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The influence of induced dysphoria on autobiographical memory specificity and social problem solving: Examining the role of executive function

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ABSTRACT

Negative mood induction leads to reductions in autobiographical memory specificity (AMS) and social problem-solving (SPS). The aim was to establish if executive function contributes to changes in AMS and SPS following negative mood induction. Forty-four participants (study 1) completed the autobiographical memory test and measures of executive function (letter & category fluency) before and after a positive or negative mood induction (MI). Forty participants (study 2) completed the means-end problem solving task (MEPS) and (letter & category) fluency tasks before and after a positive or negative MI. In study 1, participants exhibited impaired AMS and fluency performance following a sad MI. Decrease in memory specificity pre-to post-MI was related to reductions in happy mood and letter fluency. In study 2, participants exhibited poorer performance on the MEPS and fluency tasks following a sad MI. Decreases in the number of relevant solutions generated on the MEPS pre-to post-MI was linked to increases in sad mood and decreases in letter fluency. In both studies, the influence of mood became non-significant once the effect of executive function was accounted for, which suggests that changes in AMS and SPS in response to induced mood were related to concomitant changes in executive function.

1. Introduction

Depression has a major impact on cognitive (LeMoult & Gotlib, 2019) and social functioning (Renner, Cuijpers, & Huibers, 2014). Two cognitive processes that are impaired in depression, and that fulfil important social functions, are autobiographical memory (Barry, Vinograd, et al., 2019) and social problem-solving (Noreen & Dritschel, 2022). Autobiographical memory refers to the recollection of personally experienced events from one's past. This form of memory is central to an individual's sense of self and is vital for goal directed behaviour (Conway & Pleydell-Pearce, 2000). This process has typically been examined using the autobiographical memory test (AMT; Williams & Broadbent, 1986), where participants are presented with cues (usually words) and asked to retrieve specific memories (recollections of highly contextualized events lasting less than a day) in response to each cue. Individuals with clinical and subclinical depression have difficulties retrieving specific memories and instead tend to produce overgeneral memories or memories for repeated events (see Barry, Hallford, & Takano, 2021 for a review), which is predictive of future depressive episodes (Hallford et al., 2021).

Social problem-solving refers to the process of resolving difficulties that are interpersonal (e.g., an argument between friends) or intrapersonal (e.g., worrying about giving a presentation) in nature (Nezu, 2004). A widely used task for assessing this ability is the means end problem-solving task (MEPS; Platt & Spivack, 1975). Participants are presented with a series of scenarios that have an initial state, "you realize that your best friend is not talking to you" and a positive goal state, "you and your friend are back on speaking terms" and are asked to generate means of getting from the initial state to the intended goal. Individuals with clinical and subclinical depression produce both fewer relevant means, steps for solving the problem, and less effective solutions than are generated by healthy participants (Goddard & Dritschel, 1996; Noreen, Whyte, & Dritschel, 2014; Noreen & Dritschel, 2022). Social problem-solving deficits are also a longitudinal risk factor for the development of depressive symptoms (Anderson, Goddard, & Powell, 2011).

There is evidence that these two processes are related; for example, performance on the MEPS has been linked to memory specificity (Beaman, Pushkar, Etezadi, Bye, & Conway, 2007) and the number of general memories on the AMT (Arie, Apter, Orbach, Yefet, & Zalzman,

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2008; Goddard, Dritschel, & Burton, 1996). Memory specificity has also been shown mediate the influence of depression (Raes et al., 2005), anxiety (Hallford, Noory & Mellor, 2018), and disordered eating (Ridout, Matharu, Sanders, & Wallis, 2015) on social problem solving (as measured by the MEPS). Furthermore, there is evidence that increasing memory specificity leads to improved performance on the MEPS (Jing, Madore, & Schacter, 2016). However, a metanalysis of memory specificity training showed negligible effects of improving memory specificity on social problem solving (Barry, Sze, & Raes, 2019). This suggests that other factors might underpin the relationship between memory specificity and SPS.

One such factor is rumination, which is repetitive self-focused thinking about the possible causes and consequences of one's negative mood (Nolen-Hoeksema & Morrow, 1991). Rumination has been identified, in the influential CaR-FA-X model, as one possible cause of reduced memory specificity in individuals with depression (Williams et al., 2007) and has been linked to poor memory specificity in subclinical depression (Romero, Vazquez, & Sanchez, 2014). There is also evidence that rumination influences performance on the MEPS (Lyubomirsky & Nolen-Hoeksema, 1995; Noreen & Dritschel, 2022; Watkins & Baracaia, 2002). However, the results of a metanalysis showed there is negligible evidence to support the association between rumination and memory specificity, which brings into question the importance of this factor (Chiu et al., 2018).

Another influence on both memory specificity and SPS is executive function, which encompasses high level cognitive control processes (inhibition, working memory updating, & set shifting) that are vital for goal directed behaviour (Friedman & Miyake, 2017). Impaired executive function was identified in the CaR-FA-X model (Williams et al., 2007) as another possible causal factor for poor memory specificity in participants with depression. Supporting this proposal, Dalgleish et al. (2007) demonstrated that, independent of depression, memory specificity was linked to performance on measures of executive function, particularly the number of errors. They also showed that manipulations of the AMT, in ways that influenced executive demands, altered the relationships between depression and AMS, which provided further support for the importance of executive function in explaining the link between depression and memory specificity. Dalgleish et al. (2007) proposed several plausible ways in which deficits in executive function might impair performance on the AMT. The first concerns problems inhibiting task irrelevant stimuli, particularly negatively valenced thoughts, which would then deplete cognitive resources that could be utilised to complete the memory search. The second implicates problems maintaining a complete representation of all aspects of the retrieval goal in working memory, and the third refers to a reliance on automatic as opposed to strategic processing. Thus, in the context of the AMT, individuals with depression might prioritise efficiency (retrieving autobiographical material) over more strategic processing goals (retrieving representations of specific events).

Executive function has also been shown to play an important role in social problem solving. For example, performance on the MEPS has been linked to working memory capacity (Ruby, Smallwood, Sackur, & Singer, 2013), verbal fluency (Sheldon, McAndrews, & Moscovitch, 2011; Yamashita, Mizuno, Nemoto, & Kashima, 2005), and inhibitory control (Noreen & Dritschel, 2022). The mechanisms proposed by Dalgleish et al. (2007) to explain the influence of executive function on memory specificity in depression could also apply to social problem-solving. For example, inhibitory processes have been linked to SPS in subclinical depression (Noreen & Dritschel. 2022). Further, as SPS performance has been linked to working memory capacity (Ruby et al., 2013), it is plausible that individuals might not be able to adequately represent the social problem and/or their task (generating means of getting from initial to goal state) in working memory. Finally, a reliance on automatic vs-controlled processing might lead individuals to prioritise generating solutions at the expense of the potential effectiveness of these solutions.

Another influence on both autobiographical memory and social problem solving is state mood. While there is clear evidence that clinical and subclinical depression affect both autobiographical memory and social problem-solving, the influence of state changes in mood on both processes is not clearly established. This is an important avenue of research, as state changes in mood are an everyday phenomenon. The existing evidence has demonstrated that negative mood induction (MI) impairs AMS in comparison to positive or neutral MI (Maccallum, McConkey, Bryant, & Barnier, 2000; Svaldi & Mackinger, 2003; Yeung, Dalgleish, Golden, & Schartau, 2006). However, this finding might be dependent on the method used to alter mood, as McBride and Cappeliez (2004) used the Velten technique and reported no changes in AMS in either negative or elated mood conditions. Notably, only Yeung et al. (2006) controlled for the influence of current and past depression on AMS and was the only investigation to directly measure changes in state mood, and how these mood changes relate to alterations in memory function. Interestingly, Yeung et al. (2006) reported that the decrease in AMS in the negative MI group from pre-to post-MI was related to the reduction in happy mood and not, as might be expected, an increase in sad mood. This highlights the importance of considering the influence of state mood on AMS.

To date, only two studies have directly examined the influence of induced mood on social problem solving in healthy participants. Mitchell and Madigan (1984) reported that participants induced into a negative mood (using the Velten technique) exhibited impaired social problem solving in comparison to the positive and neutral mood groups. On the other hand, Nelson and Sim (2014), reported that participants induced into a positive mood (using the Velten) performed better on the MEPS than did those induced into a neutral (study 1) or negative mood (study 2). In a related study, Yoon and Joormann (2012) reported impaired social problem solving following a negative mood induction. However, this finding was only observed in participants who were encouraged to ruminate and not in those who were asked to use distraction. Dixon-Gordon, Chapman, Lovasz, and Walters (2011) demonstrated that poorer social problem solving was linked to increases in negative affect following a social rejection induction, but this was only found in participants with borderline personality disorder and not healthy controls. Williams, Barnhofer, Crane, and Beck (2005) demonstrated that patients in remission from a major depressive episode showed a reduction in the effectiveness of their generated solutions on MEPS following a negative MI. This shows the importance of controlling for a history of depression, although this finding was limited to participants who also showed suicide ideation. The contradictory nature of these findings, and the limitations of the previous work, suggests there is a need for further research to better understand the influence of state mood on social problem solving. For example, only Dixon-Gordon et al. (2011) and Williams et al. (2005) established the levels of problem-solving performance and mood prior to mood induction, and the former was the only study that established if MEPS performance was related to the changes in the participants' mood. Yoon and Joormann (2012) was the only study to control for baseline depression, but they had no comparison induction procedure (e.g., to enhance positive mood), which was also a limitation of Dixon-Gordon et al. (2011) and Williams et al. (2005).

Given the above, the aim of the current study was to examine if changes in induced sadness and/or happiness influenced AMS and SPS. As naturally occurring depression is associated with both persistent sad mood and loss of positive mood (anhedonia) it is unclear if state changes in sadness or happiness would have the same impact on memory specificity and social problem solving. Therefore, the current work aims to elucidate the role of mood changes on both functions.

An important possibility is that changes in state mood might impact upon other cognitive processes that underpin both autobiographical memory retrieval and social problem-solving, notably executive function. Evidence that state changes in mood influence executive function is somewhat equivocal. Mitchell and Phillips (2007) reported that positive mood induction impaired performance on tasks measuring planning, updating, and switching. On the other hand, they suggested that negative mood induction has limited influence on executive function. Carvalho and Ready (2010) reported that positive affect improved verbal fluency whereas negative affect had no effect on executive function. Nevertheless, there is evidence that negative mood induction impairs working memory capacity (Spies, Hesse, & Hummitzsch, 1996), verbal fluency (Bartolic, Basso, Schefft, Glauser, & Titanic-Schefft, 1999), and inhibition (King, 2020).

