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Inferential false memories for emotional events

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1. GENERAL INTRODUCTION

The human mind is a complex system that integrates stimuli, previous knowledge, current motives and emotional states to define actual behaviour. At its core stands memory, which is deeply involved in a broad range of psychological functions; autobiographical memory assists the construction of identity (Wilson & Ross, 2003), the working memory system allows the simultaneous processing of different stimuli (Baddeley, 2012), which is a core aspect of intelligence, and the elaboration of elements stored in long-term memory is what let us create hypothetical future scenarios (Schacter, Addis & Buckner, 2007). However, sometimes memory fails. As Daniel Schacter (2001) pointed out, rather than being just "failures", these phenomena are more like by-products of otherwise adaptive properties. Indeed, they reveal how human memory works, and how it is continuously committed to bring coherence to the perceived world by making inferences, establishing associations and capturing the gist of the experience.

One fundamental aspect that is investigated by research on memory is how emotional events are remembered, and how memory errors for emotional events are produced. From an evolutionary point of view, emotional memory is critical because it is involved in acquiring information from events that are relevant for survival or goal achievement. Knowledge of how emotional events are remembered and misremembered is important not only for understanding the basic mechanisms of psychological functioning, but also for its implications for the individual and the society as a whole. In the forensic field it is crucial to establish whether eyewitness memory is reliable, that is whether we can trust a witness – knowing that more often than not the remembered events are emotionally charged (think, for example, of an accident, a theft or an assault); erroneous memories in this context may lead to wrongful convictions. Also in clinical psychology, emotional memory is deeply involved. Patients are often required to think back, describe and re-assess emotional events of their personal past; understanding how these events are stored in memory and how they may be subject to transformation and re-elaboration over time, could be relevant for the practice of psychological therapy.

Luckily, memory for emotional events is often protected against errors compared to memory for ordinary events (e.g. Kensinger & Schacter, 2005, 2008). However, this protective effect does not always hold true, and it may depend on several factors, including conditions under which the encoding of the event occurred, the type of to-be-remembered material, stable traits and cognitive characteristics of the individual, and the specific affective state of the rememberer (e.g. Christianson, 1992).

In the first part of this dissertation I will briefly describe the methods that have traditionally been employed to investigate false memory and memory distortion, as well as how they have been applied to the study of memory for emotional material, and which results they brought. In the second part I will report on a series of experiments that I have conducted on memory errors for emotional events using a recently developed false memory paradigm that is based on pictorial scripted material. Through five experiments, I will describe how inferential memory errors are affected by the presentation of emotional material, and how this effect is moderated by a series of variables including conditions at encoding, post-encoding elaboration of the material and individual differences. The relevance of the results, particularly taking into account the novelty of the paradigm, will be highlighted.

1.1. A brief history of research on false memory and memory distortion

Our memory is constructive and reconstructive in nature. It encodes schemas rather than mere sensations, it stores the gist of the events, and strives to make sense of what happens

(Alba & Hasher, 1983; Bartlett, 1932). This implies that what our memory encodes goes beyond the actually presented information, and the "excessive" information may sometimes be mistaken as genuine. Indeed, as it has been widely demonstrated by research, memory distortions and false memories – often associated with high vividness and confidence – are a common fact in everyday life (e.g. Loftus, 2005; Roediger & McDermott, 1995). Bernstein and Loftus (2009) go so far as to claim that "*all memory is false to some degree (...) memory is inherently a reconstructive process*" (p. 373).

Psychological research has investigated memory distortions for almost a century, employing a range of different methods. Bartlett (1932) was a pioneer in showing that memory representations of complex events are not accurate and stable traces that are permanently stored in our mind. He required his participants to learn narrative material that belonged to a cultural background they were unfamiliar with (i.e. a Native American legend called *The War of Ghosts*) and tested their memory after time periods of increasing duration. He found that participants were prone to distort memory of the original content on the basis of the narrative schemas that were typical of their cultural background, and observed that this tendency was increasingly evident after longer periods of time. Since then, a line of research has systematically investigated how our memory is influenced, and sometimes deceived, by the reliance on schemas and previous knowledge (e.g., Alba & Hasher, 1983; Brewer & Treyens, 1981). For example, it has been shown that elements that are typical of specific contexts are also highly likely to be remembered after having observed material depicting that context, even though they were not actually presented; for example, it is possible to misremember having seen a teddy bear after having studied a photograph representing a children playroom (Friedman, 1979). Highly typical information is also likely to be misremembered after having encoded material referring to recurrent and stereotypical events (also named "scripts"); for example, it is likely to remember information about ordering food after having read a text which describes going to a restaurant, even though that specific information was omitted (Bower, Black, & Turner, 1979).

The previously described examples of false memories could be defined as self-generated, as they stem from mental processes that are essentially endogenous. Other studies have used external cues for inducing memory distortions and false memories on encoded material. For example, Elizabeth Loftus initiated a line of research that focuses on how memory of events can be manipulated by mean of external information received after encoding (Loftus, 1979; Loftus, Miller, & Burns, 1978). Since then, a series of experiments that used various types of post-encoding misleading information (or "misinformation"; Loftus, 2005) have shown that this procedure is effective not only to investigate how minor aspects of an event's memory trace can be modified, but also to demonstrate that individuals can be induced with relative ease to remember detailed accounts of entire events that never took place (Loftus & Pickrell, 1995). Crucially, these suggestibility paradigms normally require to present misleading information not just once, but repeatedly over subsequent sessions. Doing so, participants can be effectively led to produce and consolidate vivid mental representations of the suggested events, to the point that these representations cannot be distinguished from actual memories – a phenomenon that is known as imagination inflation (Garry, Manning, Loftus, & Sherman, 1996; Mazzoni & Memon, 2003). The misinformation procedure has proven effective in showing how a majority of individuals can be led to produce false memories – sometimes with dramatic results; for example, in a recent study Shaw and Porter (2015) reported that 70% of their 126 participants had been effectively misled to falsely remember having committed various types of crimes (including assault with a weapon) in their early adolescence.

The large amount of research that has been conducted on false memory was originally motivated by forensic application. The 90s saw the so-called "memory wars", i.e. a widespread dispute between some psychotherapists and memory researchers that took place over the reliability of repressed memories. Indeed, it was reported that a number of patients emerged from psychotherapy sessions claiming that they had recalled memories from a remote past, usually childhood, and accusing parents and relatives of violence, sexual abuse, or other crimes, which led to a series of court cases (Schacter, 1996). Still now the controversy is not fully settled (Patihis, Ho, Tingen, Lilienfeld, & Loftus, 2014). This highlights the great importance of increasing and disseminating knowledge, especially among the general public and in the forensic contexts, about the phenomenon of false memory, with special regard to emotional events.

The procedure that was perhaps most widely used to investigate false memories during the last two decades was the Deese-Roediger-McDermott paradigm (DRM; Roediger & McDermott, 1995; see Gallo, 2006, 2010, for extensive reviews). This paradigm consists of word lists being presented during the encoding phase. All the words within each list are semantically related to each other, and they all converge to a single non-presented “critical lure”. During a subsequent memory test, participants are required to recall or recognize the words that were presented during the encoding phase. If the critical lure is wrongly remembered, then it represents a false memory. Thanks to its simplicity and versatility, the DRM paradigm has so far been used in hundreds of experimental studies. A typical finding is that false memory of the critical lures is just as likely as correct recognition of presented words, and that false memories are often accompanied by strong confidence and claims of clear remembering (Gallo, 2010).

A majority of the findings I will refer to when discussing previous research in this field were obtained using the DRM paradigm. This must be taken into consideration, because DRM false memories have particular characteristics and point to specific theoretical implications. In the present dissertation I will underline some crucial differences between the implications of the findings obtained using the DRM paradigm and the findings obtained using the inferential memory paradigm that I employed in the current series of experiments. The two main theories that explain DRM false memories are the “spreading of activation theory” (Roediger, Balota, & Watson, 2001) and the “Fuzzy-Trace theory” (Brainerd & Reyna, 2002): the former theorizes that DRM false memories derive from processes of spreading of activation through a human memory system conceptualized as a network of interrelated nodes (i.e. when the related concept are presented, they spread activation toward the non-presented critical lure, thereby increasing the probability that it is falsely remembered); the latter theorizes that DRM false memories derive from a reliance on the semantic “gist” of a word list (i.e. the partially overlapping meaning of all words in a list) as opposed to the verbatim features of the encoded words (when they are difficult to retrieve). This suggests that the conditions that either increase or decrease the propensity to commit DRM false memories act by increasing or decreasing the spreading of activation through the memory nodes, or by encouraging the reliance on semantic gist of related concepts instead of favouring encoding of item-specific features. For example, counterintuitive as it may seem, a common finding is that adults are more likely than children to commit DRM false memories; this is the effect of age improvements in semantic memory, which facilitates gist reliance in adults compared to children (Brainerd, Reyna, & Ceci, 2008). Similarly, adults who are encouraged to memorize words using a strategy based on semantic relatedness later commit more DRM false memories than adults who are encouraged to use an item-specific strategy (McCabe, Presmanes, Robertson, & Smith, 2004).

Other types of false memories have also been studied. In particular, false memories based on inferential processes are of great interest for understanding the reconstructive processes of memory, and also for their potentially immediate application to the field of eyewitness memory. Inference-based memory errors are conceptually similar to the previously described memory distortions deriving from the use of schemas (e.g. Friedman, 1979; Bower et al., 1979). Hannigan and Reinitz (2001) described two types of inference-based false memories, i.e. schematic gap-filling errors and backward inference causal errors. The authors used sequences of photographs organized in “scripts” (i.e. real life episodes representing typical situations, about which everyone is supposed to have previous knowledge; Bower et al., 1979) as material during the encoding phase; subsequently, they tested recognition memory for presented and non-presented photographs. Gap-filling errors refer to the erroneous recognition of a photograph depicting an event that is highly typical of the script (similarly to the schematic errors described by Bower et al., 1979), while causal errors refer to the false recognition of a photograph depicting the specific, episodic antecedent of which the consequence had been seen (Hannigan & Reinitz, 2001). Recently, Lyons, Ghetti, and Cornoldi (2010), and Mirandola, Paparella, Re, and Ghetti, (2012) used a conceptually identical version of this paradigm in studies on the development of false memories, confirming and extending evidence in favour of its validity as a false memory paradigm. A key advantage of this paradigm lies in its ecological relevance; indeed, sequences of photographs depicting real persons involved in everyday life events resemble the actual use of memory more than series of unordered words (as in the DRM); on the other hand, one disadvantage lies in the difficulty to create the material, and to finely control for all the aspects of the stimuli (such as valence and arousal, as it will be discussed below). In conclusion, paradigms investigating inference-based false memories have high ecological value and examine memory errors deriving from self-generated reconstructive processes; however, they have not been systematically employed in research until now.

1.2. The memory-emotion interplay

Emotions enhance memory – with some exceptions

Emotions powerfully affect memory, and may they have contrasting effects. Most research indicates that emotionally charged contents are remembered better than non-emotional ones, both objectively and subjectively. Remembrance of real life emotional events is more lasting and accurate compared to remembrance of ordinary events (Christianson, 1992; Kensinger & Schacter, 2008); similarly, memory for emotionally arousing stimuli (both positive and negative) is enhanced and better preserved over time compared to memory for neutral stimuli (e.g., Bradley, Greenwald, Petry, & Lang, 1992). At the subjective level, memory for emotional stimuli is more likely to be associated to a vivid feeling of recollection compared to neutral stimuli (Ochsner, 2000). Accurate and subjectively compelling memories of emotional events have an obvious evolutionary rationale, as it is crucial to carefully keep trace of the events that are most relevant for survival and goal achievement. A specific pattern of enhanced neural activation, that involves interactions between the amygdala and the hippocampus, has been described as the basis of emotion-enhanced memory, especially in the case of negatively arousing material (Hamann, 2001; Kensinger & Schacter, 2005).

However, the enhancing effect of emotions on memory is not found in any condition or for any aspect of memory. High levels of arousal, especially if negative, may impair some aspects of memory reliability (e.g. Christianson, 1992; Deffenbacher, 1983; Deffenbacher, Bornstein, Penrod, & McGorty, 2004); in particular, it may lead memory to be narrowed to the core details of a scene at the expense of the peripheral ones, particularly when an arousing attention magnet – such as a weapon – appears on the scene (e.g. Christianson & Loftus, 1991; Reisberg & Heuer, 2004). This phenomenon is generally defined as emotion-induced memory trade-off (Kensinger, Garoff-Eaton, & Schacter, 2006), and has been attributed to its evolutionary relevance; indeed, it may be adaptive to quickly detect and direct attention toward threatening stimuli, even if it means overlooking the surrounding details (Öhman, Flykt, & Esteves, 2001). However, there is also evidence that in absence of attention magnets, emotionally charged events may lead to improved memory for both the central and the peripheral aspects of the scene (Laney, Campbell, Heuer, & Reisberg, 2004). See Levine and Edelstein (2009) for a comprehensive review on these findings.

