Affective feeling	Difficulty	Sensory detail	Clarity	Pre-experience	Likelihood	Affective feeling	Difficulty
High-familiarity	positive	3.77±0.73	4.44±1.06	4.61±0.88	5.24±0.64	5.64±0.67	5.24±0.64	3.74±0.93	4.88±1.05	5.12±1.08	5.50±0.83	5.86±0.65	5.34±1.11
	neutral	3.96±0.67	5.06±0.73	5.20±1.00	5.95±0.66	5.17±0.56	5.67±0.73	4.20±1.70	5.20±1.09	5.37±0.93	5.84±0.79	5.16±0.81	5.76±1.07
	negative	3.60±0.81	4.82±0.89	4.86±0.92	4.86±0.81	3.67±0.74	5.38±0.73	3.46±0.97	4.72±1.07	4.84±0.81	4.64±0.69	3.59±0.56	5.23±0.98
Low-familiarity	positive	3.74±0.82	4.09±1.05	4.01±1.05	4.36±8.85	5.32±0.64	4.84±0.92	3.46±0.87	4.32±1.10	4.28±1.04	4.44±0.90	5.60±0.59	5.10±1.22
	neutral	3.47±0.88	3.71±1.19	3.55±1.39	4.12±0.82	4.77±0.57	4.43±0.95	3.44±0.90	3.96±1.06	3.85±1.19	4.03±0.85	4.89±0.77	4.40±1.31
	negative	3.77±1.33	3.80±1.02	3.30±1.30	3.03±1.19	3.23±0.69	4.18±0.89	3.46±0.87	3.75±1.00	3.16±1.15	2.74±1.04	3.21±0.77	3.97±1.26

(Salgado & Berntsen, 2020; Szpunar & Tulving, 2010). When high-familiarity cues are presented, numerous positive events will present in the autobiographical memory system, requiring additional time for the retrieval and selection of an appropriate episodic event in a multi-layer self-memory system, which ranges from abstract information (the top) to specific details (the bottom) (Conway & Pleydell-Pearce, 2000). Consequently, for high-familiarity events, the presence of positive cues resulted in longer construction time compared to negative cues. Conversely, under the low-familiarity condition, where there are fewer options to choose from, and positive information is more accessible, less reaction time is needed for the construction of positive events in comparison to negative events.

In addition, our study also revealed that when the neutral and negative cues were provided, high-familiarity events were constructed more quickly than low-familiarity events. This suggests that the ease of retrieval for high-familiarity events contributes to their faster construction. This finding aligns with the main effect of familiarity for construction time. Furthermore, this result is supported by the main effects of familiarity for several subjective ratings. That is, high-familiarity events were associated with more details, more clarity, a stronger feeling of pre-experience, a higher likelihood of happening in the future, and less difficulty in imagination. Overall, the high-familiarity future neutral/negative events exhibited advantages in terms of imaginability. However, for positive events, no facilitation effect was observed for high-familiarity cues, unlike low-familiarity cues. This may be because it took more time to select from the numerous different familiar positive stimulus presented in the mind. It is worth noting that no group effect on reaction time for event construction was found, contradicting the initial hypothesis. This could be attributed to the fact that the construction phase primarily involves accessing the upper layer of the self-memory system (Conway & Loveday, 2015; Conway & Pleydell-Pearce, 2000), leaving limited room for the influence of state anxiety (Eysenck et al., 2007).

Regarding the elaboration phase, a significant group main effect was observed, indicating that participants with state anxiety exhibited longer reaction time compared to those in the control group. This result was consistent with our hypothesis. In the elaboration phase, participants were instructed to add as many details as possible to the previously constructed event, which involves deeper aspects of memory retrieval in the self-memory system. However, retrieving specific details (i.e., the deeper layer structure) is not always successful and leads to overgeneralization. The CaR-FA-X model, a well-known model on overgeneralization, proposes three processes that influence overgeneralization: capture and rumination (CaR), functional avoidance

(FA), and impaired executive control (X) (Park et al., 2004; Sumner, 2012). It is extensively documented that state anxiety impairs executive function (Moran, 2016; Shields et al., 2016). In the present study, state anxiety may lead to impairment of inhibition, a core executive function. When individuals engage in imagination, they must not only select and reconstruct specific details, but also need to inhibit other irrelevant information. Impairment of inhibition during the elaboration phase may result in deficient elaboration and longer reaction time. Furthermore, according to "Attentional Control Theory", state anxiety diminishes the effectiveness of inhibition, leading to the allocation of attentional resources to irrelevant stimuli and a reduction in attentional resource available for the current task (Eysenck et al., 2007).