The executive functions (i.e., inhibition, updating and shifting) are typically examined using different neuropsychological tests designed to target each distinct process. However, evidence suggests there is some common variance between these tasks, referred to as common executive function (Gustavson et al., 2019). One task thought to measure this common EF is verbal fluency. For example, Gustavson et al. (2019) examined the relationships between letter fluency (generate as many words as possible beginning with a particular letter) and category fluency (generate as many examples as possible of a particular category, e.g., animals) and performance on tasks purported to measure specific executive functions and reported that, in a large sample of adolescents and adults, fluency was correlated with the general EF factor, although there was also some shared variance with updating and shifting. Therefore, these fluency tasks were considered ideal for the purpose of measuring EF in the current investigation because they are quick to administer, have readily available parallel versions for pre- and post-mood induction conditions, and there is evidence linking verbal fluency with memory specificity (Sumner, Griffith, & Mineka, 2011; Valentino, Bridgett, Hayden, & Nuttall, 2012) and social problem solving (Sheldon et al., 2011). Furthermore, there is evidence that state mood influences fluency performance. For example, Bartolic et al. (1999) compared the effects of negative and positive mood induction on verbal and figural fluency and reported that negative MI led to better figural than verbal fluency, whereas positive MI resulted in greater verbal than figural fluency. As they did not measure task performance prior to mood induction, nor establish the link between state changes in mood and fluency performance, it is unclear if positive mood improved verbal fluency or if negative mood impaired it. Ashby, Isen, and Turken (1999) argued that positive mood would improve verbal fluency by increasing cognitive flexibility. However, Phillips, Bull, Adams, and Fraser (2002) demonstrated no difference in verbal fluency between positive and neutral mood induction conditions, which does not support this assertion. As they did not include a negative mood induction group they were not able to determine if negative mood might have led to lower verbal fluency performance compared to positive and neutral (consistent with Bartolic et al., 1999).

The aims of the current study were a) to examine if negative mood induction resulted in lower memory specificity, poorer social problem solving, and reduced verbal fluency in comparison to positive mood induction and b) to determine if changes in memory specificity and social problem solving were linked to changes in mood and/or executive function and c) to determine if the influence of mood on memory specificity and social problem solving could be accounted for by concomitant changes in executive function. Separate studies were conducted to examine the influence of state mood on memory specificity (study 1) and social problem solving (study 2). The decision to run separate studies was taken to try and isolate the effects of mood on the different processes, to deal with the issue of short-lasting changes in mood following mood induction (Kliegel et al., 2005), and to increase the likelihood of reliable results by maintaining participants' engagement with the tasks by keeping the session shorter.

2. Study 1

2.1. Overview and predictions

Healthy participants, with no history of depression, were invited to complete parallel versions of the autobiographical memory test (Williams & Broadbent, 1986) and measures of executive function (letter & category fluency tasks) before and after undergoing a mood induction (to induce either a happy or sad mood). In line with Yeung et al. (2006), it was expected that, after controlling for depression and rumination, participants in the negative MI group would retrieve fewer specific memories post MI than would participants in the positive MI group. Based on Bartolic et al. (1999), it was expected that the sad mood induction group would generate fewer words on the fluency tasks post MI than would the happy MI group. Consistent with Ashby et al. (1999) changes in verbal fluency pre-to post-MI were expected to be linked to changes in positive mood. In line with Yeung et al. (2006), it was expected that the change in memory specificity from pre-to post-MI would also be linked to the change in positive mood. Based on previous work (Sumner et al., 2011; Valentino et al., 2012) it was expected that changes in memory specificity would be linked to changes in fluency performance. If the change in memory specificity in the negative MI group was due to changes in executive function, then in a hierarchical regression, it would be expected that the association between the change in mood and the change in specificity would no longer be significant once the change in executive function was entered into the model. Other variables of interest were retrieval time in seconds, and ratings of memory vividness, and valence. Retrieval time was included to provide further evidence that mood induction changed the ease with which participants were able to retrieve specific memories. Thus, it was expected that retrieval times would be slower for the negative MI group compared to the positive MI group, but only post MI. Vividness was included to provide further evidence that the mood induction procedure altered the experiential quality of the memories retrieved. It was expected that participants in the negative MI group would report less vivid memories than would the positive MI group, but only following the mood induction. Finally, valence ratings were included to examine if the mood induction procedure led to mood congruent retrieval of events post MI. It was expected that participants in the negative MI condition might retrieve more negative memories than the positive MI group, following the mood induction.

3. Method

3.1. Design

Study 1 used a 2 (Mood Induction: Happy vs. Sad) x 2 (Cue Valence: positive vs. negative cue words) x 2 (Time: pre-vs. post-mood induction) mixed-factorial design. The between participants factor was type of mood induction (happy vs. sad) and the within participant variables were Cue Valance (positive vs. negative) and Time (pre-vs. post-mood induction). The main dependent variable was the proportion of specific memories retrieved on the AMT pre- and post-MI. Other variables of interest were self-rated happy and sad mood (measured pre- and post-MI on scales ranging between 0 and 100), the time to retrieve specific memories (in seconds), memory pleasantness and vividness (rated on scales ranging between 1 and 6), and executive function (number of words generated on the letter & category fluency tasks).

3.2. Participants

Based on previous work (Maccallum et al., 2000; Yeung et al., 2006) a large effect size would be expected for the difference in memory specificity between positive and negative mood induction groups. A power calculation using G*Power suggested that a sample size of 44 would be required to detect a significant interaction (large effect size) with a power of .8 and an alpha level of 0.05 A further power calculation using G*Power revealed that to detect medium to large effect size ($f^2 =$ 0.25) on a hierarchical regression with two tested predictors and total of four predictors with a power of .8 and an alpha level of 0.05 would require a sample of 42. Forty-four undergraduate students (36 females, 8 males; mean age = 20.3, standard deviation = 3.6), who self-reported no history of depression, took part in the study in exchange for course credit. Participants were pseudo-randomly assigned to either happy or sad mood induction conditions. Consecutive volunteers were allocated to groups such that odd numbered participants were allocated to happy mood induction and even numbered participants were assigned to the sadness mood condition. The two groups were matched for age, sex, depression, and tendency to ruminate (see Table 1). The study was approved by Aston University's research ethics committee and all participants provided full written informed consent prior to taking part in the study.

3.3. Materials and measures

3.3.1. Beck Depression Inventory, second edition (BDI-II, Beck, Steer, & Brown, 1996)

The BDI-II is a 21-item questionnaire assessing affective, somatic, and cognitive symptoms of depression. Each item consists of four statements and participants are invited to indicate the statement that best describes their mood during the preceding two weeks, including the day of testing. Each statement is scored on a scale from 0 to 3, with '0' allocated to the least depressive statement and '3' to the most depressive statement. Participant's scores are summed, resulting in a range of possible scores from 0 to 63, with higher scores equating to greater depressive symptomology. This is a valid and reliable measure of depressive symptoms (Arnau, Meagher, Norris, and Bramson (2001) reported a Cronbach's alpha of .94) and was used in the current study to screen for the presence of depressive symptoms in the participant sample and to ensure the two mood induction groups were matched on this factor, as depression is associated with deficits in autobiographical memory specificity (Barry et al., 2021; Williams et al., 2007). This factor was entered as a covariate into the analyses of mood, executive function, and autobiographical memory performance to control for the influence of recent depressed mood.

3.3.2. Ruminative response scale (RRS, Nolen-Hoeksema & Morrow, 1991)

The RRS is 22-item questionnaire that assesses the tendency of participants towards ruminative thoughts and actions when they are in a sad or depressed mood. Each item refers to different aspects of ruminative thought and actions and participants are invited to indicate how often this is true of them. Participants respond using a 4-point Likert scale, ranging from 'almost never' to 'almost always', which in turn is scored from '1–4' resulting in a range of possible scores of 22–88 with higher scores indicating a greater tendency towards rumination. This is a valid and reliable measure of rumination (Treynor, Gonzalez, and Nolen-Hoeksema (2003) reported a Cronbach's alpha of .9) and was used in the current study to screen for the tendency to ruminate in the participant sample and to ensure that the two mood induction groups were matched on this factor. Given that rumination is associated with impaired autobiographical memory specificity (Romero et al., 2014), this factor was entered as a covariate in the analysis of mood, executive function, and autobiographical memory performance.

Table 1
Participant characteristics: number of males and females and mean age, RRS and BDI scores by mood induction group (Standard Deviations are presented in parentheses).

	Happy MI (n = 22)	Sad MI (n = 22)	Test-value, p-value	Cohen's d
Sex	19 females, 3 males	17 females, 5 males	χ^2 (1) = .61, p = .70	N/A
Age	20.48 (4.9)	20.19 (1.5)	t (40) = .26, p = .799	.08
RRS	48.27 (12.2)	50.0 (13.0)	t (42) = .46, p = .652	.14
BDI-11 [1]	10.34 (7.3)	10.23 (8.7)	t (42) = .09, p = .926	.03
BDI-II [2]	10.59 (7.4)	10.32 (10.1)	t (42) = .10, p = .919	.03

RRS = ruminative Response Scale, BDI =Beck Depression Inventory, [1] = completed around one week prior to the main experimental session [2] = completed on the day of the experimental session; MI = mood induction.

3.3.3. Visual analogue scales (VAS)

Visual analogue scales were used in the current study to measure levels of happiness and sadness at different points during the study. Each scale consisted of a 100 mm line anchored at one end with 'not at all' and at the other end with 'extremely'. Participants make a mark on each scale that best represents their mood at that moment in time. Scores on each scale range from 0 to 100 with higher scores equating to more intense mood. This is a reliable method of tracking changes in mood over time (Ridout, Noreen, & Johal, 2009) and was used in the current study to track changes in mood across the study.

3.3.4. Autobiographical memory test (AMT; Williams & Broadbent, 1986)

The AMT assesses the ability of participants to access specific autobiographical memories, i.e., recollections of highly contextualized personally experienced events from their past that lasted less than a day. Two sets of cues, one for each autobiographical memory test, were drawn from Brittlebank et al. (1993). Each set consisted of six positive words (e.g., *happy, relieved*) and 6 negative (e.g., *guilty, hopeless*) and were matched for emotionality and word frequency. Word sets used pre- and post-MI were counterbalanced across participants. On each memory test, word cues were presented one at a time in a random order and participants were asked to recall a unique specific memory in response to each cue. A specific memory was defined as 'an event that happened at a particular time and place and that lasted less than a day'. Participants were given an example of a specific memory and then completed two practice trials prior to starting the main set of trials. The time (in seconds) taken to retrieve each memory was recorded. If participants' first response was general or vague, they were prompted with 'can you think of a specific occasion?' and the time was restarted. Participants had a maximum of 30 s in which to retrieve each memory. Following retrieval participants were asked to describe aloud the central details of the memory, which were audio-recorded for later analysis. After retrieving each memory, participants were asked to rate the pleasantness of the memory on a 6-point scale, where '1' indicated 'not at all pleasant' and '6' indicated 'extremely pleasant'. They also rated the vividness of the memory on a separate 6-point scale, with '1' indicating a memory that was 'not at all vivid' and '6' indicating an 'extremely vivid' memory. Memories were scored according to their specificity. Memories that referred to an event that happened at a particular time and place, and that lasted less than a day (e.g., I enjoyed Jane's party last weekend) were coded as specific. Memories that described a repeated event (e.g., I enjoy going to clubs), or an event that lasted longer than a day (e.g. I enjoyed my holiday in Portugal last year) were coded as general memories. Failures to produce a memory within 30 s were coded as omissions. All memories were scored by researcher CY, who was blind to condition, and the memories (n = 72) of six participants (14% of the sample) were scored by a second researcher (NR) who was also blind to the participants' condition. The two raters showed very high interrater agreement $\kappa = 0.88$. The time in seconds to retrieve a specific memory, the proportion of specific memories as a first response, and mean ratings of vividness and memory pleasantness were the dependent variables of interest. The proportion of specific memories was calculated for each condition (positive and negative cues, pre- and post-mood induction) by dividing the number of specific memories retrieved by the number of trials in each condition (i.e., six).[1] Only retrieval times for specific

[1] Note: the number of trials in each condition was not adjusted for omissions - as failure to retrieve any memory is a failure to retrieve a specific memory.

memories were included in the analysis.