While a majority of studies describe the effects of arousal on memory (or confound arousal and valence), the single role of valence must also to be considered. Indeed, positive and negative events with similar levels of arousal may differently affect memory. For example, in a real life memory study, Kensinger and Schacter (2006a) found that those participants who had experienced an event that was either positively or negatively arousing could similarly remember it with high subjective vividness over time. However, those who had experienced negative events had greater memory consistency compared to those who had experienced positive events, suggesting greater stability of the memory trace in the case of negative events (Kensinger & Schacter, 2006a). Also laboratory analysis on neural memory network activity shows that, even with equal levels of arousal, stimuli associated with positive vs. negative valence have different effects on memory; specifically, negative information induces larger and more widespread neural activity in the memory system compared to positive information, indicating an increased elaboration and a deeper effect (Mickley Steinmetz, Addis, & Kensinger, 2010). Consistent with it, unlike emotion-enhanced memory for positive material, emotion-enhanced memory for negative material seems automatic and less dependent on conscious attention (Talmi, Schimmack, Paterson, & Moscovitch, 2007).

Do emotions reduce false memories?

While research on the interplay between emotion and memory has a long history, specific research on how emotions influence the occurrence of false memories is relatively recent. Just as in the case of general aspects of memory, effects of emotions on false memories are nuanced (Kaplan, Van Damme, Levine, & Loftus, 2015). On the one hand, emotional material – especially negative – was found to reduce memory distortions (e.g. Kensinger & Corkin, 2004;

Kensinger, O'Brien, Swanberg, Garoff-Eaton, & Schacter, 2007; Kensinger & Schacter 2005, 2006b; Pesta, Murphy, & Sanders, 2001); on the other hand, other studies reported boosted false memories (Brainerd, Stein, Silveira, Rohenkohl, & Reyna, 2008; Gallo, Foster, & Johnson, 2009).

One crucial aspect that seems to explain the contrasting findings is which type of stimuli is shown at encoding, and thus which paradigm is used. As in the case of emotional memory in general, emotionality of the material may increase item's distinctiveness, consequently leading to more detailed encoding and reduced false memories related to emotional items (e.g. Kensinger & Corkin, 2004). In particular, emotional content seems to facilitate reality-monitoring ability (Kensinger et al., 2007; Kensinger & Schacter, 2005, 2006b), a term that refers to be ability to discriminate whether the source of an event's memory trace was external or internal (Johnson & Raye, 1981). False memory itself can be interpreted as a failure in the reality-monitoring process (Gallo & Roediger, 2002); therefore, if negative content improves this ability, it also reduces the occurrence of false memories.

While distinctiveness may account for the reduced occurrence of false memories, other aspects of emotional material may have the opposite effect. In particular, studies on false memories conducted using categorized material, for example, the DRM procedure, found that negative content is more likely to give rise to false memories than neutral content (e.g., Brainerd et al., 2008; Gallo et al., 2009). This has been explained in terms of emotional material having stronger semantic relatedness, thus boosting those associative processes (or reliance on the gist) that underlie false memories (Talmi & Moscovitch, 2004). In other words, negative categorized items share not only a common theme, but also their emotional feature, which would increase their confusability. In fact, equating word lists on their associative strength, Palmer and Dodson (2009) found that emotional (both negative and positive) material protected against false memories compared to neutral material; however, other studies also equated associative strength but found the opposite (e.g. Brainerd et al., 2008). Recently, Choi, Kensinger, and Rajaram (2012) through three experiments found that, using categorized graphic material equated in semantic relatedness, emotional items did not boost – and even reduced – the probability to incur associative false memories. The fact that existing findings are mixed suggests that more in-depth research is needed.

To my knowledge, how emotional content affects the occurrence of inference-based false memories has not yet been studied. In the present dissertation I report on a series of experiments examining the occurrence of inferential false memories for emotionally charged events. To address the issue, I used a new, highly ecological false memory paradigm, which investigates inference-based memory errors (as defined by Hannigan & Reinitz, 2001). The theoretical and practical implications will be discussed, particularly focusing on the similarities and differences with previous findings obtained using other false memory paradigms.

1.3. Overview of the experiments

The research that is described in the present dissertation has been motivated by two general questions. First, it investigates whether inference-based false memories are less likely for emotional than non-emotional events, consistently with the general notion that emotional material is better remembered and is associated to fewer memory distortions (Kensinger & Schacter 2005; Kensinger, 2007). Second and most important question, it examined whether the potential "protective" effect of emotional material against false memories could be disrupted or even reversed under certain conditions, investigating the effects of both experimental manipulations and individual differences.

To examine these two questions, I created a false memory paradigm that is based on pictorial scripted material, following the example of Hannigan and Reinitz (2001; see also

Lyons et al., 2010, and Mirandola et al., 2012, for a more recent application), but adapting it to include emotionality as a factor. A more detailed description of the paradigm will be provided in the introductory section of Experiment 1, and an example of the material is shown in the Appendix A.

In Experiment 1, I examined the effect of post-encoding elaboration of pictorial scripted material on the production of inferential false memories for negatively emotional vs. neutral events. Two groups of undergraduate students were administered an incidental memory test after having freely recalled the scripted material or having completed distracting tasks. In particular, it was examined: a) how the probability of committing inferential false memories concerning negative vs. neutral events varied in the two groups; b) whether negative events were actually re-elaborated to a greater extent compared to neutral events.

In Experiments 2 and 3, I focused on the effect of sub-clinical symptoms of internalizing disorders on the production of inferential false memories for emotional vs. neutral events. In particular, in Experiment 2 I compared a group of young adults with high levels of internalizing symptoms (both depression and anxiety) with a group of young adults with medium to low levels of internalizing symptoms. In Experiment 3, I expanded the findings of the previous experiment by adding a positively valenced condition within the scripted material, and by focusing on a group of individuals with a "purely anxious" trait, that is with a high level of trait anxiety but medium to low level of depression symptoms.

In Experiments 4 and 5, I focused on the role played by working memory (WM; Baddeley, 2000) capacity on the production of inferential false memories for neutral vs. positive and negative events. In particular, in Experiment 4 I examined the role played by WM capacity at the level of individual differences, while in Experiment 5 the results were replicated and expanded using an experimental condition that was intended to artificially manipulate WM capacity available during the encoding phase.

Findings from the five Experiments suggest that emotional events are indeed associated to reduced occurrence of inferential false memories compared to neutral events, but also that this protective effect is disrupted or even reversed under certain conditions. Results will be eventually discussed in terms of how they add to literature on emotional false memory, especially highlighting the innovative aspects of the present paradigm and its theoretical and practical implications.

2. IN SEARCH OF A PARADIGM FOR EXAMINING INFERENTIAL FALSE MEMORIES FOR EMOTIONAL EVENTS

2.1 Introduction

In this chapter I describe how a new paradigm for the study of emotional false memory has been devised and developed. Subsequently, I present a study in which it is used to investigate how the occurrence of inferential false memories for emotional events is affected by post-encoding elaboration of material.

As I mentioned earlier, research on false memory has been importantly motivated by its implications for the forensic context and eyewitness testimony (Brainerd, Reyna, & Poole, 2000). So far, the DRM paradigm (Roediger & McDermott, 1995) has provided what is probably the largest amount of findings on the phenomenon of false memory. As Gallo (2010) reported in his broad review, DRM false memory has good generalizability; for example, individuals who are likely to incur the DRM illusion are also likely to incur other types of false memories, and even autobiographical memory distortions, which suggests that the DRM paradigm is indeed useful to investigate processes that underlie the formation of different types of false memories and memory distortions (Gallo, 2010). Ultimately, however, the DRM procedure has the limitation that presents memory material that is distant from the real life experience (i.e., lists of semantically related words), and it has been criticized for being overly simplistic as a false memory paradigm (Pezdek & Lam, 2007). Eyewitness testimony, to give an example, typically involve the remembrance of visual aspects of scenes that are detailed and complex – and that possibly involve emotionally charged events affecting oneself or other individuals. Suggestibility paradigms often uses video or slides to present events about which misinformation is subsequently provided (Takarangi, Sophie, & Maryanne, 2006), or require the imagination of autobiographical events; as I previously reviewed, these paradigms have proven useful to investigate the false memory phenomenon, sometimes with impressive results (Loftus, 2005; Shaw & Porter, 2015). However, they are exclusively focused on how external information is eventually incorporated into existing memory. As human memory is schematic and reconstructive (Alba & Hasher, 1983; Bartlett, 1932), it is also of great importance to understand when and how memory itself can create its illusions through inferential and reconstructive processes (e.g., Bower et al., 1979; Friedman, 1979; Hannigan & Reinitz, 2001). A new, highly ecological paradigm to study false memories for complex visual events may therefore be useful.

To this end, I followed the intuition of Hannigan and Reinitz (2001) and created a false memory paradigm that is based on pictorial scripted material, newly adding emotionality as a factor. The material consisted of a series of photographs depicting typical everyday life events (for Experiments 1 and 2, the events include: waking up in the morning, having dinner with guests at home, going grocery shopping, playing in the playground, taking a bike ride, performing on a theatre stage, doing homework at home, going to the nurse); these events are also named "scripts" (Hannigan & Reinitz, 2001; Lyons et al., 2010), as it is assumed that everyone possesses previous knowledge about the routines that typically takes place in each of these cases. The emotionality of the scripts was manipulated by presenting different, mutually exclusive outcomes close to the end of each event at encoding; the outcomes differ in terms of emotional valence and arousal (in Experiments 1 and 2, one outcome was negatively arousing, and the other was emotionally neutral). For each script, a photograph representing the common cause of all the outcomes was created; this photograph is named "causal antecedent" (or "causal distractor"), and it is not shown at encoding, but later tested at a recognition phase. The false memory of the causal antecedent is considered to be a causal error. Other variables have also been considered; in particular, the false memory for any script-consistent but not presented photograph (excluding the causal antecedent) is considered to be a “gap-filling error”, and the correct recognition of an actually presented photograph (named “target”) is considered to be a “hit”. A graphical example of one of the script that were used in this experiment is shown in Appendix A. In the next section, I describe an experiment in which this paradigm is used to investigate how post-encoding elaboration affects the production of false memories (specifically, causal and gap-filling errors) for emotional events.

2.2 Experiment 1: The role of post-encoding elaboration[1]

We frequently reflect and think back to past events, especially when they are emotional (Christianson & Engelberg, 1999; Walker, Skowronksi, Gibbons, Vogl, & Ritchie, 2009). While rehearsing past events may help to keep them stored in memory over time, there is also evidence that subsequent re-elaboration lead to the distortion of their original narrative structure, due to an attempt to make them more consistent with previous knowledge and to bring coherence in the overall story (Bartlett, 1932; Bergman & Roediger, 1999). Even in the seminal article on the DRM paradigm (Roediger & McDermott, 1995), the observation that repeated recall provoked enhanced false memory of the critical lure at a subsequent remembering task was reported. Rehearsal-driven distortion is of potentially high concern in eyewitness testimony, where the retrieval of the original memory trace is crucial; in this context repeated eyewitness interviews could be a problem – but it is also possible that, over time, the eyewitness himself spontaneously re-think of and reconstruct what has happened, especially if the critical events were strongly emotional.

Relatively little research has been conducted to investigate if and how post-encoding elaboration stimulate false memory for emotional events. Marsh, Tversky, and Hutson (2005)

[1] Results reported in Experiment 1 have been partially described in the following article: Mirandola, C., Toffalini, E., Grassano, M., Cornoldi, C., & Melinder, A. (2014). Inferential false memories of events: Negative consequences protect from distortions when the events are free from further elaboration. Memory, 22, 451–461.

found that retelling about emotional scenes led to a greater proportion of errors in a subsequent memory recall tests, specifically when retelling was accompanied by an explicit request to talk about subjective emotional reactions to the encoded material; on the contrary, factual retelling did not have an impairing effect. Similarly, Drivdahl, Zaragoza, and Learned (2009) found that reflectively elaborating viewed material with a focus on emotional aspects led participants to higher propensity to incur false memories of non-viewed events that were being suggested through misinformation. Bornstein, Liebel, and Scarberry (1998) found that repeated memory testing about a violent scene slightly increased the number of memory errors, while the same effect was negligible for neutral scenes; however, since they focused mostly on accuracy, their participants produced a very low number of memory errors (not more than 1-2 per person), which made it difficult to perform proper analysis. Finally, and more generally, conceptual elaboration of viewed material has been found to increase false memory occurrence for events on which misinformation had been provided (Zaragoza, Mitchell, Payment, & Drivdahl, 2011). Since emotional events are more likely to be the focus of elaboration (Walker et al., 2009), it might be expected that false memories are more likely for these events than for neutral ones; to my knowledge, this hypothesis has not yet been tested.