In terms of the subjective ratings, we did not find any significant differences between the two groups in various types of evaluations. These findings are consistent with the previous study (Hallford et al., 2019), suggesting that a moderate rise in state anxiety may not affect the amount of episodic information retrieved during EFT. This may be attributed to the retention of metacognitive ability during state anxiety (Spada et al., 2010), which enables individuals to monitor their imaginary situations and guarantee the completion of the imagination process.

Regarding the interaction effect between familiarity and emotional valence in the subjective ratings, we found some interesting patterns. Specifically, under the high-familiarity condition, neutral future events were rated higher in terms of clarity, feeling of pre-experience, likelihood to happen in the future and ease of imagination compared to positive future events. Conversely, under the low-familiarity condition, positive events were rated higher on these dimensions compared to neutral events. These results suggest that the level of familiarity plays a significant role in the processing of EFT (D'Argembeau & Van der Linden, 2004; Hassabis & Maguire, 2007). When imagining high-familiarity events, common neutral memories from daily life may dominate the processing, while during imagining low-familiarity events, the positive information may be more prominent due to the positive future tendency (Hassabis et al., 2007a; Hassabis et al., 2007b; Hassabis & Maguire, 2009). Additionally, in the low-familiarity condition, neutral future events were rated to be associated with a stronger feeling of pre-experience, and higher likelihood of happening in the future and less difficulty to imagine than negative future events. These are consistent with previous studies (D'Argembeau & Van der Linden, 2004; Lench, 2009; Salgado & Berntsen, 2020; Walker et al., 2003) and may be attributed to the avoidance of negative information retrieval in individuals (Kramer & Yoon, 2007).

Based on the information provided, it can be inferred that state anxiety may have a detrimental impact on the elaboration of an imagined event. This finding not only contributes to the existing knowledge gap of the anxiety spectrum, but also offers some theoretical support and practical guidance for psychological counseling. For instance, in the context of Solution Focused Brief Therapy (SFBT), which often involves prompting clients to envision future scenarios (Whitehead et al., 2018; Zatloukal et al., 2020), counselors should be aware that individuals experiencing state anxiety may require additional time to elaborate and enrich their imagined future scenes.

Lastly, we must acknowledge some limitations in this study. First, the number of participants in the two groups is relatively small. Therefore, the generalizability of the present results is limited. Consequently, further investigation with a larger number of participants should be conducted to verify our findings. Second, different induction methods for state anxiety may elicit various levels of state anxiety, and intense anxiety state might exert different effects on EFT. Therefore, future studies should explore whether EFT could be influenced by different levels of state anxiety by using multiple induction methods.

Conclusion

In summary, the present study has revealed that state anxiety can have an impact on the cognitive process of episodic future thinking, especially during the phase of elaboration. Additionally, the factors of emotional valence and familiarity exhibit interactive effects on both the construction and elaboration phases.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s12144-024-05657-7.

Funding The Entrepreneurship and Innovation Project for High-level Overseas Returnees in Hangzhou (to HZ). Dr. Zhiguo Hu Ph.D. 0000-0002-1105-1546. The effect of state anxiety on the process of episodic future imagery [2022HSDYJSKY077] Mr Bin 0009-0002-1751-8888.

Data availability The data that support the findings of this study are available from the corresponding author upon reasonable request. Please see the details at https://www.scidb.cn/anonymous/dVlGZmVt.