3.3.5. Letter fluency task (LFT)

The LFT is a validated measure of verbal ability and executive control processes (Strauss, Sherman, & Spreen, 2006). Importantly, in the context of this study, it has been linked to autobiographical memory specificity (Sumner et al., 2011), as well as induced positive and negative mood (Bartolic et al., 1999). The LFT requires participants to retrieve as many words beginning with a given letter as they can within 60 s. However, there are several constraints on allowable words, such that proper nouns, numbers, or profanities are prohibited. Further, participants are not permitted to use same word with different suffixes (e.g., 'eat', 'eaten' and 'eating'). Parallel versions of this task were completed before and after mood induction. The letters 'F' and 'A' were used (in line with Sumner et al., 2011) and the order that the two versions were completed was counterbalanced. The total number of allowable words, excluding any repetitions, within the time limit is the dependent variable of the LFT.

3.3.6. Category fluency task (CFT)

The CFT also measures verbal ability and executive function (Strauss et al., 2006). Notably, as with the LFT, there is evidence that performance on the CFT predicts autobiographical memory specificity (Valentino et al., 2012). Participants completed two versions of the CFT, before and after the mood induction phase. On each task participants were given a category and invited to name as many different examples of that category as they can within 60 s. The categories 'animals' and 'vegetables' were used in the current study counterbalanced across pre- and post-mood induction tasks. These categories have been used in previous autobiographical memory studies (Valentino et al., 2012). The total number of allowable category exemplars within the time limit is the dependent variable in the CFT.

3.3.7. Mood induction procedure

In line with Ridout et al. (2009), the current study used autobiographical memory focus augmented with mood congruent music to induced happy and sad moods. Prior to attending the experimental session, participants were asked to think of a time from their past when they were very sad and an occasion when they were very happy. During the mood induction phase, participants were asked to focus on their happy or sad memory and to try and reinstate the feeling they had at the time of the event. During the mood induction phase, which lasted 3 min, participants were played mood congruent music to reinforce the mood induction procedure. In line with Yeung et al. (2006), the "Mazurka" from the ballet "Coppelia'' by Delibes was used to aid the induction of a happy mood and "Russia under the Mongolian Yoke" by Prokofiev was used to aid the induction of a sad mood. This procedure has been shown to produce reliable changes in self-rated happiness and sadness, as well as subsequent changes in cognitive function (Ridout et al., 2009).

3.4. Procedure

A week prior to the main experimental session participants were sent the BDI-II and RRS to complete and return. They were also asked to think of two memories, one featuring a sad event from their life and one featuring a happy event. The main session took place in a private room in the psychology labs. At the beginning of this session, participants completed the BDI-II and rated their current mood using the visual analogue scales before completing the first autobiographical memory test and the two fluency tasks. They were then allocated to either the positive or negative mood induction groups. Following the mood induction phase, participants rated their mood again using the VAS, before completing the parallel versions of the AMT and fluency tasks. The participants in the negative mood induction group then underwent a positive mood induction. All participants completed a final VAS mood scale.

3.5. Data analysis

Data were analysed using Jamovi (version 2.3.21). Initial inspection suggested the data were not normally distributed. However, as there was no problem with homogeneity of variance, parametric tests were still used (Schimder, Ziegler, Danay, Beyer, & Bühner, 2010). Mean sadness and happiness ratings were analysed using 2 (Mood Induction Group; happiness vs. sadness) x 2 (Time; pre-vs. post-mood induction) mixed factorial ANCOVA with depression and rumination scores entered as covariates. Mean retrieval times for specific memories (in seconds), the proportion of specific memories, the mean vividness ratings, and the mean pleasantness ratings were analysed using separate 2 (Mood Induction Group; happiness vs. sadness) x 2 (Time; pre-vs. post-mood induction) x 2 (Cue Valence; positive vs. negative) mixed factorial ANCOVA, with depression and rumination scores entered as covariates. Relationships between variables were assessed using Pearson tests.[2] Separate hierarchical regressions were conducted to predict variations in the indices of autobiographical memory function (specificity, retrieval time, and memory vividness). In each regression, depression and rumination scores were entered at Step 1, change in mood entered at step 2 and change in executive function was added at the final step.

4. Results

4.1. Participant characteristics

Inspection of the data in Table 1 reveals that the two mood induction groups did not differ on sex, age, tendency to ruminate or levels of depression. The two depression measures revealed good test-retest reliability, r (44).73, $p < .001$ and the scores at the two time points did not differ significantly, t (43) = 0.12, p = .904. Taken together these results suggest stable levels of dysphoria in the participant sample.

4.2. VAS mood ratings over the course of the study

Analysis of the sadness ratings revealed a significant MI Group × Time interaction (see Fig. 1, panel A); F (1, 38) = 44.05, $p < .001$, $\eta_p^2 =$ 0.54. Pairwise comparisons using Bonferroni corrected t-tests revealed that the baseline sadness ratings of the positive MI group (M = 18.45, SD = 18.1) and negative MI group (M = 22.45, SD = 21.5) did not differ significantly; t (38) = 0.93, p = .518, Cohen's d = 0.21. However, the negative MI group reported significantly higher post mood induction sadness (M = 52.5, SD = 22.8) than did the positive MI group (M = 15.86, SD = 15.4); t (38) = 7.03, $p < .001$, Cohen's d = 1.88. Furthermore, participants in the negative MI group reported significantly higher sadness post-MI than pre-MI; t (38) = 8.66. $P < .001$ (adjusted alpha = .025), Cohen's d = −1.44.

Analysis of the happiness ratings revealed a significant MI Group × Time interaction (see Fig. 1, panel B); F (1, 38) = 43.46, $p < .001$, $\eta_p^2 =$ 0.53. Pairwise comparisons using Bonferroni corrected t-tests revealed that baseline happiness did not differ between the positive MI group (M = 66.6, SD = 10) and negative MI group (M = 64.4, SD = 21.1); t (38) = 0.37, p = .982, Cohen's d = 0.12. However, the negative MI group reported significantly lower happiness post-MI (M = 41.23, SD = 20.1) than the positive MI group (M = 75.4, SD = 15.2); t (38) = 7.15, $p <$ .001, Cohen's d = 1.93. Furthermore, the negative MI group reported significantly lower happiness post-MI than pre-MI; t (38) = 6.8, $p < .001$ (adjusted alpha = .025), Cohen's d = 1.1.

[2] Findings were confirmed using Spearman tests. However, as outcome of both sets of analyses were the same the results of the parametric tests are reported.

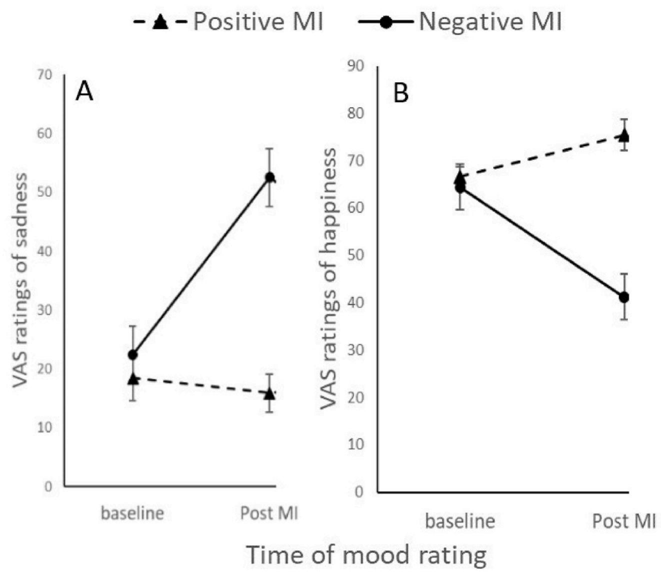

Fig. 1. Mean sadness [A] and happiness [B] ratings as a function of MI group and time of rating.

4.3. Autobiographical memory retrieval

Analysis of the proportion of specific memories (see Table 2) revealed a significant MI Group × Time interaction (see Fig. 2); $F (1, 40) = 22.75$, $p < .001$, $\eta_p^2 = 0.36$. Pairwise comparisons using Bonferroni corrected t-tests revealed that the baseline specificity of the positive MI group (M = 0.87, SD = 0.10) and negative MI group (M = 0.89, SD = 0.08) did not differ significantly, $t (40) = 0.77$, $p = .813$, Cohen's $d = 0.22$. However, the negative MI group retrieved significantly fewer specific memories post-MI (M = .72, SD = 0.13) than did the positive MI group (M = 0.89, SD = 0.10); $t (40) = 5.12$, $p < .001$, Cohen's $d = 1.47$. Whilst the proportion of specific memories retrieved by the positive MI group pre- and post-MI did not differ significantly, $t (21) = 0.78$, $p = .444$, Cohen's $d = 0.17$, the negative MI group retrieved significantly fewer specific memories post-MI than at baseline; $t (21) = 6.02$, $p < .001$ (adjusted alpha = .025), Cohen's $d = 1.28$.

Analysis of the retrieval times for specific memories (see Table 2) revealed a significant MI Group × Time interaction (see Fig. 3); $F (1, 40) = 5.35$, $p = .026$, $\eta_p^2 = 0.12$. Pairwise comparisons using Bonferroni corrected t-tests revealed that baseline retrieval times of the positive MI group (M = 8.53, SD = 3.2) and negative MI group (M = 7.73, SD = 3.7) did not differ significantly, $t (38) = 0.77$, $p = .867$, Cohen's $d = 0.23$. The retrieval times of the negative MI group post MI were slower (M = 10.93, SD = 2.67) than the positive MI group (M = 9.11, SD = 3.16), but this difference was not significant; $t (40) = 2.4$, $p = .087$, Cohen's $d = 0.56$. Whilst retrieval times for the positive MI group pre- and post-MI did not differ significantly, $t (21) = 1.28$, $p = .214$, Cohen's $d = -0.27$, post MI retrieval times of the negative MI group were significantly slower than pre-MI, $t (21) = 3.19$, $p = .004$ (adjusted alpha = .025), Cohen's $d = -0.68$.

Analysis of the pleasantness ratings (see Table 3) revealed a significant main effect of cue valence, such that participants, regardless of MI Group or Time, rated memories retrieved in response to negative cues as significantly less pleasant (mean = 1.89, SD = 0.4) than memories retrieved to positive cues (M = 4.98, SD = 0.6); $F (1, 40) = 75.75$, $p < .001$; $\eta_p^2 = 0.65$. There were no other significant main effects or interactions, all tests $F < 1$.

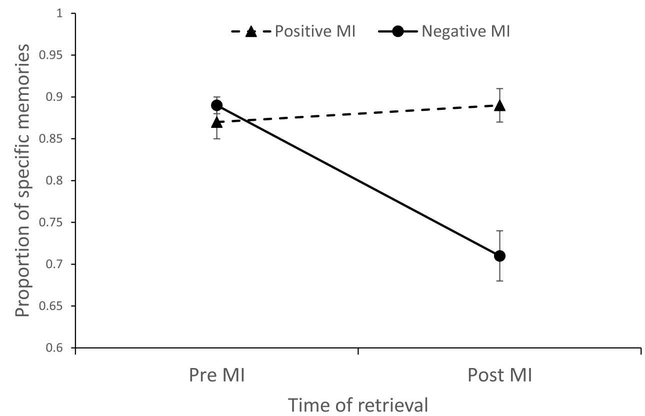

Fig. 2. Mean retrieval time (in seconds) as a function of mood induction group and time of retrieval (error bars show ± 1 standard error of the mean).