In the present study, the effect of post-encoding elaboration on the production of inferential false memory for negatively arousing vs. neutral events is examined. Using the previously outlined paradigm based on pictorial scripted material (Hannigan & Reinitz, 2001; Lyons et al., 2010), causal and gap-filling errors were considered. Different hypotheses were tested. On the one hand, it was hypothesized that emotionally arousing material would lead to fewer false memories, due to its higher distinctiveness and its generally beneficial effect on memory accuracy (Kensinger, 2007; Kensinger & Schacter, 2008). On the other hand, it was hypothesized that this would happen only in a control condition, while in a post-encoding elaboration condition emotional material was expected to boost false memories, due to its higher probability of being the focus of the elaboration, which in turns is expected to entail those reconstructive processes that are at the basis of inferential false memory. Finally, written reports of post-encoding elaboration were analysed to understand whether emotional events are indeed more likely to be elaborated.

It is important to note that different effects were expected on the two different types of inferential false memories. As both causal and gap-filling errors are thought to stem from reconstructive processes, it was expected that both types of errors could be similarly affected by post-encoding elaboration *per se*; the same, however, was not expected in the case of the effect of valence. Indeed, as it is clearly described in the Method section (see also the graphical representation of one of the scripts in Appendix A), due to the characteristics of the paradigm, only causal errors are directly linked to the specific outcomes through which valence is manipulated. Therefore, albeit it was not excluded that valence of an event could "spill" its effect over the entirety of the script in which the event is embedded , thus influencing all memory aspects, gap-filling errors (i.e. false memories of events that are consistent with the viewed episode) were not necessarily expected to be affected by valence; the same applies to memory accuracy (i.e. correct recognition of actually presented events within the script).

2.2.1 Method

Participants

Participants were 96 undergraduate students (mean age = 24.13 years, SD = 5.01; 60 females). They were randomly assigned to either the control group (*N* = 53; 39 females) or to the post-encoding elaboration group (*N* = 43; 21 females); while the former group performed only the recognition test after a 15-minutes retention interval during which they were administered filler tasks, the post-encoding elaboration group was require to perform a free recall task during the retention interval, immediately before completing the recognition test. All participants provided written and oral consent prior to participation. The study was approved by the local ethical committee.

Materials

Pictorial stimuli for encoding

Stimuli consisted of a series of colour photographs depicting 8 everyday episodes or "scripts", as described before. For each episode, a series of 17 photographs were created. Out of them, 11 were used as targets and depicted the body of the script, i.e. typical actions that are likely to be performed in a particular context; other 3 photographs, similar to the previous ones, were used as script-consistent distractors during the recognition phase. Target and distractors were counterbalanced across participants. Finally, other 3 photographs for each script depicted a cause-effect pattern. This pattern consists of one single cause which results in two similar but mutually exclusive outcomes that differ in emotionality: one outcome is negatively arousing, while the other is neutral. Emotionality of the presented outcomes was counterbalanced across participants, as for each script the neutral outcome was shown to half of the participants, while the negative outcome was shown to the remaining half. All 8 scripts were presented one after the other without interruptions, following the procedure already adopted in studies that used similar versions of this paradigm (e.g. Hannigan & Reinitz, 2001; Lyons et al., 2010). Actors and settings were different across all 8 scripts to avoid potential confusion between the episodes. As it is known that stimuli in the initial and final positions are better remembered compared to the others (i.e. primacy and recency effects), 5 script-inconsistent photographs were shown at the very beginning of the entire sequence, and other 5 were shown at the very end. A total of 106 photographs were shown during the encoding phase.

Assessment of emotionality of the pictorial stimuli for encoding

Prior to the experiment, a pilot study was conducted to make sure that the 16 photographs representing the outcomes (i.e. 8 neutral and 8 negative outcomes) were actually emotional or non-emotional as they were intended to be. To this end, 11 undergraduate students (who did not subsequently participated in the main experiment) rated the 16 outcomes in terms of both valence and arousal on two 9-point scales using the SAM (Self-Assessment Manikin; Bradley & Lang, 1994), where 9 indicates high arousal and strongly positive valence, and 1 indicates low arousal and strongly negative valence (5 is the midpoint in both scales, indicating relatively high arousal and neutral valence respectively). Each outcome was presented for two seconds on a computer screen (i.e., in a condition similar to that of the main experiment), and was followed by a self-paced rating phase. Means, standard deviations, and 95% confidence intervals of the means (based on *t* distribution) for the ratings of valence and arousal of the outcomes were as follows:

- Valence of neutral outcomes, *M* = 5.96, *SD* = 1.05, 95% CI [5.74, 6.18];
- Valence of negative outcomes, *M* = 3.28, *SD* = 1.12, 95% CI [3.05, 3.51];
- Arousal of neutral outcomes, *M* = 3.15, *SD* = 1.48, 95% CI [2.84, 3.46];
- Arousal of negative outcomes, *M* = 5.50, *SD* = 1.30, 95% CI [5.23, 5.77].

The differences between neutral and negative outcomes were thus large on both valence and arousal: for valence, Cohen's *d* = 2.47; for arousal, Cohen's *d* = 1.69 (see Cohen, 1988, for an interpretation of the effect size).

Pictorial stimuli for recognition

A sequence of 80 photographs was shown during the recognition test. Photographs were presented in a randomized order. For each episode, 4 target photographs, 3 script-consistent distractors and, crucially, the photograph depicting the cause whose outcome had been shown during the encoding phase, were tested. The remaining 16 photographs were script-inconsistent, half of which were actually shown during the encoding phase.

Procedure

Participants were told that they would see a series of photographs depicting typical situations in which youths do different daily activities. As the encoding was incidental, participants were not told about the memory test, and were only required to pay attention to the sequence of photographs, to understand what they represent. Photographs were presented on a computer screen place at about 50 centimetres from the participant's head; photographs were shown for 2 seconds each, and were divided by black slides lasting 2 seconds as the interstimuli. For each script, 12 photographs were shown in adjacent positions and in logical order.

During a subsequent 15 minutes retention interval, participants in the control group completed a version of the Stroop Test (D-KEFS Colour-Word Interference Test; Delis, Kaplan, & Kramer, 2001) the scores of which were not further considered, as this was used only as a filler task to prevent participants from re-elaborating the encoded material. On the contrary, participants in the post-encoding elaboration group were given pencil and paper, and were asked make an effort to remember and describe what they had just seen, and specifically to try to "narrate" the episodes by writing them down.

The final recognition test was identical for the two groups, and was self-paced. For each photograph, participants were required to respond either "yes" or "not" based on whether they thought that they had seen that photograph among those that were presented during the encoding phase or not.

2.2.2 Results

All analyses were performed using R (R Core Team, 2015). Generalized mixed-effects models were run using the package “lme4” (Bates, Maechler, Bolker, & Walker, 2015). Graphical effects were obtained using the package “effects” (Fox, 2003).

Response variables were obtained from responses provided by participants during the recognition test. Three types of responses were provided: responses to targets, responses to script-consistent distractors, and responses to causal distractors. As all the responses were of a binomial type (“yes”: 1, or “no”: 0), they were analysed using logistic mixed-effects models (Baayen, 2008; Jaeger, 2008). The “yes” responses to causal and script-consistent distractors were considered as causal and gap-filling errors respectively, while “yes” responses to target photographs were hits. In all three cases, the fixed effects that were tested were Group (with 2 levels: control group vs. post-encoding elaboration group), Valence (with 2 levels: neutral vs. negative), and their interaction. Random effects were Participants and Photographs. Likelihood ratio tests for nested models based on the chi-square distribution (Pinheiro & Bates, 2000) were used to assess the significance of both fixed and random effects; the significance of the random effects was calculated by removing them, one at a time, from the full model. Furthermore, given the well-known limitations of the p-value significance test (Burnham & Anderson, 2002), an information-criterion approach was also used. In particular, the Akaike Information Criterion (AIC; Akaike, 1974) was reported for each model (lower AIC indicates better model); furthermore, evidence ratio based on the Akaike weights was used to quantify the evidence in favour of the existence of each fixed effect. The evidence ratio was calculated as $Exp((AIC_1-AIC_2)/2)$, following the procedure suggested by Wagenmakers and Farrell (2004). In the present case, evidence ratio indicates how many times a model that includes a certain fixed effect is more likely to be the best model (in terms of minimizing the Kullback–Leibler discrepancy; Wagenmakers & Farrell, 2004) compared to the corresponding model that excludes that effect.

Causal errors

For causal errors, no significant main effect of Group emerged, $\chi^2(1) = .97$, $p = .32$ (model with Group: AIC = 904.38; model without Group: AIC = 903.36; evidence ratio = 0.60). Also, no significant main effect of Valence was found, $\chi^2(1) = .11$, $p = .74$ (model with Valence: AIC = 904.38; model without Valence: AIC = 902.49; evidence ratio = 0.39). However, a significant Group x Valence interaction was found on causal errors, $\chi^2(1) = 5.53$, $p = .02$ (model with the interaction: AIC = 900.85; model without the interaction: AIC = 904.38; evidence ratio = 5.84). Both random effects were significant: for Participants, $\chi^2(1) = 30.97$, $p < .001$ (full model: AIC = 900.85; model without Participants: AIC = 929.81); for Photographs, $\chi^2(1) = 124.70$, $p < .001$ (model without Photographs: AIC = 1023.55). The estimated probabilities of producing causal errors in the two groups and in the two conditions of valence are reported in Figure 2.1. See Table 2.1 for detailed information on the model, including estimated parameters and odds ratios.

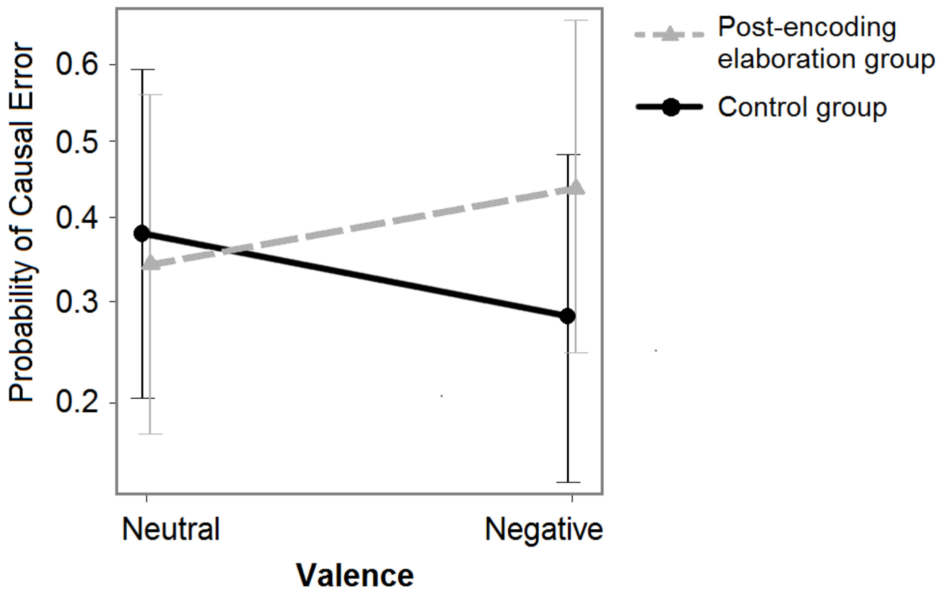

Figure 2.1. Estimated probability of causal error by Group and Valence for Experiment 1. Error bars represent 95% confidence intervals.

Gap-filling errors

For gap-filling errors, a significant main effect of Group was found, $\chi^2(1) = 5.32$, $p = .02$ (model with Group: AIC = 2380.70; model without Group: AIC = 2384.0; evidence ratio = 5.21); analysis of parameters (see Table 2.1) indicated that the probability of producing gap-filling errors was higher in the post-encoding elaboration group than in the control group. No significant main effect of Valence was found, $\chi^2(1) = 1.52$, $p = .22$ (model with Valence: AIC = 2380.7; model without Valence: AIC = 2380.2; evidence ratio = 0.78). Furthermore, no significant Group x Valence interaction emerged on gap-filling errors, $\chi^2(1) = .69$, $p = .41$ (model with the interaction: AIC = 2382.0; model without the interaction: AIC = 2380.7; evidence ratio = 0.52). Both random effects were significant: for Participants, $\chi^2(1) = 204.04$, $p < .001$ (full model: AIC = 2380.7; model without Participants: AIC = 2582.7); for Photographs, $\chi^2(1) = 326.26$, $p < .001$ (model without Photographs: AIC = 2704.9). The estimated probabilities of producing gap-filling errors in the two groups and in the two conditions of valence are reported in Figure 2.2. See Table 2.1 for detailed information on the model.