Declarations

Ethical approval All procedures performed in the study involving human participants were in accordance with the ethical standards of the institutional research committee at the Affiliated Hospital of Hangzhou Normal University [2023(E2)-KS-085].

Informed consent Informed consent was obtained from all individual participants included in the study.

Conflict of interest The authors declare that they have no conflict of interest.

References

Abram, M., Picard, L., Navarro, B., & Piolino, P. (2014). Mechanisms of remembering the past and imagining the future – new data from autobiographical memory tasks in a lifespan approach. *Consciousness and Cognition*, *29*, 76–89.

Addis, & Schacter, D. L. (2008). Constructive episodic simulation: Temporal distance and detail of past and future events modulate hippocampal engagement. *Hippocampus*, *18*(2), 227–237. https://doi.org/10.1002/hipo.20405.

Addis, D. R., Wong, A. T., & Schacter, D. L. (2007). Remembering the past and imagining the future: Common and distinct neural substrates during event construction and elaboration. *Neuropsychologia*, *45*(7), 1363–1377. https://doi.org/10.1016/j.neuropsychologia.2006.10.016.

Ansuini, C., Cavallo, A., Pia, L., & Becchio, C. (2016). The role of perspective in mental time travel. *Neural Plasticity*, 3052741. https://doi.org/10.1155/2016/3052741.

Brunette, A. M., & Schacter, D. L. (2021). Cognitive mechanisms of episodic simulation in psychiatric populations. *Behavior Research and Therapy*, *136*, 103778. https://doi.org/10.1016/j.brat.2020.103778.

Buckner, R. L., & Carroll, D. C. (2007). Self-projection and the brain. *Trends in Cognitive Sciences*, *11*(2), 49–57. https://doi.org/10.1016/j.tics.2006.11.004PMID – 17188554.

Conway, M. A., & Loveday, C. (2015). Remembering, imagining, false memories & personal meanings. *Consciousness and Cognition*, *33*, 574–581. https://doi.org/10.1016/j.concog.2014.12.002PMID – 25592676.

Conway, M. A., & Pleydell-Pearce, C. W. (2000). The construction of autobiographical memories in the self-memory system. *Psychological Review*, *107*(2), 261–288. https://doi.org/10.1037//0033-295X.

Conway, M. A., Pleydell-Pearce, C. W., & Whitecross, S. E. (2001). The neuroanatomy of autobiographical memory: A slow cortical potential study of autobiographical memory retrieval. *Journal of Memory and Language*, *45*(3), 493–524. https://doi.org/10.1006/jmla.2001.2781.

D'Argembeau, A., & Van der Linden, M. (2012). Predicting the phenomenology of episodic future thoughts. *Consciousness and Cognition*, *21*(3), 1198–1206. https://doi.org/10.1016/j.concog.2012.05.004.

D'Argembeau, A., Ortoleva, C., Jumentier, S., & Van der Linden, M. (2010). Component processes underlying future thinking. *Memory & Cognition*, *38*(6), 809–819. https://doi.org/10.3758/mc.38.6.809.

D'Argembeau, A., & Mathy, A. (2011). Tracking the construction of episodic future thoughts. *Journal of Experimental Psychology: General*, *140*(2), 258–271. https://doi.org/10.1037/a0022581.

D'Argembeau, A., & Van der Linden, M. (2004). Phenomenal characteristics associated with projecting oneself back into the past and forward into the future: Influence of valence and temporal distance. *Consciousness and Cognition*, *13*(4), 844–858. https://doi.org/10.1016/j.concog.2004.07.007.

De Brigard, F., Addis, D. R., Ford, J. H., Schacter, D. L., & Giovanello, K. S. (2013). Remembering what could have happened: Neural correlates of episodic counterfactual thinking. *Neuropsychologia*, *51*(12), 2401–2414. https://doi.org/10.1016/j.neuropsychologia.2013.01.015.

de Vito, S., Neroni, M. A., Gamboz, N., Sala, S. D., & Brandimonte, M. A. (2014). Desirable and undesirable future thoughts call for different scene construction processes. *Quarterly Journal of Experimental Psychology*, *68*(1), 75–82. https://doi.org/10.1080/17470218.2014.937448.