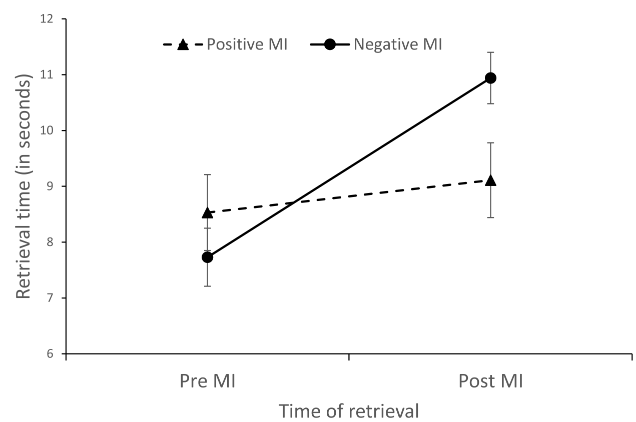

Fig. 3. Mean proportion of specific memories retrieved as a function of mood induction group and time of retrieval (error bars show ± 1 standard error of the mean).

Table 2
Mean retrieval times (in seconds) and proportion of specific memories retrieved by the participants in the two groups pre and post mood induction (Standard deviations are presented in parentheses).

		Positive MI		Negative MI	
		Pre MI	Post MI	Pre MI	Post MI
Positive Cues	**RT**	6.90 (3.8)	7.21 (3.5)	7.02 (3.6)	9.03 (3.2)
	Specificity	.84 (.16)	.92 (.11)	.91 (.10)	.77 (.17)
Negative Cues	**RT**	8.30 (2.9)	9.20 (3.7)	7.74 (4.1)	9.01 (3.6)
	Specificity	.89 (.13)	.86 (.12)	.88 (.13)	.67 (.18)

RT = retrieval time, MI = mood induction.

Table 3
Mean pleasantness and vividness ratings for the memories retrieved by the participants in the two groups pre and post mood induction (Standard deviations are presented in parentheses).

		Positive MI		Negative MI	
		Pre MI	Post MI	Pre MI	Post MI
Positive Cues	**Pleasantness**	4.99 (0.5)	5.1 (0.6)	5.04 (0.7)	4.87 (0.6)
	Vividness	4.63 (0.6)	4.46 (1.2)	4.80 (0.8)	4.32 (0.9)
Negative Cues	**Pleasantness**	1.89 (0.6)	1.83 (0.5)	1.93 (0.6)	1.90 (0.5)
	Vividness	4.17 (1.1)	4.26 (0.8)	4.38 (1.0)	3.24 (0.7)

MI = mood induction.

Analysis of vividness ratings (see Table 3) revealed a significant MI Group x Time x Cue Valence interaction; F (1, 40) = 4.13, p = .049; η_p^2 = 0.09. Pre-MI, the vividness ratings of the two groups did not differ for memories retrieved in response to positive or negative cues; t (42) = 0.79, p = .435 and t (42) = 0.69, p = .496, Cohen's d = −0.24 and −0.21. Post-MI the vividness ratings for memories retrieved to positive cues did not differ between groups; t (42) = 0.46, p = .650, Cohen's d = 0.14. However, participants in the negative MI group rated memories retrieved to negative cues as less vivid than did the positive MI group; t (42) = 4.46, p < .001, Cohen's d = 1.35. Participants in the positive MI group rated memories retrieved in response to positive cues pre-MI as more vivid than memories retrieved to negative cues, t (21) = 2.42, p = .025 (adjusted alpha = .025), Cohen's d = 0.52. The vividness ratings of the participants in the negative MI condition did not differ for the memories retrieved pre-MI in response to positive and negative cues; t (21) = 1.95, p = .064, Cohen's d = 0.42. However, post MI they rated memories retrieved to positive cues as more vivid (M = 4.27, SE = 0.20) than memories retrieved to negative cues (M = 3.3, SE = 0.16); t (21) = 4.85, p < .001 (adjusted alpha = .025), Cohen's d = 1.03. They also rated memories retrieved in response to positive cues post MI as less vivid than memories retrieved to positive cues pre-MI, but this was not significant; t (21) = 2.22, p < .038 (adjusted alpha = .025), Cohen's d = 0.47 and memories retrieved to negative cues post-MI as less vivid than memories retrieved to negative cues post-MI; t (21) = 5.13, p < .001 (adjusted alpha = .025), Cohen's d = 1.09. Interestingly, vividness ratings for memories retrieved to negative cues post MI were positively related to proportion of specific negative memories; r (44) = 0.47, p < .001.

4.4. Performance on the fluency tasks

Analysis of the performance on the letter fluency task revealed that the MI Group × Time interaction was not-significant (see Fig. 4, panel A); F (1, 40) = 3.75, p = .058, η_p^2 = 0.09. However, as we had a priori predictions concerning differences in the performance of the two MI groups pre- and post-MI, we conducted pairwise comparisons. The performance of the positive MI group (M = 12.54, SD = 3.7) and negative MI group (M = 12.27, SD = 3.3) did not differ at baseline; t (42) = 0.31, p = .762, Cohen's d = 0.09. However, the negative MI group generated significantly fewer words post MI (M = 11, SD = 2.9) than did the positive MI group (M = 14.1, SD = 5.2), t (38) = 2.44, p = .019, Cohen's d = 0.74. Whilst the number of words generated pre and post MI by the positive MI group did not differ significantly, t (21) = 1.3, p = .019, Cohen's d = −0.28, the negative MI group generated fewer words post-MI than pre-MI, but this difference was not significant; t (21) = 1.53, p = .071 (one-tailed), Cohen's d = 0.33.

Analysis of the performance on the category fluency task revealed some evidence of a MI Group × Time interaction (see Fig. 4, Panel B), but this was not statistically significant; F (1, 40) = 3.53, p = .067, η_p^2 = 0.08. However, as we had a priori predictions about group differences in category fluency pre- and post-MI we conducted post hoc tests to investigate this interaction. The number of words generated on the category fluency task by the positive MI group (M = 17.32, SD = 5.2) and negative MI group (M = 16.18, SD = 5.3) did not differ pre-MI, t (42) = 0.68, p = .478, Cohen's d = 0.22. However, the negative MI group generated significantly fewer words (M = 12.82, SD = 4.8) post MI than did the positive MI group (M = 17.55, SD = 4.3), t (42) = 3.42, p = .001, Cohen's d = 1.04. The number of words generated pre and post MI by the positive MI group did not differ significantly; t (21) = 0.22, p = .588, Cohen's d = −0.05. On the other hand, the negative MI group generated fewer words on the category fluency task post-MI than pre-MI, but this was not significant once alpha was adjusted for multiple comparisons; t (21) = 2.1, p = .047 (adjusted alpha = .025), Cohen's d = 0.45.

4.5. Relationships between changes in mood, executive function, and autobiographical memory

To determine if the change in memory performance (specificity, and vividness) from pre-to post-MI was related to change in mood and/or change in executive function, we calculated difference scores (post-MI scores minus pre-MI scores), with negative scores equating to a reduction in mood, specificity, vividness, retrieval times, and executive function. Partial correlations, controlling for rumination and depression, revealed that the change in specificity was positively related to the changes in happy mood; r (44) = 0.34, p = .031, letter fluency; r (44) = 0.38, p = .012, and vividness; r (44) = 0.57, <0.001, and negatively related to change in negative mood, r (44) = -0.32, p = .038. Change in vividness was also positively related to changes in happy mood; r (44) = 0.36, p = .021, letter fluency; r (44) = 0.39, p = .012, and category fluency; r (44) = 0.31, p = .049. Changes in RT was positively related to change in sad mood; r (44) = 0.45, p = .003 and negatively related to change in category fluency, but this was not significant; r (44) = -0.29, p = .061. Change in letter fluency was positively related to change in happiness but this relationship was not significant; r (44) = 0.24, p = .059. On the other hand, change in category fluency was negatively related to change in sad mood, but this relationship was not significant; r (44) = -0.25, p = .058. Change in letter fluency was not related to change in sad mood; r (44) = -0.17, p = .293 and change in category fluency was not related to change in happy mood; r (44) = 0.11, p = .510.

A hierarchical linear regression (see Table 4) was conducted to

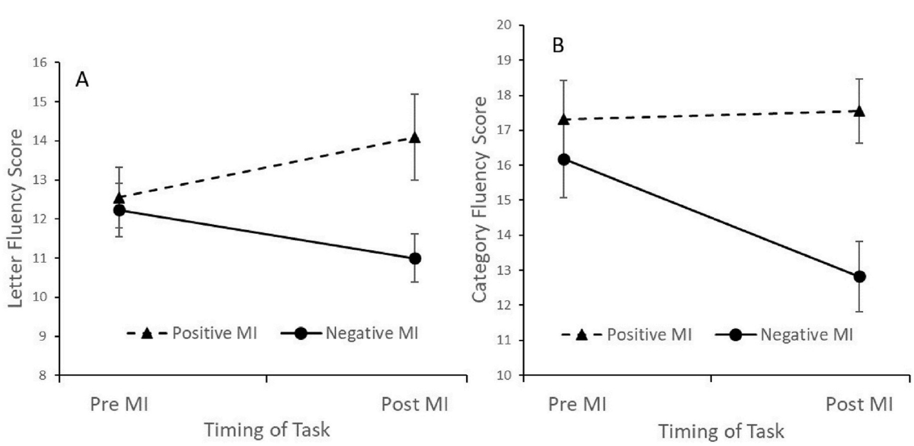

Fig. 4. Mean number of words generated on the letter [A] and category [B] fluency tasks as a function of MI group and timing of the task (error bars show ± 1 standard error of the mean).

Table 4
Hierarchical regression to predict change in memory specificity with change in happiness and change in letter fluency as predictor variables (controlling rumination and depression).

DV = Δ specificity		Model Summary				Contribution of each factor at Step 3				
		R^2	$R^2\Delta$	F	p	B	SE	b	t	p
Step 1		.05	–	1.1	.355					
	RRS					−.00	.00	−.13	−.87	.386
	BDI					−.00	.00	−.12	−.80	.428
Step 2		.16	.11	5.0	**.031**					
	Δ happiness					.00	.00	.25	1.74	.090
Step 3	Δ fluency	.25	.09	4.7	**.036**	.01	.00	.31	2.18	**.036**

RRS = ruminative response scale, BDI=Beck Depression Inventory, Δ specificity = change in memory specificity, Δ happiness = change in happiness ratings, Δ fluency = change in letter fluency.

predict change in specificity with depression and rumination entered at the first step, change in positive mood entered at the second step and Δ letter fluency entered at the final step. Results revealed that depression and rumination together explained 5% of the variance in the change in specificity $R^2 = 0.05$, but this model was not significant; F (2, 41) = 1.1, p = .355 and neither factor entered as a significant predictor, depression p = .479 and rumination p = .308. Change in happiness explained an additional 11% of the variance, which was significant; $\Delta R^2 = 0.11$; F (1, 40) = 5.03, p = .031. Change in positive mood entered as the only significant predictor, β = 0.33 (SE = 0.001), p = .031. The addition of change in letter fluency at the final step explained an additional 9% of the variance in the change in memory specificity, which was significant; $\Delta R^2 = 0.09$; F (1, 39) = 4.74, p = .036. Change in letter fluency entered as a significant predictor; β = 0.31 (SE = 0.004), p = .036. However, change in happy mood no longer entered as a significant predictor; β = 0.25 (SE = 0.001), p = .090.