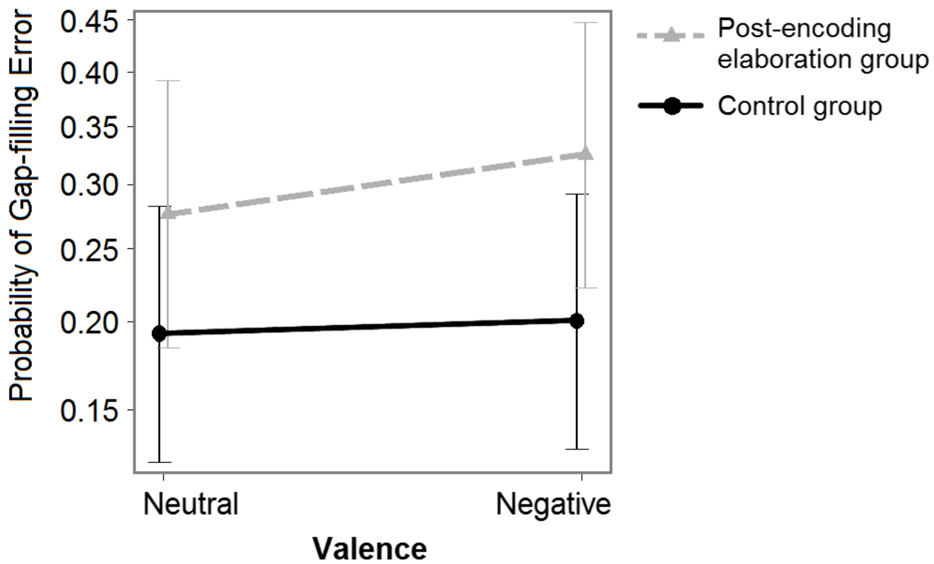

Figure 2.2. Estimated probability of Gap-filling Error by Group and Valence for Experiment 1. Error bars represent 95% confidence intervals.

Accuracy

For hits, no significant main effect of Group was found, although a tendency emerged, $\chi^2(1) = 3.40$, $p = .07$ (model with Group: AIC = 2917.2; model without Group: AIC = 2918.6; evidence ratio = 2.01); contrasts indeed showed that the probability of producing Hits was slightly higher in the control group than in the post-encoding elaboration group. No significant main effect of Valence was found either, $\chi^2(1) = .60$, $p = .44$ (model with Valence: AIC = 2917.2; model without Valence: AIC = 2915.8; evidence ratio = 0.50). Finally, no significant Group x Valence interaction emerged on Hits, $\chi^2(1) = 1.38$, $p = .24$ (model with the interaction: AIC = 2917.8 ; model without the interaction: AIC = 2917.2; evidence ratio = 0.74). As no significant fixed effects were found, significance of random effects are not reported. The estimated probabilities of Hits in the two groups and in the two conditions of valence are however displayed in Figure 2.3. See Table 2.1 for detailed information on the model.

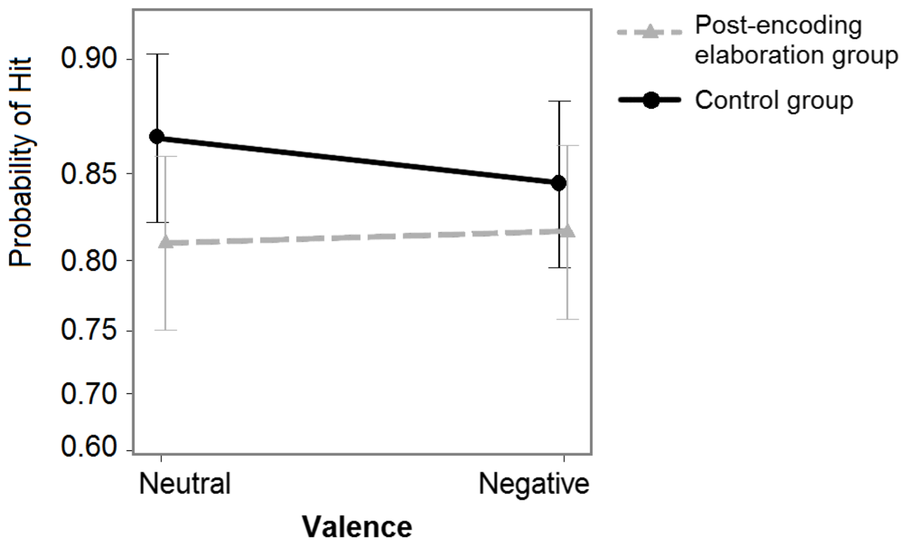

Figure 2.3. Estimated accuracy (i.e. probability of hit) by Group and Valence for Experiment 1. Error bars represent 95% confidence intervals.

Table 2.1. Fixed effects of Group, Valence, and Group x Valence on causal errors, gap-filling errors and hits, in Experiment 1, using logistic mixed-effects models.

Fixed effect	*B*	*SE*	*Odds ratio*	χ^2*(df)*
Dependent variable: Causal errors				
Group				.97 (1)
Post-encoding elaboration	.25	.25	1.29	
Valence				.11 (1)
Negative	-.06	.17	.94	
Group x Valence				5.53* (1)
Post-encoding elab. x Negative	.84	.35	2.31*	
Dependent variable: Gap-filling errors				
Group				5.32* (1)
Post-encoding elaboration	.56	.24	1.76*	
Valence				1.52 (1)
Negative	.13	.11	1.14	
Group x Valence				.69 (1)
Post-encoding elab. x Negative	.18	.21	1.20	
Dependent variable: Hits				
Group				3.40 (1)
Post-encoding elaboration	-.31	.16	.74	
Valence				.60 (1)
Negative	-.08	.16	.93	
Group x Valence				1.38 (1)
Post-encoding elab. x Negative	.23	.19	1.28	

Note. Baseline category for Group was "control group", baseline category for Valence was “neutral”. Random effects were Participants and Photographs. Number of observations was 768 for causal errors, 2304 for gap-filling errors, and 3072 for hits. Number of photographs was 8 for causal errors, 48 for gap-filling errors, and 56 for hits. Number of participants = 96. *$p < .05$.

Additional analysis on recalled scripts in the post-encoding elaboration group

As it was hypothesized that post-encoding elaboration would moderate the effects of valence on recognition via a preferential focus on emotional aspects, free-recall reports from participants in the post-encoding elaboration group were examined. Because instructions were informal, generally requiring to describe "what happened" in the viewed episodes, it was difficult to define quantitative variables from the written reports; however, it was possible to define which scripts were mentioned by each participants and which were not (as a proxy for which scripts were at least partially elaborated and which were not). Two independent judges read the reports and assigned, for each participant, "1" to scripts that were mentioned and "0" to scripts that were not mentioned. Very few cases of discrepancy between the two judges were discussed together until an agreement was reached.

As expected, mixed effects logistic regression (with scripts and participants as random effects) showed that valence had a significant effect on probability of mentioning scripts, $\chi^2(1) = 13.39$, $p < .001$ (estimated probability of mentioning a script was .74 when valence was neutral and .91 when valence was negative). Having mentioned a script, however, did not in turn directly predict the probability of committing causal error for that script, $\chi^2(1) < .01$, $p = .94$ (estimated probability of causal errors was .39 for both mentioned and non-mentioned scripts), but it directly predicted the probability of committing gap-filling errors, $\chi^2(1) = 6.24$, $p = .01$ (estimated probability of gap-filling errors was .38 for mentioned scripts and .23 for non-mentioned scripts), as well as the probability of correctly recognizing target photographs (i.e., the probability of hits), $\chi^2(1) = 9.87$, $p = .002$ (estimated probability of hits was .84 for mentioned scripts and .75 for non-mentioned scripts).

2.2.3 Discussion

The present experiment newly examined the effect of post-encoding elaboration on the production of inference-based memory errors, particularly for negative vs. neutral events. The main finding was that post-encoding elaboration increased the propensity to incur causal errors for negatively charged (but not neutral) events. Furthermore, the elaboration increased the propensity to incur gap-filling errors across the board. The results generally confirmed the expectations, although with some exceptions.

With regard to causal errors, the opposite patterns that emerged in the two groups were predicted on the basis of previous literature; indeed, the fact that participants who only performed the recognition task (without further re-elaboration) were less likely to incur negative than neutral false memories is consistent with the idea that emotional material encourage a more detailed and careful encoding, thus reducing distortions and false memories (Kensinger & Schacter, 2006b; Pesta et al., 2001). On the contrary, participants who re-elaborated the viewed episodes showed the opposite pattern. A two-step process was hypothesized to underlie this finding. First, it is known that emotionally charged events are more likely to be the focus of subsequent elaboration (Christianson & Engelberg, 1999; Walker et al., 2009), and indeed participants in the present study were more likely to mention the episodes having a negative outcome than those having a neutral outcome. Second, it is known that rehearsal of encoded material may lead to increased memory intrusions (e.g. Roediger & McDermott, 1995; Zaragoza et al., 2011), likely due to boosted reconstructive processes, in an attempt to bring coherence to the complexity of an event (Bergman & Roediger, 1999). Reconstructive processes may have been particularly relevant in the case of inference-based memory errors, which I examined in the present dissertation.

With regard to gap-filling errors, an across-the-board increase in the occurrence of false memories was observed. No interaction between group and valence emerged in this case, but it was expected; indeed, valence was manipulated through the outcomes of the episodes, which are temporally continuous and logically tied to the photographs representing the causal antecedents of the outcomes (i.e. to the causal errors), while they are less strictly related to the rest of the script. Nonetheless, it is interesting to note that post-encoding elaboration increased the tendency to produce false memories concerning aspects that fill the gaps between the scenes, thus confirming the notion that reconstructing an event leads in fact to manipulate and possibly distort the original memory trace (as first suggested by Bartlett, 1932). Consistently with this view, additional analysis showed that gap-filling errors (as well as hits) were more likely for episodes that were mentioned (and thus, to a certain extent, re-elaborated) than for those that were not mentioned in the written reports.

Some aspects still remain unclear, and raise new questions. First, it could be expected to observe a main effect of group not only for gap-filling errors, but also for causal errors; indeed, while the group-valence interaction in the latter case is of great interest, it is not clear why post-encoding elaboration did not increase, albeit to a smaller extent, also the probability of incurring neutral causal errors. Furthermore, although emotional episodes were more likely to be mentioned, being mentioned did not in turn directly increase causal errors probability. One hypothesis is that, since causal errors stem from an inferential elaboration concerning a very specific episodic aspect, an episode just being mentioned in its entirety is not a proper index of the fact that the specific causal episode has been elaborated. This should be investigate by more in-depth research. In general, however, a limitation of the present study is that the amount of evidence in favour of the effects, both in the case of causal and gap-filling errors, was not large. Furthermore, also the size of the effects (as it can be seen from the estimated probability in the figures, as well as from the *odds ratios* in Table 2.1) is limited; the estimated probability of gap-filling errors goes from around .20 in the control group to around .30 in the post-encoding elaboration group, while the probability of causal errors in the negative episodes goes from just below .30 in the control group to just above .40 in the post-encoding elaboration group. This suggest that a large portion of these probabilities depend on other aspects, which will need to be investigated. Finally, in the present experiment valence and arousal were inherently confounded; showing negatively arousing events was decided in order to resemble ecological situations that could be forensic-relevant (i.e. memory of potential crimes); however, future research may try to extend the results presenting positive events or low-arousal negative events.

Despite some limitations, the present study offers important suggestions, and practical implications can be derived. Indeed, while rehearsal and memory testing may help to improve long-term retention (e.g. Roediger & Karpicke, 2006), the present study indicates that free, unguided elaboration of witnessed events may have undesired effects, such as increasing inferential false memories. From a forensic point of view, this may indicate that repeated interviews should be avoided, especially with regard to negatively charged events; however, it may be interesting for future research to investigate how post-encoding elaboration (assuming that in certain cases it is inescapable) could be guided to minimize the occurrence of inference-based memory errors.