Dedovic, K., Renwick, R., Mahani, N. K., Engert, V., Lupien, S. J., & Pruessner, J. C. (2005). The Montreal imaging stress Task: Using functional imaging to investigate the effects of perceiving and processing psychosocial stress in the human brain. *Journal of Psychiatry and Neuroscience*, *30*(5), 319–325.

Du, J. Y., Hallford, D. J., & Grant, J. B. (2022). Characteristics of episodic future thinking in anxiety: A systematic review and meta-analysis. *Clinical Psychology Review*, *95*, https://doi.org/10.1016/j.cpr.2022.102162.

Du, Q., Liu, H., Yang, C., Chen, X., & Zhang, X. (2022b). The development of a short Chinese version of the state-trait anxiety inventory. *Frontiers in Psychiatry*, *13*, 854547. https://doi.org/10.3389/fpsyt.2022.854547.

Duffy, J., & Cole, S. N. (2021). Functions of spontaneous and voluntary future thinking: Evidence from subjective ratings. *Psychological Research Psychologische Forschung*, *85*(4), 1583–1601. https://doi.org/10.1007/s00426-020-01338-9PMID – 32318803.

Ernst, A., Noblet, V., Gounot, D., Blanc, F., de Seze, J., & Manning, L. (2015). Neural correlates of episodic future thinking impairment in multiple sclerosis patients. *Journal of Clinical and Experimental Neuropsychology*, *37*(10), 1107–1123. https://doi.org/10.1080/13803395.2015.1080228.

Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: Attentional control theory. *Emotion*, *7*(2), 336–353. https://doi.org/10.1037/1528-3542.7.2.336. PMID – 17516812.

Grysman, A., Prabhakar, J., Anglin, S. M., & Hudson, J. A. (2015). Self-enhancement and the life script in future thinking across the lifespan. *Memory (Hove, England)*, *23*(5), 774–785.

Hallford, D. J., & D'Argembeau, A. (2021). Why we imagine our future: Introducing the functions of future thinking scale (FoFTS). *Journal of Psychopathology and Behavioral Assessment*, *44*(2), 376–395. https://doi.org/10.1007/s10862-021-09910-2.

Hallford, D. J., Mellor, D., Bafit, L., Devenish, B., Bogeski, T., Austin, D. W., & Kaplan, R. (2019). The effect of increasing state anxiety on autobiographical memory specificity and future thinking. *Journal of Behavior Therapy and Experimental Psychiatry*, *65*, 101488. https://doi.org/10.1016/j.jbtep.2019.101488.

Hassabis, D., & Maguire, E. A. (2007). Deconstructing episodic memory with construction. *Trends in Cognitive Sciences*, *11*(7), 299–306. https://doi.org/10.1016/j.tics.2007.05.001.

Hassabis, D., & Maguire, E. A. (2009). The construction system of the brain. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1521), 1263–1271. https://doi.org/10.1098/rstb.2008.0296. PMID – 19528007.

Hassabis, D., Kumaran, D., & Maguire, E. A. (2007). Using imagination to understand the neural basis of episodic memory. *The*