A further hierarchical regression (see Table 5) was conducted to predict change in memory vividness with depression and rumination entered at step 1, change in happy mood entered at step 2, and change in letter fluency entered at the final step. Depression and rumination combined explained less than 1% of the variance in the change in memory vividness; $R^2 = 0.01$; F (2, 41) = 0.16, p = .852 and neither factor entered as a significant predictor, depression p = .583 and rumination p = .976. The addition of change in happy mood at step 2 explained an additional 13% of the variance in change in memory vividness, $\Delta R^2 = 0.13$, which was significant; F (1, 40) = 5.79, p = .021. Change in happy mood entered as a significant predictor; β = 0.36 (SE = 0.01), p = .021. The addition of change in letter fluency at the final step explained an additional 9% of the variance in change in memory vividness, which was significant; $\Delta R^2 = 0.09$; F (1, 39) = 4.76, p = .035. Change in letter fluency entered as a significant predictor; β = 0.32 (SE = 0.02), p = .035. However, change in happy mood no longer entered as a significant predictor; β = 0.28 (SE = 0.01), p = .064.

5. Discussion

The aims of study 1 were a) to examine if negative mood induction resulted in lower memory specificity and reduced executive function in comparison to positive mood induction and b) to determine if changes in memory specificity were linked to changes in mood and/or executive function and c) to determine if the influence of mood on memory specificity was accounted for by concomitant changes in executive function.

As predicted, participants in the sad MI group retrieved fewer specific memories post-MI than did participants in the happy MI group. They also showed a reduction in the proportion of specific memories retrieved from pre-to post-MI. These findings are consistent with previous research (Maccallum et al., 2000; Svaldi & Mackinger, 2003; Yeung et al., 2006). Change in memory specificity (pre-to post-MI) was related to the change in happy mood, in line with Yeung et al. (2006). We also found a significant relationship between the change in sad mood and change in specificity. These findings confirm that memory specificity can be influenced by transitory changes in state mood. However, it should be noted that, in line with Yeung et al. (2006), memory specificity was not related to baseline depression (self-reported via the Beck Depression Inventory).

As expected, retrieval times for the sad MI group were slower post-MI than pre-MI and were slower than those of the happy MI group, but only post MI. Taken together these findings are consistent with the notion that participants in the sad MI group found it harder to generate specific memories post MI. Interestingly, this slowing was not influenced by the valence of the cue. Importantly, the change in RT from pre-to post-MI was related to change in sad mood, such that increases in sad mood were related to slower RTs.

As predicted, the sad MI group reported less vivid memories post MI compared to pre-MI. However, this finding was only evident for negative memories. This plausibly reflects a reduction of specificity of the negative memories in the sad MI group. Consistent with this notion, post MI specificity and vividness for negative cues were positively related. Furthermore, the change in vividness from pre-to post-MI was linked to the change in happy mood, as was the change in memory specificity. These findings support the functional avoidance explanation of impaired memory specificity in psychopathology from the influential CaR-FA-X model (Williams et al., 2007). Functional avoidance refers to the

Table 5
Hierarchical regression to predict change in memory vividness with change in happiness and change in letter fluency as predictor variables (controlling rumination and depression).

DV = Δ vividness		Model Summary				Contribution of each factor at Step 3				
		R^2	$R^2\Delta$	F	p	B	SE	b	t	p
Step 1		.01	–	0.2	.852					
	RRS					.00	.01	.03	.22	.827
	BDI					.01	.01	.09	.80	.555
Step 2		.13	.12	5.8	**.021**					
	Δ happiness					.01	.01	.28	1.9	.064
Step 3	Δ fluency	.23	.09	4.7	**.036**	.05	.02	.32	2.18	**.035**

RRS = ruminative response scale, BDI=Beck Depression Inventory, Δ vividness = change in memory vividness, Δ happiness = change in happiness ratings, Δ fluency = change in letter fluency.

strategic avoidance of specific negative memories by individuals in a depressed mood in an attempt at mood regulation.

As the sadness induction involved thinking in detail about a previous negative event, it might have led to a ruminative cycle. Therefore, rumination is another plausible explanation for the changes in memory specificity, retrieval times, and vividness observed in the sad MI group. The capture and rumination element of the CaR-FA-X model (Williams et al., 2007) suggests that ruminative self-focused thinking depletes cognitive capacity that can be utilised to conduct the autobiographical memory search. However, trait rumination in the current study was not related to autobiographical memory specificity, vividness, or retrieval times, which does not support this proposal, but is consistent with a metanalysis showing that rumination has a negligible effect on memory specificity (Chiu et al., 2018). Furthermore, Park, Goodyer, and Teasdale (2004) reported that induced rumination only reduced memory specificity in patients with major depression and not healthy participants, such as the current sample. Taken together, this suggests rumination is not a good candidate process to explain the current findings.

As expected, the negative MI group produced fewer words on the fluency tasks (post MI) than did the positive MI group. They also showed a reduction in the number of words generated on the fluency tasks pre-to post-MI. This was significant for category fluency but a non-significant trend for letter fluency ($p = .06$). These findings are consistent with Bartolic et al. (1999) who reported lower verbal fluency following negative than positive mood induction. The finding that the change in letter fluency was related to the change in happy mood is consistent with Carvalho and Ready (2010). Positive mood might improve fluency performance by increasing cognitive flexibility (Ashby et al., 1999) and/or by enhancing motivation to continue with the task, due to greater expectancy of success (Erez and Isen (2002). Thus, as the negative MI in the current study reduced happy mood, it may also have decreased cognitive flexibility and/or motivation, resulting in fewer words on the letter fluency. The current finding that the change in category fluency was linked to the change in sad mood is consistent with the resource allocation model (Ellis & Ashbrook, 1988), which proposes that sad mood acts as a cognitive load that depletes cognitive resources that can be applied to perform the task in hand (i.e., category fluency). The findings of lower fluency performance in the negative MI group contradict the claim of Mitchell and Phillips (2007) that negative mood induction has a negligible influence on executive function but are consistent with other studies reporting lower executive function following a negative MI (King, 2020; Spies et al., 1996). Discrepancies in findings across studies might relate to the variations in mood induction techniques. For example, Spies et al. (1996) used the Velten technique and reported impaired executive function in negative mood condition, whereas Phillips et al. (2002), who used film clips and music, found no executive deficits in the negative MI group. The use of autobiographical memory focus in the current study is notable, as internally generated emotions in response to autobiographical memory recall are more intense than emotional responses to film clips (Salas, Radovic, & Turnbull, 2012). Thus, more intense changes in state affect may have occurred in the current study compared to some previous mood induction studies, which might account for differences in findings.

An important novel aspect of current work was to examine the possible influence of concomitant changes in executive function in accounting for reduced memory specificity in response to a negative mood induction. Notably, decreases in both memory specificity and letter fluency were linked to reductions in happy mood from pre-to post-MI. The change in letter fluency predicted the change in memory specificity, which is consistent with evidence that executive function plays an important role in reduced memory specificity in clinical and subclinical depression (Dalgleish et al., 2007; Williams et al., 2007). Importantly, the change in positive mood was no longer significantly related to the change in memory specificity once the change in letter fluency entered the regression model, which suggests that positive mood was influencing memory specificity indirectly via concomitant changes in executive function.

In sum, following a sad mood induction participants exhibited reduced autobiographical memory specificity (and vividness) and slower retrieval times on the AMT. They also produced lower scores on the measures of executive function (verbal fluency). Changes in memory specificity pre-to post-MI were predicted by changes in positive mood and executive function (letter fluency). Importantly, once the influence of the change in executive function was accounted for, the relationship between mood and memory specificity became non-significant. The implications of these findings are that transitory variations in mood, in addition to clinical and subclinical depression, impact upon memory specificity and executive function. In line with the CaR-FA-X model, executive function appears to underpin poor memory specificity in induced negative mood, as well as enduring depressed mood.

As noted previously, there are established links between autobiographical memory and social problem solving (Arie et al., 2008; Beaman et al., 2007; Goddard et al., 1996), suggesting there might be common cognitive processes involved in both functions. Given the findings of study 1 and the evidence that social problem solving (SPS), as measured by the means-end problem solving task (MEPS), has been linked to verbal fluency (Sheldon et al., 2011; Yamashita et al., 2005) and transitory changes in mood (Mitchell & Madigan, 1984; Nelson & Sim, 2014). An important question that remains is whether mood related changes in SPS would be linked to associated changes in verbal fluency. Therefore, the aim of Study 2 was to generate further evidence of the influence of changes in state mood on social problem solving and executive function, and further, to establish if the influence of mood on social problem solving was related to concomitant changes in executive function (as measured by fluency tasks).

6. Study 2

6.1. Overview and predictions

Healthy, never-depressed, participants completed parallel versions of the means end problem solving task (MEPS) and measures of executive function (letter & category fluency tasks) before and after undergoing a mood induction procedure to induce either a happy or sad mood. Based on Mitchell and Madigan (1984), it was expected that individuals in the sad mood induction group would generate fewer relevant means on the MEPS post MI than would the happy MI group. It was also expected that the solutions generated by the negative MI group post MI would be rated as less effective than would those generated by the positive MI group. The number of means generated by the negative MI group, and the rated effectiveness of these solutions, was expected to be lower post MI compared to pre-MI. In Study 1, the change in memory specificity from pre-to post-MI and in Yeung et al. (2006) was linked to reductions in positive mood. Therefore, given the established links between memory specificity and social problem solving (Beaman et al., 2007), it was expected that SPS performance would also be linked to reductions in positive mood. In line with Study 1, it was expected that participants in the negative MI group would generate fewer words on the fluency tasks post MI than would the positive MI group. Consistent with the findings of Study 1, it was expected that changes in SPS performance would be linked to changes in state mood. Based on Sheldon et al. (2011), it was expected that performance on the MEPS would be linked to changes in executive function (verbal fluency). Finally, assuming decreases in SPS were due to concomitant reductions in executive function, it was expected that, in a hierarchical regression, the association between change in mood and change in SPS performance would no longer be significant once change in executive function was entered into the model.

7. Method

7.1. Design

Study 2 incorporated a 2 (Mood Induction: Happy vs. Sad) x 2 (Time: pre-vs. post-mood induction) mixed-factorial design. The between participants factor was the Mood Induction Group (happy vs. sad mood) and the within participant variables was Time (pre-vs. post-mood induction). The dependent variables were the number of relevant means and the effectiveness (ratings out of 7) of the solutions generated on the MEPS. Other variables of interest were self-rated mood and executive function (performance on letter and category fluency tasks).