3. INDIVIDUAL DIFFERENCES IN THE OCCURRENCE OF INFERENTIAL FALSE MEMORIES FOR EMOTIONAL EVENTS IN INDIVIDUALS WITH EMOTIONAL PROBLEMS

3.1 Introduction

As previously mentioned, the memory-emotion interplay has been considered not only with regard to the emotionality of encoded material, but also in terms of how mood and affective states influence memory performance, as well as how the two aspects interact. Bower (1981) was one of the first who systematically studied and reported effects of mood-congruency, i.e. effects by which memory is facilitated when material is characterized by the same emotional valence as the affective state of the rememberer. This phenomenon has been reported also in the case of false memories (Ruci, Tomes, & Zelenski, 2009); as the authors used the DRM paradigm, they argued that this was due to increased activation of the memory nodes that are related to current mood, which would make them more easily accessible. While a number of studies investigated the effect of transient mood states on false memory (e.g. Storbeck & Clore, 2011), relatively little is known about the effects of stable and long-lasting conditions, such as individual traits or emotional disorders (i.e. depression and anxiety). While transient negative mood may have beneficial effects on memory and even on other general aspects of cognitive functioning (Forgas, 2013), long-lasting depression has opposite and clearly deleterious effects (Burt, Zembar, & Niederehe, 1995; Gotlib & Joormann, 2010). Emotional disorders are in general characterized by specific patterns of reasoning, attitude and interpretations of the events. Specifically, depression is accompanied by “increased elaboration of negative information, by difficulties disengaging from negative material, and by deficits in cognitive control when processing negative information” (Gotlib & Joormann, 2010).

Similarly, anxiety is characterized by attentional and memory biases for negative stimuli, especially if they are threat-related (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van Ijzendoorn, 2007; Mitte, 2008). Both anxiety and depression thus entail an abnormal processing of negative information, which in various ways seems to affect memory. Detecting the specific cognitive biases that underlie emotional disorders is important to understand which mechanisms are involved in their pathogenesis and maintenance. Emotional disorders themselves have been conceptualized as a vicious circle between a systematically biased interpretation of the world and the resulting clinical symptoms (Teasdale, 1983); in this light, enhanced memory accessibility of negative information may therefore exacerbate emotional symptoms (Joormann, Teachman, & Gotlib, 2009).

Research began to investigate emotional false memory in individuals with emotional disorders only recently, and existing evidence is still partial and have limitations. One common finding is that individuals with depressive disorder are more prone than the general population to falsely remember negatively charged emotional items (Howe & Malone, 2011; Joormann et al., 2009; Moritz, Voigt, Arzola, & Otte, 2008; Yeh & Hua, 2009). Although it is not yet fully clear what is the mechanism that underlies this phenomenon, a popular hypothesis is that depression is characterized by an increase in “resting” activation level of negative nodes within the memory network; as a consequence, spontaneous false memories related to negative concepts would be more likely to be committed, due to their higher baseline accessibility (Howe & Malone, 2011; Joormann et al., 2009). It is important to note that this explanation is well suited to the DRM paradigm, which is the procedure that – at least to my knowledge – has been used in all published studies on emotional false memories in individuals with depression and anxiety. This points to a limitation of the existing literature. Indeed, it is not clear what would happen using different paradigms, and investigating false memories that do not arise from spreading of activation or reliance on semantic gist, as in the case of the DRM paradigm.

Furthermore, it is unknown what would happen when false memories stem from the interpretation of an emotional context even without testing inherently emotional items; this investigation is made possible by the inferential memory paradigm that was used in Experiment 1, in which the critical items (the most important of which being the causal antecedents, i.e. the equivalent of the "critical lures") are all non-emotional *per se*.

Aside from the type of false memory, other points that require further investigation are: a) whether enhanced false memory for negative material is specific to emotional problems that reach the clinical level, or may also be found in sub-clinical conditions; b) what happens when using positive material, as it is known that emotional disorders are characterized by abnormal elaboration of all emotional information, including positive one (Gotlib & Joormann, 2010); and c) whether the false memory bias is specific to depression, or it can be found also in the case of anxiety (i.e. the other important type of emotional disorder). With regard to the first point, Stea, Lee, and Sears (2013) recently found that individuals suffering from dysphoria at the sub-clinical level were more likely to commit false memory for negative DRM lists compared to control individuals; however, the pattern or results that they reported was not fully clear, as they also found increased correct recognition of negative items in dysphoric individuals, indicating the possibility of a response bias to negative material rather than a genuine false memory effect (Stea et al., 2013). Nonetheless, it is well known that sub-clinical symptoms of emotional disorders can be characterized by biases in cognitive processing of emotional material (e.g. Joormann, 2010; Krompinger & Simons, 2009; Mitte, 2008). With regard to the second point evidence is mixed. Indeed, while some studies (Howe & Malone, 2011; Joormann et al., 2009) found that the false memory bias accompanying depression was specific to negative or depression-relevant material, Moritz, Gläscher, and Brassen (2005) found a false memory bias generalized to all emotionally charged material; they suggested that this could be due to the fact that depressive thinking in fact involve rumination on positive concepts, although in a negative light (e.g. the “happiness” that is missing, the “joy of living” that has been lost, and so on). Indeed, there is evidence that depression is characterized by abnormal cognitive processing of both negative and positive information (e.g. Gotlib & Joormann, 2010). Finally, with regard to the last point, only one published study could be found on the effect of anxiety on emotional false memories, and it failed to find the expected result (Wenzel, Jostad, Brendle, Ferraro, & Lystad, 2004); however, the authors examined only individuals with specific phobias and tested false memories using DRM word lists having participants’ own phobic objects as the critical lures. This may have led to a mix of different processes: enhanced accessibility to the critical lure, which would increase false memory occurrence, and its rejection on the basis of the perceived salience and memorability (e.g. “Had I seen it, I would have certainly noticed!” – following a process similar to that described by Ghetti, 2003; see also the “distinctiveness heuristic”, Dodson & Schacter, 2002).

Hereinafter I describe two experiments that adds to the existing literature by examining new hypotheses concerning the relationship between anxiety and depression symptoms and the production of inferential false memories for emotional events. To this purpose, the same paradigm based on pictorial scripted material that was used in Experiment 1 has been employed. While in Experiment 2 I focused on individuals with strong presence of internalizing symptoms, in Experiment 3 the specific case of trait anxiety was considered; furthermore, in Experiment 3 positively charged material was included in the paradigm. The specific hypotheses are detailed below.

3.2 Experiment 2: The role of sub-clinical internalizing symptoms[2]

The purpose of Experiment 2 was to investigate inferential false memories for emotionally charged events in individuals with strong internalizing symptoms. As a control group, individuals with average to low levels of internalizing symptoms were tested. Based on the extant literature, it was hypothesized that the probability of committing false memories for negative vs. neutral events would have shown different patterns in internalizing and control participants. In particular, it was expected that while negatively emotional events would have been accompanied by a lower probability of committing false memories compared to neutral events in control participants (consistently with the general notion that negative material reduces memory distortions; e.g. Kensinger & Schacter, 2006b, 2008), this protective effect would have disappeared – or would have been even reversed – in participants with strong internalizing symptoms. The latter case was hypothesized on the basis of previous findings on increased negative false memories in individuals with emotional disorders (e.g. Joormann et al., 2009), but bearing in mind that in the present case there are three fundamental differences, that have both theoretical and practical implications: a) the present study focuses on participants who are characterized by general internalizing symptoms at the subclinical level, and not by a clinical diagnosis (as it is explained below, symptoms of anxiety vs. depression were not considered separately because they were found to correlate very strongly, suggesting that it would be appropriate to merge them into a single dimension); b) inferential instead of associative false memories are analysed; c) the critical items that are used to test emotional false memories are logically linked to emotional contexts but not emotional themselves. Therefore, in the present case it was hypothesized that, since individuals with depressive and

[2] Results reported in Experiment 2 have been partially described in the following article: Toffalini, E., Mirandola, C., Drabik, M. J., Melinder, A., & Cornoldi, C. (2014). Emotional negative events do not protect against false memories in young adults with depressive-anxious personality traits. *Personality and Individual Differences, 66*, 14–18.

anxious traits (even at the sub-clinical level) have the tendency to focus their attention, rehearse and over-elaborate negative material (Joormann, 2010; Mitte, 2008), they would be highly likely to commit inference-based false memories for negatively charged events (similarly to participants who were asked to re-elaborate viewed material in Experiment 1).

Finally, just as in Experiment 1, it was expected that emotionality of material would have affected causal errors – to which it is more closely tied, as previously explained – but not necessarily the other variables. With regard to gap-filling errors and hits, they were not expected to vary across groups, due to the fact that significant impairments in the general functioning of memory would be expected in the case of clinical disorders (e.g. Burt et al., 1995) but not at the sub-clinical level.

3.2.1 Method

Participants

Participants were selected through a screening based on the Q-Pad questionnaire (Sica, Chiri, Favilli, & Marchetti, 2011; see Materials section) on a group of 168 students attending the last year of secondary education in three different high schools in Northern Italy. Participants who exceeded the 80^{th} percentile in the combined anxiety-depression scale of the Q-Pad were assigned to the "internalizing group" (*N* = 30, mean age = 18.38 years, SD = 1.19, 22 females), while an equal number of participants, matched for gender and with similar age, who were below the 60^{th} percentile in all the Q-Pad scales expressing malaise, were assigned to the control group (*N* = 30, mean age = 18.29, SD = 1.21, 22 females). Both the screening and the subsequent memory experiment were conducted during the school hours. All participants provided written and oral consent to participate in the experiment. For all individuals under 18 years of age, written parental permission was obtained prior to the study.

Materials and procedure

The Q-Pad questionnaire

The Q-Pad (Questionario per la valutazione della psicopatologia in adolescenza – Questionnaire for the assessment of psychopathology in adolescence; Sica et al., 2011) is a nine-scale, 81-item questionnaire that has been developed to assess the presence of common psychopathological symptoms within the adolescent and young-adult population, covering a range of dimensions that are typical of the youth malaise (the scales include body dissatisfaction, anxiety, depression, substance abuse, interpersonal conflicts, family issues, uncertainty about the future, psychosocial risk, self-esteem/well-being). Responses to items are given on a 4-point Likert scale ranging between 1 (completely false for me, not describing my situation) to 4 (completely true for me, absolutely describing my situation). Raw score of each scale is computed as the algebraic sum of the corresponding items. Final scores are expressed in percentiles based on the normative data provided by Sica et al. (2011), who standardized the questionnaire on a sample of 1454 youths in a range between 14 and 19 years of age (normative data are provided for different age groups as relevant). Cronbach's $\alpha \geq .80$ for each scale in the present screening sample confirmed good to excellent reliability of the questionnaire. As the anxiety and the depression scales were very strongly correlated, $r(168) = .76$, $p < .001$, it was not possible to distinguish between different profiles of "internalizing" individuals (e.g. between "purely anxious" vs. "purely depressed"), and a combined scale was used in the present study (a convenience that has also been confirmed by the authors of the questionnaire). The items composing the anxiety and the depression scales of the Q-Pad are reported in Appendix B.

Pictorial stimuli and procedure

All pictorial stimuli that were used during the encoding and the recognition phases, as well as the procedure, were the same as in Experiment 1. The only procedural differences were that all participants were required to complete distracting filler tasks during the 15 minutes retention interval (i.e. there was no "post-encoding elaboration" condition), and that they were tested in a quiet room within their own school (instead of in a laboratory setting).

3.2.2 Results

As in Experiment 1, causal errors, gap-filling errors, and hits were analysed. As they were treated as repeated measurements of a binomial response, a logistic mixed-effects model approach was used (Jaeger, 2008). Again, fixed effects were Group, Valence, and their interaction, while random effects were Participants and Photographs. AIC (Akaike, 1974) was also reported, and evidence ratio based on the Akaike weights (Wagenmakers & Farrell, 2004) was used to quantify the evidence in favour of each fixed effect (see Experiment 1).

Causal errors

For causal errors, a significant main effect of Group was found, $\chi^2(1) = 20.60$, $p < .001$ (model with Group: AIC = 550.65; model without Group: AIC = 569.25; evidence ratio = 10938.02). No significant main effect of Valence was found, $\chi^2(1) = .62$, $p = .43$ (model with Valence: AIC = 550.65; model without Valence: AIC = 549.27; evidence ratio = 0.50). Crucially, a significant Group x Valence interaction was found on causal errors, with strong evidence, $\chi^2(1) = 12.58$, $p < .001$ (model with the interaction: AIC = 540.08; model without the interaction: AIC = 550.65; evidence ratio = 197.35); the interaction seems to qualify the main effect of Group; indeed, as it can be seen in Figure 3.1, the two groups diverge in the probability of committing false memory in the negative rather than in the neutral condition.