Journal of Neuroscience, *27*(52), 14365–14374. https://doi.org/10.1523/jneurosci.4549-072007. PMID – 18160644.
Hassabis, D., Kumaran, D., Vann, S. D., & Maguire, E. A. (2007b). Patients with hippocampal amnesia cannot imagine new experiences. *Proceedings of the National Academy of Sciences, 104*(5), 1726–1731. https://doi.org/10.1073/pnas.0610561104. PMID – 17229836.
Hill, P. F., & Emery, L. J. (2013). Episodic future thought: Contributions from working memory. *Consciousness and Cognition*, *22*(3), 677–683. https://doi.org/10.1016/j.concog.2013.04.002.
Journal of American College Health, *71*(7), 2123–2130. https://doi.org/10.1080/07448481.2021.1960849.
Kleim, B., Graham, B., Fihosy, S., Stott, R., & Ehlers, A. (2013). Reduced specificity in episodic future thinking in posttraumatic stress disorder. *Clinical Psychological Science*, *2*(2), 165–173.
Kramer, T., & Yoon, S. O. (2007). Approach-Avoidance motivation and the Use of Affect as Information. *Journal of Consumer Psychology*, *17*(2), 128–138. https://doi.org/10.1016/s1057-7408(07)70019-0.
Lench, H. C. (2009). Automatic optimism: The affective basis of judgments about the likelihood of future events. *Journal of Experimental Psychology: General*, *138*(2), 187–200. https://doi.org/10.1037/a0015380.
Luo, P., Zhuang, M., Jie, J., Wu, X., & Zheng, X. (2018). State anxiety down-regulates empathic responses: Electrophysiological evidence. *Frontiers in Human Neuroscience*, *12*(502), 1–8. https://doi.org/10.3389/fnhum.2018.00502.
Madore, K. P., Gaesser, B., & Schacter, D. L. (2014). Constructive episodic simulation: Dissociable effects of a specificity induction on remembering, imagining, and describing in young and older adults. *Journal of Experimental Psychology: Learning Memory and Cognition*, *40*(3), 609–622. https://doi.org/10.1037/a0034885. PMID – 24188466.
Miloyan, B., & McFarlane, K. A. (2019). The measurement of episodic foresight: A systematic review of assessment instruments. *Cortex; a Journal Devoted to the Study of the Nervous System and Behavior*, *117*, 351–370. https://doi.org/10.1016/j.cortex.2018.08.018.
Miloyan, B., Pachana, N. A., & Suddendorf, T. (2014). The future is here: A review of foresight systems in anxiety and depression. *Cognition and Emotion*, *28*(5), 795–810. https://doi.org/10.1080/02699931.2013.863179.
Miloyan, B., Bulley, A., & Suddendorf, T. (2016). Episodic foresight and anxiety: Proximate and ultimate perspectives. *British Journal of Clinical Psychology*, *55*(1), 4–22. https://doi.org/10.1111/bjc.12080.
Moran, T. P. (2016). Anxiety and working memory capacity: A meta-analysis and narrative review. *Psychological Bulletin*, *142*(8), 831–864. https://doi.org/10.1037/bul0000051.
Moscovitch, D. A., Vidovic, V., Lenton-Brym, A. P., Dupasquier, J. R., Barber, K. C., Hudd, T., & Romano, M. (2018). Autobiographical memory retrieval and appraisal in social anxiety disorder. *Behavior Research Therapy*, *107*, 106–116. https://doi.org/10.1016/j.brat.2018.06.008.
Moustafa, A. A., Morris, A. N., ElHaj, M., Bø, S., & Wolff, K. (2018). A review on future episodic thinking in mood and anxiety disorders. *Reviews in the Neurosciences*, *30*(1), 85–94. https://doi.org/10.1515/revneuro-2017-0055.
Noël, X., Saeremans, M., Kornreich, C., Chatard, A., Jaafari, N., & D'Argembeau, A. (2022). Reduced calibration between subjective and objective measures of episodic future thinking in alcohol use disorder. *Alcoholism: Clinical and Experimental Research*, *46*(2), 300–311. https://doi.org/10.1111/acer.14763. PMID – 35181906.
Park, R. J., Goodyer, I. M., & Teasdale, J. D. (2004). Effects of induced rumination and distraction on mood and overgeneral autobiographical memory in adolescent major depressive disorder and controls. *Journal of Child Psychology and Psychiatry*, *45*(5), 996–1006. https://doi.org/10.1111/j.1469-7610.2004.t01-1-00291.x. PMID – 15225341.