7.2. Participants

Forty never-depressed undergraduate students (32 females) took part in exchange for course credit. Twenty participants (16 female) were pseudo-randomly allocated to each mood induction group. The participants were aged between 18 and 23 years. The two groups were matched for age range, sex, depression, anxiety, and tendency to ruminate (see Table 6). Based on Mitchell and Madigan (1984) a large effect size (f = 0.5) was expected for the difference in the number of means between the positive and negative mood induction conditions. A power calculation using G*Power indicated that to detect a large effect (f = 0.5) on a mixed ANOVA with a power of .80 and an alpha level of 0.05 would require a sample of 36 participants. A further power calculation also using G*Power revealed that to detect medium to large effect size ($f^2 = 0.25$) on a hierarchical regression with two tested predictors and total of five predictors with a power of .8 and an alpha level of 0.05 would require a sample of 42. In line with Study 1, consecutive volunteers were allocated to groups whereby even numbered participants were allocated to happy mood induction and odd numbered participants were assigned to the sadness mood condition. The study was approved by Aston University's Research Ethics Committee and all participants provided full written informed consent prior to taking part in the study.

7.3. Measures

7.3.1. Hospital anxiety and depression scale (HADS; Zigmond & Snaith, 1983)

The HADS was used to ensure the two mood induction groups were matched for depression and anxiety. The HADS is a 14-item self-report questionnaire, which features seven items relating to depression and seven items relating to anxiety. Each item is scored from 0 to 3, giving a range of possible scores of 0–21 on each subscale, where higher scores indicate more severe depression or anxiety. This measure has shown to be reliable, with both scales showing an average Cronbach's alpha of .82 and valid, with average correlation coefficients between other depression and anxiety questionnaires being 0.63 for anxiety and 0.65 for depression (Bjelland, Dahl, Haug, & Neckelmann, 2002). The responses on the measure in the current study were reliable for both anxiety (Cronbach's alpha = .79) and depression (Cronbach's alpha = .84).

Table 6
Participant characteristics: number of males and females plus mean depression, anxiety, and rumination scores by mood induction group (Standard Deviations are presented in parentheses).

	Happy MI (n = 20)	Sad MI (n = 20)	t-value, p-value	Cohen's d
Sex	16 females, 4 males	16 females, 4 males		
HADS-A	6.85 (2.9)	7.80 (4.6)	t (38) = .82, p = .416	.26
HADS-D	3.50 (3.0)	4.10 (4.0)	t (38) = .79, p = .433	.25
RRS-B	10.75 (3.1)	9.30 (3.5)	t (38) = 1.38, p = .176	.44
RRS-R	11.65 (3.1)	10.90 (2.8)	t (38) = .83, p = .412	.26

MI = mood induction; HADS = hospital anxiety and depression scale; A = anxiety subscale; D = depression subscale; RRS = ruminative response scale; B = brooding subscale; R = reflection subscale.

7.3.2. Ruminative response scales – short form (RRS; Treynor et al., 2003)

The short form of the RRS was included to ensure the two groups did not differ in their tendency to ruminate in response to a sad mood and to determine if changes in SPS following mood induction were related to participants tendency to ruminate. The RRS is a 10-item self – report questionnaire, with five items related to brooding, and five related to reflection. Each item is scored on a 4-point Likert Scale, ranging 1 ("almost never") to 4 ("almost always"), thus the scores on each subscale range between 5 and 20, with high scores equating to greater brooding and reflection. This measure has shown good reliability (Cronbach's alphas for reflection = 0.72 and for brooding = 0.77) and validity (correlation with full version of the RRS = 0.9). The responses on the measure in the current study were reliable (Cronbach's alpha = .77).

7.3.3. The means – end problem solving task (MEPS; Platt & Spivack, 1975)

A modified version of the MEPS was used to test the participants' ability to generate potential solutions for a series of social problem-solving scenarios. Participants were presented with a printed sheet featuring an initial state (e.g., *"you realize that your best friend is not talking to you"*) and a goal state (e.g., *"your friend is talking to you again"*) and were asked to generate possible steps they could take to get from the initial situation to the goal state. Their responses were audio-recorded to allow them to be scored. The number of generated relevant means (steps) was taken as one measure of successful social problem-solving. In addition, the solutions generated were rated for effectiveness on a 7-point scale, where 1 = totally ineffective and 7 = extremely effective. The eight scenarios used in the current study were selected from the 12 used in the original MEPS (Platt & Spivack, 1975) and adapted to ensure their relevance to the student population. These scenarios were randomly assigned to two blocks of four problems and the order in which participants completed the blocks was counterbalanced. The MEPS has good internal consistency (0.80–0.84) and has good internal validity (Platt & Spivack, 1975). One researcher (MM) scored and rated all responses on the MEPS, and a subsample of problem solutions (n = 48) from six participants (15% of the sample) were scored and rated by the first author (NR), who was blind to the condition of the participants. Interclass correlations were conducted to establish the degree of inter-rater reliability, which revealed good agreement for both number of means (0.75) and rated effectiveness (0.83).

7.3.4. Visual analogue scales (VAS)

As in Study 1, 100 mm visual analogue scales were used to measure self-rated happiness and sadness at various points across the course of the study.

7.3.5. Verbal fluency tasks

As in Study 1, the same parallel versions of the letter and category fluency tasks were used as a measure of executive function.

7.3.6. Mood induction procedure

In line with Study 1, autobiographical memory focus augmented with mood congruent music was used to induce either happy or sad mood. In line with Study 1, prelude et Mazurka de "Coppelia" (Leo Delibes) was used to reinforce the happy mood induction, whereas the music to reinforce sad induction was changed from "Russia under the Mongolian yoke" by Prokofiev to Samuel Barber's Adagio for Strings, which has previously been used successfully to support the induction of sad mood (Morrison & O'Connor, 2008).

7.4. Procedure

After providing informed consent, participants completed the HADS and RRS and then indicated their baseline mood using the VAS. Next, they completed the first block of MEPS trials and fluency tasks, before undergoing the mood induction procedure. Participants were asked to focus on their happy or sad memory (depending on condition) whilst listening to mood congruent music. The mood induction phase lasted 3 min. Participants then rated their mood for a second time using VAS, before completing parallel versions of the MEPS and fluency tasks. They were then asked to complete a third set of VAS before leaving the laboratory. Prior to completing this VAS, individuals in the negative mood induction group underwent a positive mood induction.

7.5. Data analysis

Data were analysed using Jamovi (version 2.3.21). Initial inspection suggested the data were not normally distributed. However, there was no problem with homogeneity of variance, thus parametric tests were still used (Schimder et al., 2010). The number and effectiveness of generated means on the MEPS, the happiness and sadness ratings (VAS), and the number of words generated on the category and letter fluency tasks were analysed using separate 2 (Mood Induction Group; happy vs. sad) x 2 (time; pre-vs. post-mood induction) mixed factorial ANCOVA, with depression, anxiety and rumination entered as covariates. The relationships between mood, executive function, and social problem solving were examined using Pearson tests,[3] partialling out the influence of depression, anxiety, and rumination. Hierarchical linear regression was used to examine if changes in mood and/or executive function predicted changes in social problem solving whilst controlling for the influence of depression, anxiety, and rumination.

8. Results

8.1. Participant characteristics

Inspection of Table 6 reveals that the two groups did not differ significantly in terms of their levels of depression, anxiety, or rumination (brooding and reflection).

8.2. VAS ratings of mood across the study

Analysis of sadness ratings revealed a significant MI Group × Time interaction (see Fig. 5, Panel A); F (1, 35) = 22.8, p < .001, $\eta_p^2 = 0.40$. Subsequent pairwise comparisons, using Bonferroni corrected t-tests, revealed that pre-MI sadness ratings did not differ between the negative MI group (M = 17.6, SE = 4.4) and positive MI group (M = 19.3, SE = 4.4); t (35) = 0.43, p = .973, Cohen's d = 0.09. However, the negative MI group reported significantly higher sadness ratings post MI (M = 52.2, SE = 4.4) than did the positive MI group (M = 12.9, SE = 4.4); t (35) = 6.2, p < .001, Cohen's d = 2.07. The baseline and post MI sadness ratings of the participants in the positive MI group did not differ significantly; t (19) = 1.39, p = .179 (adjusted alpha = .025), Cohen's d = 0.31, whereas participants in the negative MI group reported significantly higher sadness ratings post MI than at baseline; t (19) = 5.40, p < .001 (adjusted alpha = .025), Cohen's d = 1.21.

Analysis of the happiness ratings revealed a significant MI Group × Time interaction (Fig. 5, Panel B); F (1, 35) = 25.8, p < .001, $\eta_p^2 = 0.42$. Subsequent pairwise comparisons using Bonferroni corrected t-tests revealed that pre-MI happiness ratings of the positive (M = 54.8, SE = 4.8) and negative (M = 63.3, SE = 4.5) mood induction groups did not differ, t (35) = 1.28, p = .580, Cohen's d = 0.23. However, the negative MI group reported significantly lower happiness ratings (M = 39.3, SE = 4.7) post mood induction than did the positive MI group (M = 70.3, SE = 4.5); t (35) = 4.93, p < .001, Cohen's d = 1.55. Furthermore, participants in the negative MI group reported significantly lower happiness post MI relative to baseline; t (19) = 5.18, p < .001 (adjusted alpha = .025), Cohen's d = 1.16, whereas participants in the positive MI group reported higher happiness post MI than at baseline, but this difference was not significant; t (19) = 2.19, p = .041 (adjusted alpha = .025), Cohen's d = 0.49.

8.3. Social problem-solving performance (MEPS)

Analysis of the number of means generated on the means end problem-solving (MEPS) task revealed a significant MI Group × Time interaction (see Fig. 6); F (1, 35) = 31.49, p < .001, $\eta_p^2 = 0.47$. Subsequent pairwise comparison, using Bonferroni corrected t-tests, revealed that the performance of the negative MI group (M = 8.2, SE = 0.56) and positive MI group (M = 6.3, SE = 0.56) did not differ at baseline; t (35) = 2.4, p = .076, Cohen's d = 0.79. However, participants in the negative MI group generated fewer relevant means post MI (M = 5.2, SE = 0.56) than did the positive MI group (M = 7.38, SE = 0.56); t (35) = 2.81, p = .040, Cohen's d = 0.89. The number of means generated by the positive MI group pre- and post-MI did not differ significantly; t (19) = 1.8, p = .091 (adjusted alpha = .025), Cohen's d = 0.09, whereas participants in the negative MI group generated fewer means post MI than at baseline; t (19) = 7.66, p < .001 (adjusted alpha = .025), Cohen's d = 1.71.

Analysis of the rated effectiveness of the means generated on the MEPs revealed a significant MI Group × Time interaction (see Fig. 7); F (1, 35) = 12.86, p < .001, $\eta_p^2 = 0.27$. Subsequent pairwise comparisons, using Bonferroni corrected t-tests, revealed that the effectiveness of the means generated by the negative MI group (M = 17.1, SE = 0.81) and positive MI group (M = 15.7, SE = 0.81) pre-MI did not differ significantly; t (35) = 1.17, p = .593, Cohen's d = 0.29. However, participants in the negative MI group generated less effective solutions post MI (M = 12.9, SE = 0.65) than did the participants in the positive MI group (M = 16, SE = 0.65); t (35) = 3.31, p < .014, Cohen's d = 1.03. The effectiveness of the solutions generated by the positive MI group pre- and post-MI did not differ significantly; t (19) = 1.1, p = .960, (adjusted alpha = .025), Cohen's d = 0.01, whereas participants in the negative MI group generated less effective solutions post MI than pre-MI; t (19) = 6.62, p < .001 (adjusted alpha = .025), Cohen's d = 1.48.

The number of means generated on the MEPS and the rated effectiveness of these means were positively correlated; pre MI, r (40) = 0.55, p < .001 and post-MI, r (40) = 0.58, p < .001. Also, the change in MEPS from pre-to post-MI was positively related to change in effectiveness; r (40) = 0.60, p < .001.