Both random effects were significant: for Participants, $\chi^2(1) = 3.86$, $p = .04$ (full model: AIC = 540.08; model without Participants: AIC = 541.93); for Photographs, $\chi^2(1) = 50.65$, $p < .001$ (model without Photographs: AIC = 588.72). The estimated probabilities of producing causal errors in the two groups and in the two conditions of valence are reported in Figure 3.1. See Table 3.1 for detailed information on the model, including estimated parameters and odds ratios.

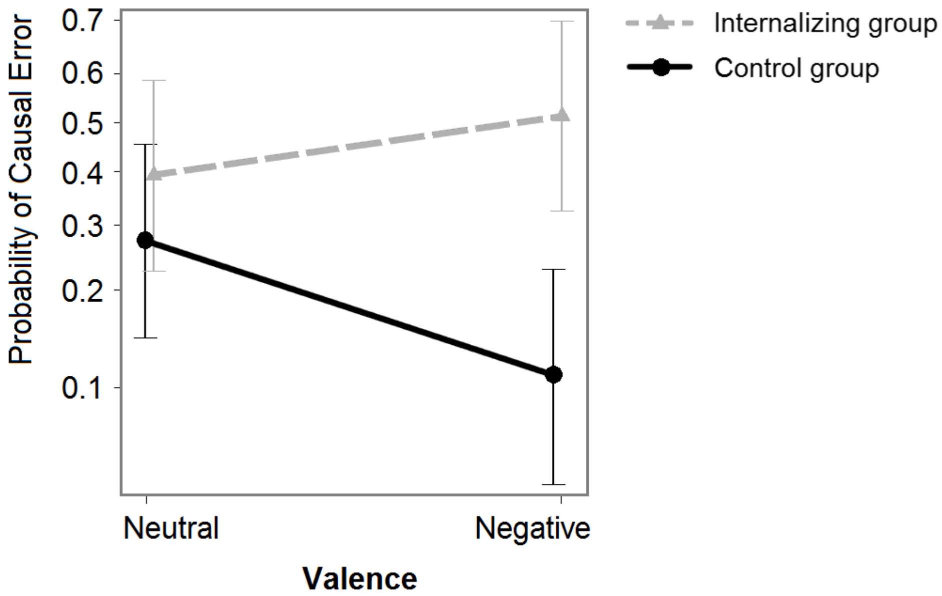

Figure 3.1. Estimated probability of causal error by Group and Valence for Experiment 2. Error bars represent 95% confidence intervals.

Gap-filling errors

For gap-filling errors, no significant effect of Group was found, $\chi^2(1) = 1.30$, $p = .25$ (model with Group: AIC = 1222.0; model without Group: AIC = 1221.3; evidence ratio = 0.70). No significant main effect of Valence was found either, $\chi^2(1) < .001$, $p = .98$ (model with Valence: AIC = 1221.98; model without Valence: AIC = 1219.98; evidence ratio = 0.37). No significant Group x Valence interaction emerged, although there was a tendency accompanied by a very weak degree of evidence, $\chi^2(1) = 3.08$, $p = .08$ (model with the interaction: AIC = 1220.89; model without the interaction: AIC = 1221.98; evidence ratio = 1.73). Both random effects were significant: for Participants, $\chi^2(1) = 64.18$, $p < .001$ (full model: AIC = 1220.89;

model without Participants: AIC = 1283.08); for Photographs, $\chi^2(1) = 157.64$, $p < .001$ (model without Photographs: AIC = 1376.53). The estimated probabilities of producing gap-filling errors in the two groups and in the two conditions of valence are reported in Figure 3.2. See Table 3.1 for detailed information on the model.

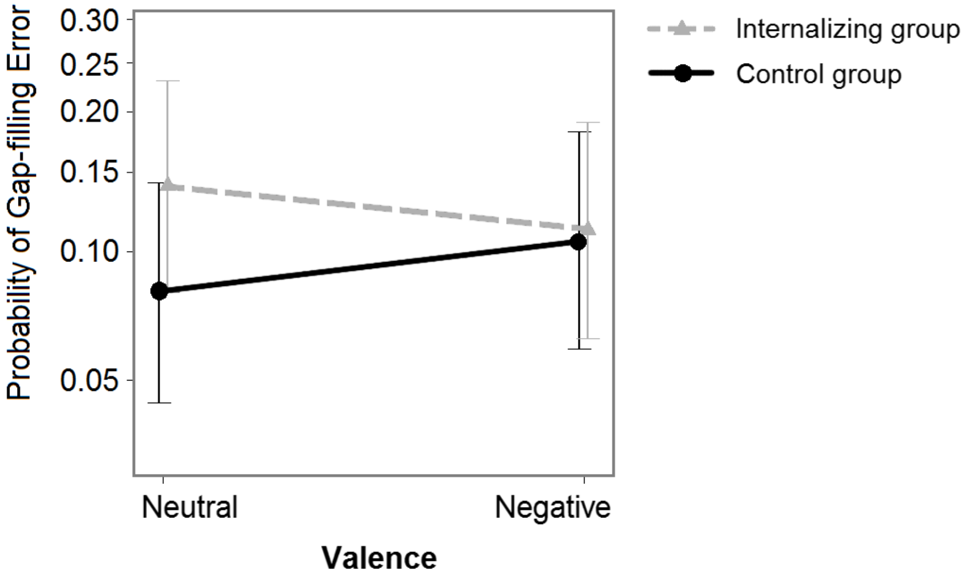

Figure 3.2. Estimated probability of Gap-filling Error by Group and Valence for Experiment 2. Error bars represent 95% confidence intervals.

Accuracy

For hits no significant fixed effects were found. For Group, $\chi^2(1) = .17$, $p = .68$ (model with Group: AIC = 1719.61; model without Group: AIC = 1717.78; evidence ratio = 0.40). For Valence, $\chi^2(1) = .03$, $p = .86$ (model with Valence: AIC = 1719.61; model without Valence: AIC = 1717.64; evidence ratio = 0.37). Finally, no significant Group x Valence interaction emerged, $\chi^2(1) = .68$, $p = .41$ (model with the interaction: AIC = 1720.92; model without the interaction: AIC = 1719.61; evidence ratio = 0.74). As no fixed effects emerged, significance of random effects are not reported. The estimated probabilities of hits in the two groups and in the two conditions of valence are however shown in Figure 3.3. Detailed information on the models is reported in Table 3.1.

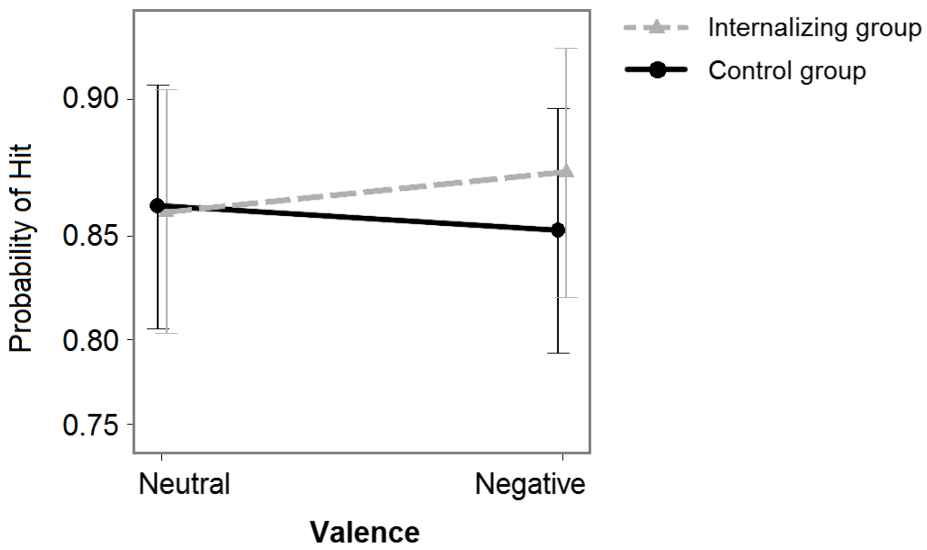

Figure 3.3. Estimated accuracy (i.e. estimated probability of hit) by Group and Valence for Experiment 2. Error bars represent 95% confidence intervals.

Table 3.1. Fixed effects of Group, Valence, and Group x Valence on causal errors, gap-filling errors and hits, in Experiment 2, using logistic mixed-effects models.

Fixed effect	*B*	*SE*	*Odds ratio*	$\chi^2(df)$
Dependent variable: Causal errors				
Group				20.60*** (1)
Internalizing	1.26	.27	3.51***	
Valence				.62 (1)
Negative	-.17	.22	.84	
Group x Valence				12.58*** (1)
Internalizing x Negative	1.62	.46	5.05***	
Dependent variable: Gap-filling errors				
Group				1.30 (1)
Internalizing	.34	.29	1.41	
Valence				< .01 (1)
Negative	< .01	.15	1.00	
Group x Valence				3.08 (1)
Internalizing x Negative	-.56	.31	.57	
Dependent variable: Hits				
Group				.17 (1)
Internalizing	.09	.21	1.09	
Valence				.03 (1)
Negative	.02	.13	1.02	
Group x Valence				.68 (1)
Internalizing x Negative	.21	.25	1.24	

Note. Baseline category for Group was "control group", baseline category for Valence was “neutral”. Random effects were Participants and Photographs. Number of observations was 480 for causal errors, 1440 for gap-filling errors, and 1920 for hits. Number of photographs was 8 for causal errors, 48 for gap-filling errors, and 56 for hits. Number of participants = 60. ***$p < .001$.

3.2.3 Discussion

Experiment 2 was designed to investigate how a strong presence of internalizing symptoms affects the production of false memories for emotional vs. neutral events. Results showed that individuals with strong internalizing symptoms and control participants have different patterns in the probability of committing inferential false memories as a function of the emotionality of encoded material. As hypothesized, while false memories were less likely for emotional than neutral material in control participants, the opposite happened in participants with strong internalizing symptoms. It is important to note that this pattern was specific to causal errors, i.e. to the aspects that represent the proximal causes of the viewed (emotional vs. neutral) effects, and that are most crucial to understand the specific happenings. On the contrary, no relevant differences between the two groups emerged in the case of gap-filling errors and hits, indicating that these aspects are little or no affected by emotionality of the outcome embedded in the script; this also suggests that the strong presence of internalizing symptoms at the sub-clinical level does not entail general impairments in memory functioning (i.e., with the major exception of causal errors, the performance was similar across the two groups).

The main result is consistent with previous literature, and extends it in important ways. With regard to control participants, the lower probability of committing negative false memory compared to the probability of committing neutral false memory replicates and strengthens evidence obtained in Experiment 1, and is consistent with the general notion that emotional material, in basic conditions, reduces the occurrence of memory distortions and false memories (Kensinger, 2007; Kensinger & Schacter, 2008). Most important, the fact that this protective effects was reversed in individuals with strong internalizing symptoms is consistent with previously reported mood-congruent false memory bias observed in individuals with emotional disorders, specifically in the case of depression (e.g., Howe & Malone, 2011; Joormann et al., 2009; Yeh & Hua, 2009). The present study also points to new important implications. First, the encoded material consisted of series of photographs representing everyday events, instead of word lists as in the DRM procedure; this allowed to investigate a conceptually different type of false memory, namely inferential memory errors (Hannigan & Reinitz, 2001). Second, unlike the critical lures in the DRM paradigm, the critical items that were used to test false memories in this experiment (i.e., photographs representing either gap-filling or the causal antecedents of specific outcomes) were not emotional themselves. These two points suggest that the mechanisms involved in false memory production in the present case are different from those described in previous studies that used the DRM procedure (e.g. Howe & Malone, 2011). Specifically, the increase in emotional causal errors observed in the internalizing group could not be attributed to the enhanced baseline activation of negatively charged material; rather, it may involve active reconstructive processes that focus on specific categories of events, namely negative events in the case of internalizing participants. This suggestion is consistent with the evidence that individuals with symptoms of depression have difficulties diverting attention away from negative information, and tend to over-elaborate it (Joormann, 2010; Joormann & Gotlib, 2008). According to this interpretation, a similar mechanism would have been at play in both Experiment 1 and 2, i.e. increased reconstructive processes fuelling inferential memory errors (these processes were clearly explicit in Experiment 1, but could have been implicit in Experiment 2). Another important point that emerged in the present study is that this emotional false memory bias could be observed at the sub-clinical level; this is consistent with findings of biased cognitive processing of emotional material in individuals suffering from symptoms of depression, and may suggest that these biases are *trait markers* of emotional disorders (e.g. Joormann, 2010; Krompinger & Simons, 2009; Mathews & MacLeod, 2005).