Parodi, K. B., Holt, M. K., Green, J. G., Porche, M. V., Koenig, B., & Xuan, Z. (2021). Time trends and disparities in anxiety among adolescents, 2012–2018. *Social Psychiatry and Psychiatric Epidemiology57*, 127–137. https://doi.org/10.1007/s00127-021-02122-9.
Raby, C. R., & Clayton, N. S. (2009). Prospective cognition in animals. *Behavior Processes*, *80*(3), 314–324. https://doi.org/10.1016/j.beproc.2008.12.005.
Salgado, S., & Berntsen, D. (2020). My future is brighter than yours: The positivity bias in episodic future thinking and future self-images. *Psychological Research Psychologische Forschung*, *84*(7), 1829–1845. https://doi.org/10.1007/s00426-019-01189-z.
Schacter, D. L., Benoit, R. G., & Szpunar, K. K. (2017). Episodic future thinking: Mechanisms and functions. *Current Opinion Behavioral Sciences*, *17*, 41–50. https://doi.org/10.1016/j.cobeha.2017.06.002.
Shek, D. T. L. (1993). The Chinese version of the state-trait anxiety inventory: Its relationship to different measures of psychological well-being. *Journal of Clinical Psychology*, *49*(3), 349–358. https://doi.org/10.1002/1097-4679.
Shields, G. S., Moons, W. G., Tewell, C. A., & Yonelinas, A. P. (2016). The effect of negative affect on cognition: Anxiety, not anger, impairs executive function. *Emotion*, *16*(6), 792–797. https://doi.org/10.1037/emo0000151.
Spada, M. M., Georgiou, G. A., & Wells, A. (2010). The relationship among metacognitions, attentional control, and state anxiety. *Cognitive Behavior Therapy*, *39*(1), 64–71. https://doi.org/10.1080/16506070902991791.
Suddendorf, T., & Corballis, M. C. (2007). The evolution of foresight: What is mental time travel, and is it unique to humans? *Behavioral and Brain Sciences*, *30*(3), 299–313. https://doi.org/10.1017/S0140525X07001975.
Sumner, J. A. (2012). The mechanisms underlying overgeneral autobiographical memory: An evaluative review of evidence for the CaR-FA-X model. *Clinical Psychology Review*, *32*(1), 34–48. https://doi.org/10.1016/j.cpr.2011.10.003.
Szpunar, K. K., & Tulving, E. (2010). Varieties of future experience. In M. Bar (Ed.), *Predictions in the brain: Using our past to generate a future* (pp. 1198–1212). Oxford University Press.
Thorstad, R., & Wolff, P. (2018). A big data analysis of the relationship between future thinking and decision-making. *Proceeding of the National Academy of Sciences*, *115*(8), E1740–E1748. https://doi.org/10.1073/pnas.1706589115.
Tovote, P., Fadok, J. P., & Lüthi, A. (2015). Erratum: Neuronal circuits for fear and anxiety. *Nature Reviews Neuroscience*, *16*(7), 439–439. https://doi.org/10.1038/nrn3984.
Wang, X. D., Wang, X. L., & Ma, H. (1999). Manual for the mental health rating scale (in Chinese). *Chinese Mental Health Journal*, 240–241.
Wang, T., Yue, T., & Huang, X. T. (2016). Episodic and semantic memory contribute to Familiar and Novel Episodic Future thinking. *Frontier Psychology*, *7*, 1746. https://doi.org/10.3389/fpsyg.2016.01746.
Wang, C., Wen, W., Zhang, H., Ni, J., Jiang, J., Cheng, Y., Zhou, M., Ye, L., Feng, Z., Ge, Z., Luo, H., Wang, M., Zhang, X., & Liu, W. (2021). Anxiety, depression, and stress prevalence among.
Whitehead, L., Allan, M. C., Allen, K., Duchak, V., King, E., Mason, C., Mooney, L., & Tully, S. (2018). 'Give us a break!': Using a solution focused programme to help young people cope with loss and negative change. *Bereavement Care*, *37*(1), 17–27. https://doi.org/10.1080/02682621.2018.1443597.
Zatloukal, L., Žákovský, D., & Tkadlčíková, L. (2020). 'Kids' skills' and 'Mission possible' innovations: Solution-focused brief

therapy models for working with children and adolescents revised and expanded. *Australian and New Zealand Journal of Family Therapy*, *41*(1), 29–41. https://doi.org/10.1002/anzf.1399.