8.4. Executive function (fluency task performance)

Analysis of the number of words generated on the letter fluency task revealed a significant MI Group × Time interaction (see Fig. 8, Panel A); F (1, 35) = 9.75, p = .004, $\eta_p^2 = 0.22$. Subsequent Bonferroni corrected t-tests revealed that the performance of the negative mood induction group (M = 11.2, SE = 1.2) and positive MI group (M = 10.1, SE = 1.2) did not differ significantly pre-MI; t (35) = 0.67, p = .852, Cohen's d = 0.31. However, the negative MI group generated significantly fewer words post MI (M = 8.02, SE = 1.0) than did the positive MI group (M = 12, SE = 1.0); t (35) = 2.78, p = .042, Cohen's d = 1.01. The number of words generated by the positive MI group did not differ significantly pre- and post-MI; t (19) = 2.03, p = .056 (alpha adjusted = .025), Cohen's d = 0.46, whereas the negative MI group generated significantly fewer words post MI than pre-MI; t (19) = 3.01, p = .007 (alpha adjusted = .025), Cohen's d = 0.67.

Analysis of the number of words generated by the two groups on the category fluency task revealed a significant MI Group × Time interaction (See Fig. 8, Panel B); F (1, 35) = 11.09, p = .002, $\eta_p^2 = 0.24$. Subsequent

[3] Results were confirmed with non-parametric tests, but as the findings were identical we report the results of the parametric analyses.

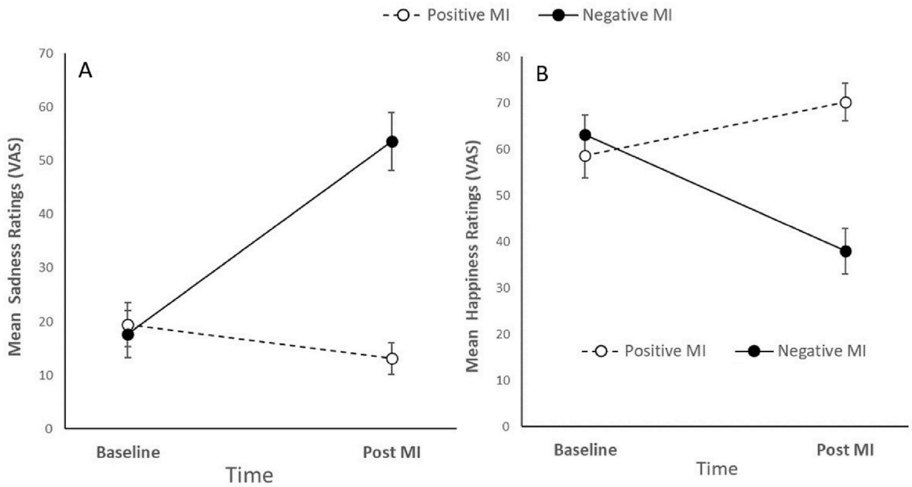

Fig. 5. Mean sadness [A] and happiness [B] as a function of mood induction group pre- and post the MI procedure.

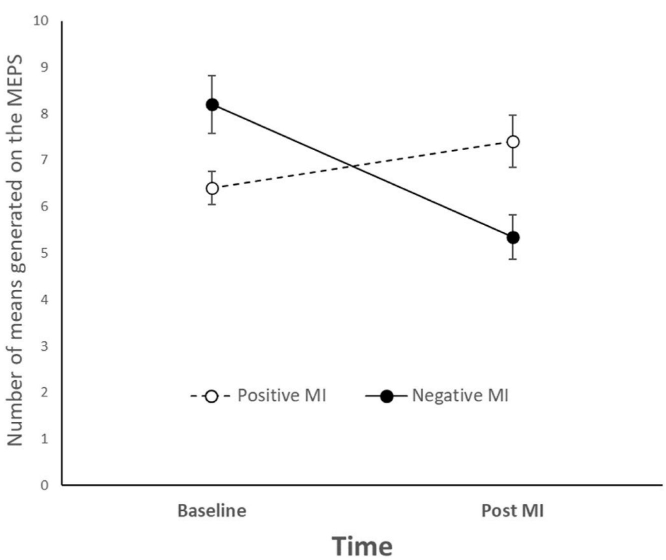

Fig. 6. Average number of solutions (relevant) means generated on the MEPS by the participants in the two groups pre- and post the MI procedure.

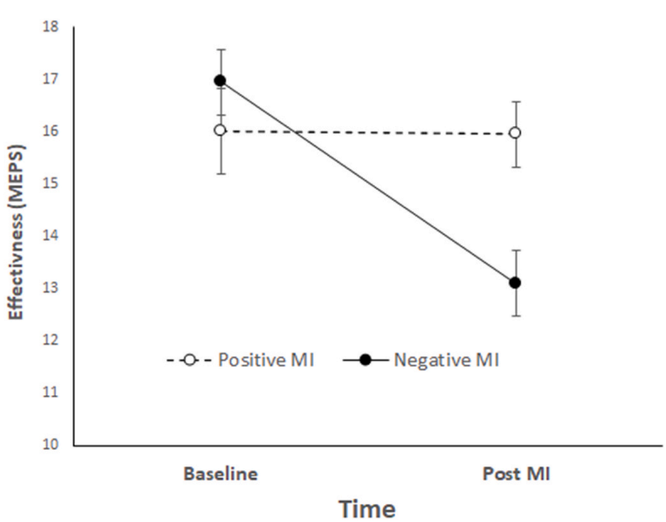

Fig. 7. Mean rated effectiveness of the means generated on the MEPS by the participants in the two groups pre- and post the MI procedure.

Bonferroni corrected t-tests revealed that the performance of the positive MI group (M = 17.4, SE = 1.6) and negative MI group (M = 20.4), SE = 1.6) did not differ significantly pre-MI; t (35) = 1.33, p = .477, Cohen's d = 0.53. However, the negative MI group generated fewer words (M = 13.7, SE = 1.2) post MI than did the positive MI group (M = 18.7, SE = 1.2); t (35) = 2.96, p = .028, Cohen's d = 0.96. The performance of the positive MI group did not differ pre-to post-MI; t (19) = 1.19, p = .247 (adjusted alpha = .025), Cohen's d = 0.27, whereas participants in the negative MI group generated significantly fewer words post-MI than pre-MI; t (19) = 3.54, p < .001 (adjusted alpha = .025), Cohen's d = 0.79.

8.5. Relationships between changes in mood, executive function, and social problem solving

To determine if a change in social problem solving was linked to changes in mood and/or executive function, difference scores were calculated by subtracting pre-MI values from post-MI scores, with negative values equating to a reduction in the scores from pre-to post-MI. Partial correlations (controlling for depression, anxiety, and rumination) revealed that the change in the number of means generated on the MEPS was negatively related to the change in sadness; r (40) = -0.33, p = .047 and positively related to the change in letter fluency; r (40) = 0.40, p = .015. The change in the number of means generated was also positively related to change in happiness and change in category fluency, but neither of these tests was significant; r (40) = 0.31, p = .063 and r (40) = 0.31, p = .062. Change in effectiveness of the means generated on the MEPS was negatively related to change in sadness and positively related to change in happiness, but neither of these tests was significant; r (40) = -0.28, p = .088 and r (40) = 0.28, p = .099. Change in the effectiveness of the means was not related to changes in letter or category fluency, p = .554 and p = .282. Changes in letter and category fluency were negatively related to changes in sadness; r (40) = -0.32, p = .052 and r (40) = -0.49, p = .002, but were not related to changes in happiness; letter, r (40) = 0.30, p = .073 and category, r (40) = 0.25, p = .130.

A hierarchical regression was conducted to predict the change in number of means generated on the MEPS with depression, anxiety, and rumination entered at Step 1, change in sadness entered at Step 2 and change in letter fluency entered at Step 3. The results of this analysis are presented in Table 7. The combined effect of depression, anxiety and rumination at Step 1 explained 1% ($R^2 = 0.01$) of the variance in the change in the number of means generated on the MEPS, which was not significant; F (3, 36) = 0.13, p = .940. None of the factors entered as significant predictors of the change in MEPS performance; depression (p

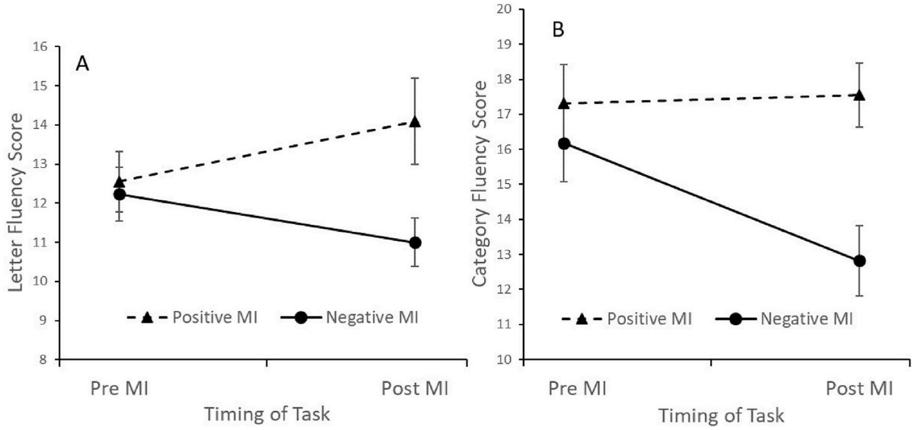

Fig. 8. Mean number of words generated on the letter [A] and category [B] fluency tasks by the participants in the two groups pre- and post the MI procedure.

Table 7
Hierarchical regression to predict change in the number of means generated on the means-end problem solving task (MEPS) with change in sadness and change in letter fluency as predictor variables (controlling rumination, anxiety, and depression).

DV = Δ MEPS		Model Summary				Contribution of each factor at Step 3				
		R^2	$R^2\Delta$	F	p	B	SE	b	t	p
Step 1		.01	–	0.1	.940					
	RRS					−.01	.09	−.03	−.15	.881
	HADS-A					.07	.18	.09	.40	.691
	HADS-D					−.06	.17	−.07	−.35	.726
Step 2		.12	.11	4.2	**.047**					
	Δ Sadness					−.02	.01	−.23	1.38	.177
Step 3	Δ fluency	.21	.09	4.1	**.051**	.17	.08	.33	2.0	**.051**

RRS = ruminative response scale, HADS-A = Hospital Anxiety and Depression Scale (anxiety subscale), HADS-D = Hospital Anxiety and Depression Scale (depression subscale), Δ MEPS = change in number of means generated on means end problem solving task, Δ sadness = change in sadness ratings, Δ fluency = change in letter fluency.

= .809), anxiety (0.886) and rumination (p = .602). The addition of change in sad mood at Step 2 explained an additional 12% of the variance ($\Delta R^2 = 0.12$), which was significant F (1, 35) = 4.23, p = .047. The change in sad mood entered as a significant predictor of the change in means generated on the MEPS; β = −0.34 (SE = 0.01), p = .047. The inclusion of change in letter fluency at Step 3 explained an additional 9% of the variance in the change in MEPS performance ($\Delta R^2 = 0.09$), but this was not significant; F (1, 34) = 4.08, p = .051. The change in letter fluency was positively related to the change in performance on the MEPS, but it was not a significant predictor; β = 0.33 (SE = 0.08), p = .051. Change in sad mood no longer predicted the change in MEPS performance once the change in letter fluency entered the model; β = −0.23 (SE = 0.01), p = .177.