Despite the evidence offered by Experiment 2, a series of questions remain open. First, it is not clear what the specific contributions of anxiety vs. depression symptoms are. The very strong correlation between the two aspects did not allow to properly address the point in the present study; this was not surprising, as it is well know that depression and anxiety are frequently in comorbidity in clinical cases (Mineka, Watson, & Clark, 1998) and strongly correlate in the general population (Mitte, 2008). Previous literature would suggest that depression plays a major role (e.g. Howe & Malone, 2011; Joormann et al., 2009) and that the effect of anxiety on false memory is questionable (Wenzel et al., 2004). However, the evidence is not conclusive and more research is needed. A second question that remains open is whether emotional material associated with positive valence would also affect the propensity of committing false memories in individuals with internalizing symptoms. These two questions were the focus of Experiment 3.

3.3 Experiment 3: The role of trait anxiety[3]

Experiment 3 was aimed to extend the evidence offered by Experiment 2. The most important point that I addressed was the specific role of anxiety. As I reviewed before, previous studies brought evidence that depression enhances false memory for negative material (e.g. Joormann et al., 2009), leaving unclear whether the same was true also in the case of anxiety. To my knowledge, only one study addressed the point, and failed to find a false memory bias (Wenzel et al., 2004); however, as I explained before, the experiment conducted by Wenzel and colleagues (2004) had particular characteristics that may have limited their conclusions, particularly the fact that they used specific feared objects as the critical lures to

[3] Results reported in Experiment 3 have been partially described in the following article: Toffalini, E., Mirandola, C., Coli, T., & Cornoldi, C. (2015). High trait anxiety increases inferential false memories for negative (but not positive) emotional events. *Personality and Individual Differences, 75*, 201–204.

investigate emotional false memories in phobic individuals, perhaps causing a “distinctiveness heuristic” (Dodson & Schacter, 2002). Therefore it is possible that, when an emotional context (instead of a specific and distinctive lure) is used, false memories are boosted also in anxious individuals, due to their over-elaboration of negative information, and consistently with the evidence of a general memory bias for negatively arousing (i.e. threat-relevant) information (see Mitte, 2008).

The second point that I addressed in Experiment 3 concerned the effect of emotional material associated to positive valence. Previously reviewed studies on false memory in emotional disorders seem to indicate that positive material does not lead to enhanced false memory, but the evidence is mixed (see Moritz et al., 2005); furthermore, it is known that the cognitive processing of both negative and positive material is abnormal in emotional disorders (e.g. Mathews & McLeod, 2005). In brief, understanding whether a potential anxiety-related false memory bias is limited to negative material or it extends to all emotionally arousing information, may provide a useful insight into how anxiety affects the elaboration of emotional information.

Through a larger screening on a youth population, in Experiment 3 I managed to create and test a group of participants who had strong symptoms of anxiety but average or low presence of depressive symptoms. Furthermore, I created a whole new set of scripted episodes to be used as the encoding material, in order to include a positively arousing outcome in each episode (besides the negative and the neutral ones). For the rest, the experimental design and the hypotheses were the same as in Experiment 2.

3.3.1 Method

Participants

As in Experiment 2, participants were selected through a wide screening using the Q-Pad questionnaire (Sica et al., 2011). A total of 321 youths were screened, including 5^{th} grade high school students and undergraduate students attending their first year of university (age ranged between 17 and 21 years). To shorten the screening process, only the anxiety, depression, and self-esteem/well-being scales of the Q-Pad were used (the latter was included only to balance a questionnaire that would otherwise have been composed exclusively by items expressing malaise). Based on the scores at the Q-Pad scales, two groups were formed. The "anxious group" was composed of participants (N = 34, mean age = 19.34, SD = 2.00, 22 females) whose score at the anxiety scale exceeded the 80^{th} percentile, but whose score at the depression scale was below the 60^{th} percentile. The control group was composed of an equal number of participants (N = 34, mean age =19.39, SD = 1.99, 17 females) whose scores at both the anxiety and the depression scales were below the 60^{th} percentile. Cronbach's α was .87 for the anxiety scale and .85 for the depression scale in the screening sample, indicating very good reliability for both scales. As in Experiment 2, the two scales were strongly correlated, $r(321) = .65$, $p < .001$, but this time the larger sample size allowed to identify a sufficiently large group of individuals whose profile was specifically "anxious" (i.e. the "anxious group").

Consent, both written and oral, was obtained from all participants prior to the study. For all individuals under 18 years of age, written parental permission was obtained.

Materials and procedure

The experimental material and the procedure strictly followed those used in Experiment 2, the only difference being that the outcomes of the scripts included a positive condition of valence alongside a negative and a neutral one. To this purpose a new set of scripts, similar to those used for Experiment 1 and 2, were created, the details of which are described below.

Pictorial stimuli for encoding

Encoding stimuli consisted of a series of colour photographs representing 9 everyday episodes or scripts. A total of 21 photographs were created for each script. Out of them, 11 were shown during the encoding phase as targets, and represented the body of the script, while other 3 photographs, similar to previous ones, were used as script consistent distractors to examine gap-filling errors; target and script consistent distractors were counterbalanced across participants, just as in Experiments 1 and 2. Furthermore, 7 photographs were created for each script to depict cause-effect patterns. Out of them, one photograph depicts the single, common antecedent for each of three similar but mutually exclusive outcomes which vary in emotionality: one outcome is negatively arousing, one outcome is positively arousing, and the remaining is neutral. Each of the three alternative outcomes is depicted by 2 photographs. Emotionality of the presented outcomes was counterbalanced across participants, such as each of the three alternative outcomes was presented to one third of the participants, and each participants encoded 3 negative, 3 positive, and 3 neutral outcomes overall (for a total of 9). All scripts were shown sequentially without interruptions, just as in Experiments 1 and 2 and in previous studies (e.g. Lyons et al., 2010). Actors and settings differed across all 9 scripts to make them easy to distinguish. Furthermore, as in the previous two experiments, 5 script-inconsistent photographs were shown at the beginning of the encoding sequence, and 5 at the very end, to avoid primacy and recency effects. The encoding phase thus consisted of a total of 127 photographs.

Assessment of emotionality of the pictorial stimuli for encoding

Just as for the previous version of the false memory paradigm (i.e. that used in Experiments 1 and 2), a pilot study was conducted to establish whether the photographs representing the outcomes (i.e. 9 neutral vs. 9 positive vs. 9 negative outcomes) were actually different in terms of valence and arousal as they were intended to be. Twenty-one undergraduate students (who did not subsequently participated in the main experiment) rated each of the 27 outcomes in terms of their valence and arousal using the 9-point scales of the SAM (Bradley & Lang, 1994), just as it was done in the assessment of the pictorial material for Experiment 1; the procedure was exactly the same.

Means, standard deviations, and 95% confidence intervals of the means (based on the t distribution) for the ratings of valence and arousal of the outcomes were as follows:

- Valence of neutral outcomes: $M = 5.31$, $SD = 1.35$, 95% CI [5.11, 5.50];
- Valence of positive outcomes: $M = 7.41$, $SD = 1.36$, 95% CI [7.22, 7.61];
- Valence of negative outcomes: $M = 2.57$, $SD = 1.43$, 95% CI [2.36, 2.77];
- Arousal of neutral outcomes: $M = 2.21$, $SD = 1.67$, 95% CI [1.83, 2.31];
- Arousal of positive outcomes: $M = 4.12$, $SD = 2.51$, 95% CI [3.76, 4.48];
- Arousal of negative outcomes: $M = 5.34$, $SD = 2.32$, 95% CI [5.01, 5.67].

The differences between neutral, positive, and negative outcomes were thus in general large in terms of both valence and arousal:

- Valence: neutral vs. positive, Cohen's $d = 1.56$;
- Valence: neutral vs. negative, Cohen's $d = 1.97$;
- Valence: positive vs. negative, Cohen's $d = 3.47$;
- Arousal: neutral vs. positive, Cohen's $d = .96$;
- Arousal: neutral vs. negative, Cohen's $d = 1.62$;
- Arousal: positive vs. negative, Cohen's $d = .51$.

Therefore, while the ratings confirmed that the outcomes are in general really appropriate as for their emotionality, it also appeared that the positive and negative outcomes are not in fact equal in terms of arousal. Indeed, although both categories of outcomes are largely more arousing than the neutral outcomes, it was also found that negative outcomes are more arousing than positive ones, with an effect size that could be defined as medium (Cohen, 1988).

Pictorial stimuli for recognition

A sequence of 90 photographs in a randomized order was presented at the recognition test. As in the previous two experiments, 4 target photographs, 3 script-consistent distractors and, crucially, the photograph depicting the cause whose outcome had been shown during the encoding phase, were tested for each episode. The remaining 18 photographs were script-inconsistent, of which half were actually presented during the encoding phase.

3.3.2 Results

Data analysis was conducted with the same logic as in Experiments 1 and 2. Causal errors, gap-filling errors and hits were treated as repeated measurements of binomial responses, and were analysed using logistic mixed-effects models (Jaeger, 2008). Significance of fixed effects of Group, Valence, and their interaction were assessed through likelihood ratio tests for nested models (Pinheiro & Bates, 2000), and evidence ratio was reported to quantify the evidence in favour of each fixed effect (Wagenmakers & Farrell, 2004), as in the previous two experiments. Participants and Photographs were again inserted in all models as random effects.

A preliminary analysis on the raw scores at the Q-Pad scales showed that, despite the careful selection made on the basis of the percentiles, the two groups still differed in terms of the depression scores; for the control group: M = 10.32, SD = 2.01; for the anxious group: M = 11.91, SD = 2.12; $t(66) = -3.17$, p = .002. Depression and anxiety scores indeed positively correlated both within the control group (r = .49, $p < .001$) and within the anxious group (r = .32, p = .07). Nonetheless, both groups were considerably below the available norms for the Q-Pad depression scale (M = 14.30, SD = 4.9). However, to avoid any risk of a confounding effect of depression, the depression score (and its interaction with valence of material, were relevant) was included in all models as a control variable; the pattern of results were nearly identical.

Causal errors

As for causal errors, no significant main effect of Group was found, $\chi^2(1) = 1.86$, $p = .17$ (model with Group: AIC = 796.58; model without Group: AIC = 796.44; evidence ratio = 0.93). No significant main effect of Valence was found either, $\chi^2(2) = .39$, $p = .82$ (model with Valence: AIC = 796.58; model without Valence: AIC = 792.97; evidence ratio = 0.16). Importantly, a significant Group x Valence interaction was found, supported by strong evidence, $\chi^2(2) = 19.65$, $p < .001$ (model with interaction: AIC = 780.93; model without interaction: AIC = 796.58; evidence ratio = 2502.39). Both random effects were significant: for Participants, $\chi^2(1) = 20.50$, $p < .001$ (full model: AIC = 780.93; model without Participants: AIC = 799.43); for Photographs, $\chi^2(1) = 31.45$, $p < .001$ (model without Photographs: AIC = 810.37). The estimated probabilities of producing causal errors in the two groups and in the three conditions of valence are displayed in Figure 3.4. Detailed information on the models, including estimated parameters and odds ratios, is reported in Table 3.2.

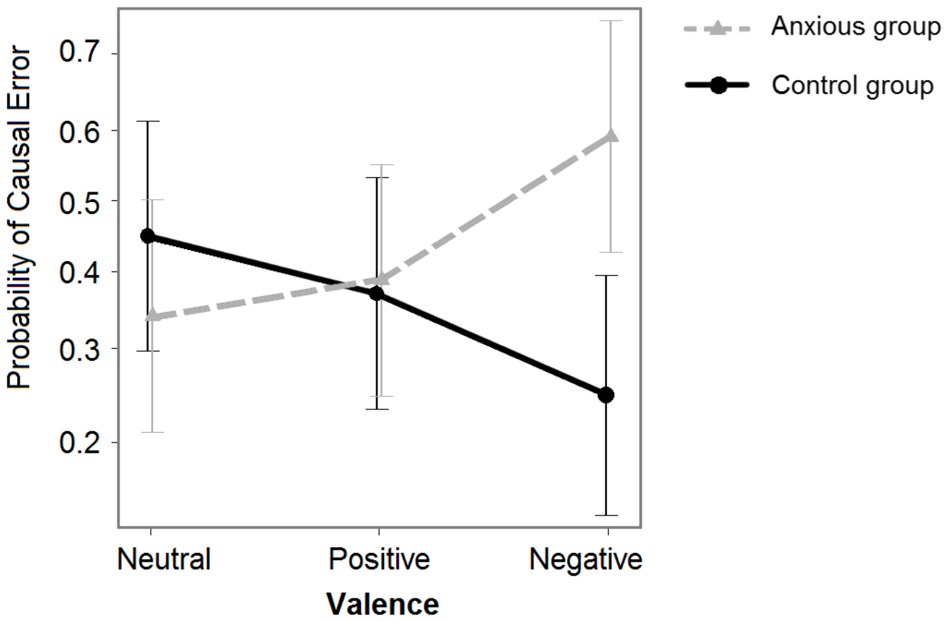

Figure 3.4. Estimated probability of causal error by Group and Valence for Experiment 3. Error bars represent 95% confidence intervals.