9. Discussion

The aim of study 2 was to generate further evidence of the influence of state mood on social problem solving and executive function (as measured by fluency tasks), and to establish if changes in social problem solving were related to concomitant changes in executive function. As expected, individuals in the negative MI group generated fewer relevant means on the MEPS post MI than did the positive MI group, and these solutions were rated as less effective than those generated by the positive MI group. Furthermore, as predicted, the number of means generated by the negative MI group, and the rated effectiveness of these solutions, was lower post MI compared to pre-MI. These results are consistent with Mitchell and Madigan (1984) but contradict the findings of Nelson and Sim (2014), who reported that negative MI did not influence performance on the MEPS. The current findings are also somewhat consistent with Yoon and Joormann (2012), who also reported a reduction in MEPS performance following a negative mood induction. However, in their study the reduction in MEPS performance was only evident in participants who were experimentally induced to ruminate. Given the nature of the mood induction procedure (memory focus) in the current study, it is plausible that this might have led participants to spontaneously ruminate, which in turn may have impaired social problem solving. This notion is consistent with previous findings that induced rumination impairs performance on the MEPS (Lyubomirsky & Nolen-Hoeksema, 1995; Watkins & Baracaia, 2002). However, Noreen and Dritschel (2022) reported that rumination only predicted the number of relevant means on the MEPS for unresolved and not resolved social problems. Also, the finding from the current study that trait rumination was not significantly related to performance indices on the MEPS does not support this proposal. This could be examined in future using a rumination/distraction induction in addition to the mood induction procedure, consistent with Yoon and Joormann (2012).

An important novel finding of the current study was that the reduction in the number of means on the MEPS from pre-to post-MI was linked to increases in sad mood, which is consistent with the studies that have demonstrated deficits in SPS in clinical and subclinical depression (Goddard et al., 1996, 2001; Marx, Williams, & Claridge, 1992; Noreen et al., 2014) and in participants in remission from a major depressive episode (Williams et al., 2005). This finding is also somewhat consistent with Dixon-Gordon et al. (2011), who reported that change in MEPS post social rejection manipulation was linked to increases in negative affect. However, they only observed this change in participants with borderline personality disorder and not healthy controls. In the current study, decreases in the effectiveness of solutions was also negatively related to change in sadness, which is also consistent with the previous findings in participants with depression. However, it should be noted that this relationship was only trend significant, once the influence of anxiety, depression, and rumination had been controlled, so needs to be considered with caution.

As expected, participants in the negative mood induction condition generated fewer words on the fluency tasks post MI than did the positive MI group. This result is consistent with the findings of study 1 and with Bartolic et al. (1999). It is also consistent with previous studies showing decreased executive function following a negative mood induction (King, 2020; Spies et al., 1996), but does not support the claim of Mitchell and Phillips (2007) that negative MI has a negligible effect on executive function. However, in contrast to study 1, and the findings Carvalho and Ready (2010), changes in letter fluency were linked to changes in sad and not happy mood. Category fluency was once again linked to changes in sad mood, which is consistent with the finding of study 1.

One possible explanation is that sad mood may have acted as a cognitive load, in the form of extraneous task-irrelevant thoughts (Ellis & Ashbrook, 1988), which in turn may have depleted the cognitive resources that could have been utilised to perform the fluency and MEPS tasks. It is also possible that decreases in executive function (in response to increases in sad mood) could then have impaired performance in the MEPS. In line with that proposal, decreases in MEPS performance (number of generated means) was linked to reductions in executive function (letter fluency), which is consistent with Sheldon et al. (2011) and with our findings for memory specificity (study 1). Furthermore, once the influence of executive function was entered into the regression model, the link between the change in sad mood and the change in social problem solving was no longer significant, which suggests that sad mood influenced social problem solving indirectly via its effect on executive function. This confirms the importance of executive function for social problem solving (Goddard, Dritschel, & Burton, 1998; Noreen & Dritschel, 2022). However, it should be noted that the influence of the change in letter fluency was only trend significant in the final regression model, therefore this finding needs to be considered with caution. Interestingly, change in letter fluency only predicted change in the number of generated means and not the effectiveness of the solutions. It could be that the task of creating relevant means relies more on processes associated with fluency like generating as many options as possible. In contrast effectiveness may be more complex and rely on a combination of executive functions, such as inhibition of irrelevant solutions and/or switching between different kinds of solution. Therefore, future work should look at the influence of a wider range of executive tasks on the relationship between mood and social problem-solving.

In sum, participants in the negative MI group exhibited decreases in social problem solving (SPS) and executive function. Reductions in SPS were linked to increases in sad mood pre-to post-MI and decreases in letter fluency. However, once the influence of letter fluency entered the regression model this link between sad mood and SPS was no longer significant, which suggests that sad mood was influencing SPS indirectly via its effect on executive function, possibly by acting as an additional cognitive load. These findings suggest that transitory sad mood is associated with similar decreases in social problem solving and executive function that have been observed in participants with depression (Goddard et al., 1998; Noreen & Dritschel, 2022) and those in remission from major depressive episode (Williams et al., 2005). Further, these findings confirm that studies of state mood on cognitive function need to account for the possible role of executive function.

10. General discussion

The findings of the current work provide convincing evidence that negative mood induction (using memory focus augmented with mood congruent music) decreases autobiographical memory specificity (Study 1), social problem-solving performance (Study 2), and executive function (studies 1 and 2) post MI. Importantly, in both studies the influence of the change in state mood on the change in memory specificity (study 1) and SPS (study 2) became non-significant once the influence of executive function (letter fluency) was entered into the statistical model.

In both studies, negative MI led to a significant increase in sad mood and a significant decrease in happy mood from pre-to post-MI, whereas positive MI did not significantly alter state mood. These findings are consistent with previous studies using autobiographical memory focus augmented with mood congruent music to influence state mood (Noreen & Ridout, 2016; Ridout et al., 2009). The current findings also confirmed that, in both studies, negative MI led to a decrease in letter and category fluency from pre-to post MI, whereas positive MI did not significantly alter performance on either fluency task. These findings are consistent with previous studies showing impaired executive function following negative MI (King, 2020; Spies et al., 1996), but do not support the claim of Mitchell and Phillips (2007) that negative MI has a negligible effect on executive function. However, in the current work, there was some variation in the relationships between mood changes and alterations in verbal fluency across the two studies. In study 1, change in letter fluency was related to reductions in happy mood whereas the change in category fluency was linked to increases in sad mood. In study 2, changes in both letter and category fluency from pre-to post-MI were linked to increases in sad mood and not to changes in happy mood. One possible explanation for the discrepancies in observed relationships between these variables is the unstable nature of associations in relatively small samples (Schönbrodt & Perugini, 2013). Nevertheless, the current studies were adequately powered for the expected effect sizes.

Given that social problem-solving deficits have been linked to impaired autobiographical memory specificity (Beaman et al., 2007; Goddard et al., 1996; Ridout et al., 2015) and that induced negative mood has been linked to deficits in memory specificity (Yeung et al., 2006; Study 1 of the current work), it is plausible that impaired SPS observed in Study 2 might be a consequence of reduced AMS in the those who underwent the negative mood induction. This would have made it harder for the participants in the negative mood induction group to generate relevant means on the MEPS. In line with this proposal, Williams et al. (2005) demonstrated, in patients in remission from a major depressive episode, that reductions in SPS following a negative mood induction were linked to impaired memory specificity post mood induction. However, if this was the case then it would have been expected that in the current studies the negative mood induction procedure would have exerted the same influence on both tasks (autobiographical memory and social problem-solving). Yet, our findings showed that reduction in memory specificity from pre-to post-MI was linked to a decrease in happy mood and reduction in SPS performance was linked to an increase in sad mood. Nevertheless, as the decrease in memory specificity in study 1 was also linked to an increase in sad mood, it is still possible that performance on the MEPS was reduced post MI because participants in the sad MI condition were finding it harder to access specific memories in their attempt to generate relevant means of solving the social problems. This could be examined in future work.

One limitation of both studies is that only one measure of executive functioning was examined. Gustavson et al. (2019) reported that fluency was correlated with the general EF factor, although there was also some shared variance with updating and shifting. Nevertheless, Dalgleish demonstrated that inhibition, shifting and updating might all play a role in the retrieval of specific memories. Similarly, Noreen and Dritschel (2022) demonstrated that impaired inhibition of negative stimuli was implicated in the deficits is social problem solving exhibited by individuals with subclinical depression. Therefore, it is important to extend the current findings using a range of executive tasks that tap into different executive components. Further, it would be interesting to examine the interaction between autobiographical memory retrieval and executive functioning with respect to social problem solving. It would also be useful to examine to possible role of rumination. Although, in the current study, trait rumination was not significantly related to autobiographical memory, social problem-solving, or executive function, it is plausible that the mood induction procedure (memory focus) might have encouraged state ruminative thinking, which may then have influenced performance post MI. This could be examined using a rumination/distraction manipulation in addition to the mood induction procedure, in line with Yoon and Joormann (2012).

Another possible consideration is motivation. For example, Erez and Isen (2002) reported that positive mood induction improved performance on cognitive tasks by increasing motivation via the expectancy of success. However, they did not manipulate negative mood, so it is difficult to draw firm conclusions on the likely influence of this factor. In study 1 of the current work, change in memory specificity and fluency function was linked to change in happy mood, so it is plausible that the reduction of happy mood might have reduced expectancy of success and hence motivation. The current findings from study 2 showed that change in social problem solving (number of means on the MEPS) and fluency were linked to changes in sad mood, but not happy mood, which is not consistent with this explanation. However, it is notable that change in fluency and memory function in study 1 were also related to change in sad mood. Thus, it is plausible that increases in sad mood might have reduced motivation, possibly be reducing expectancy of success. Future work is required to examine this possibility.

Taken together, the results of the study studies confirm that transitory changes in mood are linked to similar decreases in autobiographical memory function and social problem solving that have been observed in participants with clinical and subclinical depression. The results also suggest that negative mood induction leads to reductions in executive function, at least as measured by verbal fluency. Furthermore, the changes in letter fluency in response to variations in mood appear to account for decreases in autobiographical memory and social problem-solving performance. Future work should include bias corrected bootstrapping to conduct a mediation analyses to explicitly test the significance of the indirect pathways between positive mood and memory specificity, and between negative mood and social problem solving via the potential mediator of executive function (letter fluency). The current study was not powered for such an analysis (Fritz & MacKinnon, 2007), but the regression data are suggestive that such a mediation is plausible. This suggests that future studies of state mood on cognitive function need to account for the possible influence of executive function.

CRediT authorship contribution statement

Nathan Ridout: designed the study, conducted the main data analysis, and wrote the initial draft of the manuscript and the revision. **Barbara Dritschel:** contributed to the interpretation of the data and the writing of the initial manuscript and revision. **Meera Morjaria:** contributed to the initial design of the studies, collected the data, performed the initial data analysis, and contributed to the writing of the manuscript. **Chanelle Yankey:** contributed to the initial design of the studies, collected the data, performed the initial data analysis, and contributed to the writing of the manuscript. All authors approved the final submission.

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Declaration of competing interest

The authors have no conflicts of interest to declare.

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The data supporting this publication is available via Mendeley Data at DOI: 10.17632/39bhmkddwd.1.

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