Gap-filling errors

For gap-filling errors, no significant effect of Group was found, $\chi^2(1) = .80$, $p = .37$ (model with Group: AIC = 1959.88; model without Group: AIC = 1958.68; evidence ratio = 0.55). However, a significant main effect of Valence was found, $\chi^2(2) = 7.76$, $p = .02$ (model with Valence: AIC = 1959.88; model without Valence: AIC = 1963.64; evidence ratio = 6.55); analysis of the parameters (see Table 3.2) and observation of the estimated probabilities (see Figure 3.5) indicate that this is due to gap-filling errors being less likely in the positive than in the negative condition, but this main effect seems to be fully qualified by a Group x Valence interaction. Indeed, a significant Group x Valence interaction was found, supported by a good degree of evidence, $\chi^2(2) = 9.64$, $p = .008$ (model with the interaction: AIC = 1954.24; model without the interaction: AIC = 1959.88; evidence ratio = 16.78); as it can be seen in Figure 3.5, this is due to anxious participants committing fewer gap-filling errors than control participants in the positive condition, while the two groups do not seem to differ in the other two conditions . Both random effects were significant: for Participants, $\chi^2(1) = 173.47$, $p < .001$ (full model: AIC = 1954.24; model without Participants: AIC = 2125.71); for Photographs, $\chi^2(1) = 41.79$, p

< .001 (model without Photographs: AIC = 1994.03). The estimated probabilities of producing gap-filling errors in the two groups and in the three conditions of valence are reported in Figure 3.5. Detailed information on the models is reported in Table 3.2.

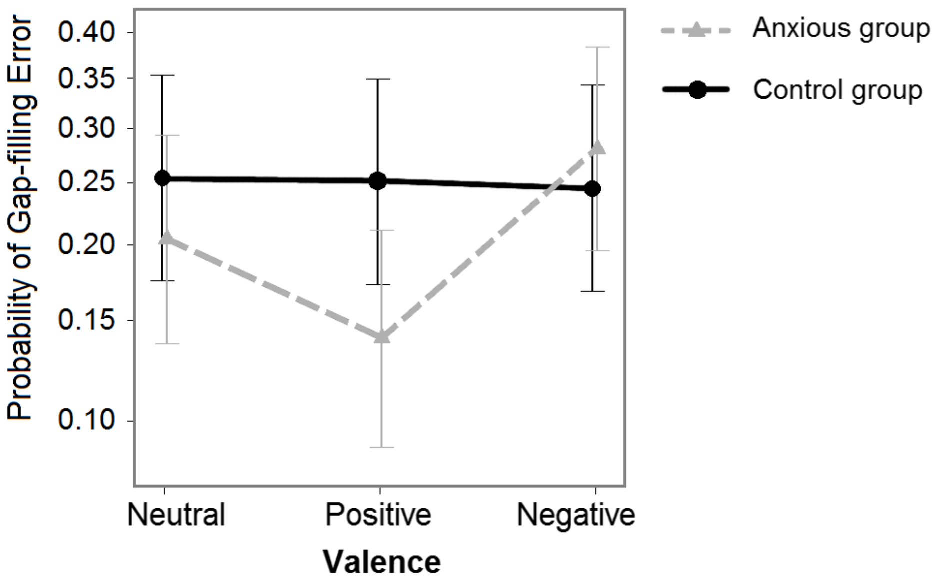

Figure 3.5. Estimated probability of Gap-filling Error by Group and Valence for Experiment 3. Error bars represent 95% confidence intervals.

Accuracy

For hits no significant fixed effects were found. For Group, $\chi^2(1) = .22$, $p = .64$ (model with Group: AIC = 2630.65; model without Group: AIC = 2628.87; evidence ratio = 0.41). For Valence, $\chi^2(2) = 1.44$, $p = .49$ (model with Valence: AIC = 2630.65; model without Valence: AIC = 2628.09; evidence ratio = 0.28). Finally, no significant Group x Valence interaction emerged, $\chi^2(1) = .43$, $p = .81$ (model with the interaction: AIC = 2634.22; model without the interaction: AIC = 2630.65; evidence ratio = 0.17). As no fixed effects emerged, significance of random effects are not reported. Nonetheless, the estimated probabilities of hits in the two groups and in the three conditions of valence are displayed in Figure 3.6. Detailed information on the models is reported in Table 3.2.

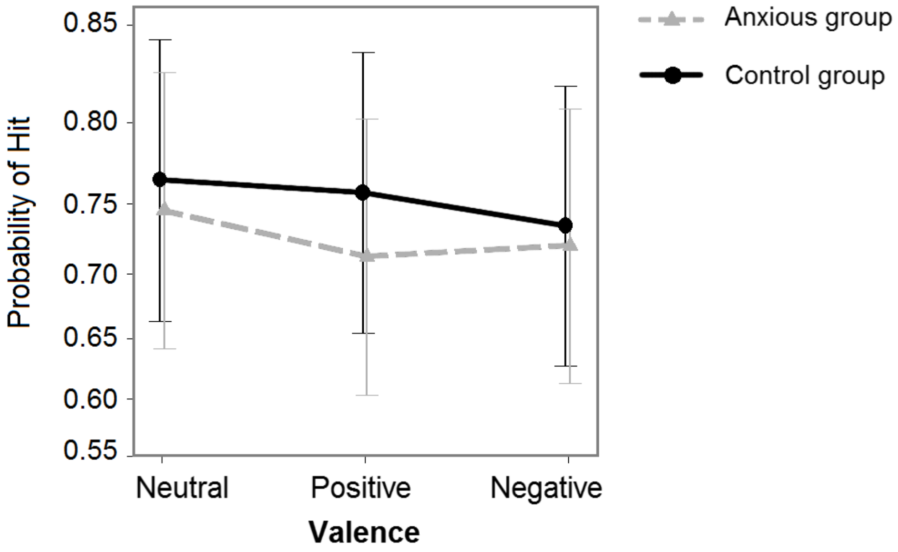

Figure 3.6. Estimated accuracy (i.e. estimated probability of hit) by Group and Valence for Experiment 3. Error bars represent 95% confidence intervals.

Table 3.2. Fixed effects of Group, Valence, and Group x Valence on causal errors, gap-filling errors and hits, in Experiment 3, using logistic mixed-effects models.

Fixed effect	*B*	*SE*	*Odds ratio*	χ^2*(df)*
Dependent variable: Causal errors				
Group				1.86 (1)
Anxious	.35	.26	1.42	
Valence				.39 (2)
Positive	-.06	.22	.94	
Negative	.07	.22	1.07	
Group x Valence				19.65*** (2)
Anxious x Positive	.53	.44	1.71	
Anxious x Negative	1.94	.46	6.99***	
Dependent variable: Gap-filling errors				
Group				.80 (1)
Anxious	-.25	.28	.78	
Valence				7.76* (2)
Positive	-.22	.14	.80	
Negative	.18	.14	1.20	
Group x Valence				9.64** (2)
Anxious x Positive	-.44	.29	.65	
Anxious x Negative	.46	.28	1.59	
Dependent variable: Hits				
Group				.22 (1)
Anxious	-.14	.29	.87	
Valence				1.44 (2)
Positive	-.11	.12	.90	
Negative	-.14	.12	.87	
Group x Valence				.43 (2)
Anxious x Positive	-.12	.25	.89	
Anxious x Negative	.04	.25	1.04	

Note. Baseline category for Group was "control group", baseline category for Valence was “neutral”. Random effects were Participants and Photographs. Number of observations was 612 for causal errors, 1836 for gap-filling errors, and 2448 for hits. Number of photographs was 9 for causal errors, 54 for gap-filling errors, and 63 for hits. Number of participants = 68.
**p* < .05, ***p* < .01 ****p* < .001.

3.3.3 Discussion

In Experiment 3 the effect of high trait anxiety on the production of inferential false memories was examined. A key goal of Experiment 3 was to disentangle the effect of anxiety from the effect of depression, which was a question left open after Experiment 2. In fact, in the present study the anxious group still had higher depression scores than the control group; however, both groups were well below the mean score of the Q-Pad depression scale for the general youth population as reported by Sica et al. (2011); furthermore, the effect of anxiety was found even after controlling for the depression scores in the analysis. Having chosen a group of participants who have high trait anxiety but who are around or below the median in terms of their depression levels provides important information. Indeed, it has been suggested that, when anxiety and depression symptoms co-occurs (which is common, see for example Mineka et al., 1998), peculiar memory biases for emotional material can be found, which are different from those found in "pure" anxiety or depression (e.g. Bar-Haim et al., 2007; Tarsia, Power, & Sanavio, 2003). Previously published studies on false memory bias for emotional material in depression did not systematically control this aspect; indeed, only Howe and Malone (2011) excluded participants who had comorbid anxiety, while other studies (e.g. Joormann et al., 2009; Moritz et al., 2005; Yeh & Hua, 2009) either do not provide information on this point or do not exclude comorbidity.

This is, to my knowledge, the first study that reports a specific anxiety-related false memory bias for emotional information. The main result was that anxious individuals made more causal errors for negative – but not positive or neutral – events than control participants. This supports and extends previous findings showing that individuals who suffer from emotional disorders such as depression (see previously reviewed studies) and strong internalizing traits at the sub-clinical level (see Experiment 2) may be highly likely to commit false memories for emotional information. The fact that a memory bias was found in the case of anxiety at the sub-clinical level is consistent with previous research (Mitte, 2008)

Importantly, the negative events that I showed as part of the encoding material were also *arousing*. In previous research on false memory biases in depression, either negative but non-arousing verbal material was used (e.g., Joormann et al., 2009) or the distinction between valence and arousal was not explicitly considered (Yeh & Hua, 2009; although reading their DRM word lists suggest that negative material was also more arousing than neutral one; e.g. “destruction”, “violence”, and “sufferance” were among their negative critical lures). Negative arousing material is usually threat-relevant, and it is the type of information that anxious individuals are quicker at detecting and elaborating (Bar-Haim et al., 2007; Mitte, 2008). Therefore, the emotional material that I used could be especially suitable for research on memory and anxiety. Anxious individuals are known to be more likely to focus on, elaborate, and make inferences about threatening events compared to non-anxious individuals; this could provide a straightforward explanation of why anxious participants were found highly likely to commit inferential false memories for negative arousing events.

Two other results are worth mentioning. First, anxious participants were less likely than control participants to incur gap-filling errors within the episodes associated to positive outcomes. This had not been hypothesized, but is consistent with the idea that anxious participants focused on and elaborated in an extensive way the events that contained threat-related information (i.e. only the negative arousing events), possibly diverting their attention away from threat-inconsistent information (i.e. mainly from the positive events). Second, the fact that control participants were less likely to incur causal errors for negative than for neutral material replicates and strengthens the evidence obtained in Experiments 1 and 2, and is consistent with the hypothesis that, in basic conditions, emotional material protects against memory distortions (Kensinger & Schacter, 2008). Finally, with regard to the probability of committing causal errors for positive events, it also seems to be lower than the probability of committing causal errors for neutral events, which is consistent with the finding that positive emotional material also protects against false memories (e.g. Palmer & Dodson, 2009); however, in this case the evidence is weak (as it can be seen in Figure 3.4, the estimated probability of committing causal errors in the positive condition is included in the 95% confidence interval of the estimated probability of committing causal errors in the neutral condition), and thus it needs further replication, possibly with a larger sample size.

A series of questions remain open, and should be addressed by future research. First, the present pattern of results was obtained in a group of young adults, but extending the evidence through the entire range of adult age would be important. Second, the effect of anxiety could be explored on its continuum; indeed, in both Experiments 2 and 3 the focus was on the comparisons between extreme groups, and this was done to simplify research and seek for a clear pattern of results. However, a future experiment could try to test whether, for example, the effects of anxiety or internalizing traits on the production of false memories is linear and progressive, or if it is a threshold-like function. Finally, a comparison between the effects of high vs. low arousal events could be made; indeed, as I suggested before, it is possible that only high arousing negative events lead anxious participants to an increase in false memories.

4. WORKING MEMORY AND THE OCCURRENCE OF INFERENTIAL FALSE MEMORIES FOR EMOTIONAL EVENTS

4.1 Introduction

The previous chapter offered evidence that individual differences, particularly with regard to the level of internalizing traits, affect the occurrence of false memories for emotional events. It seems reasonable that also individual differences in cognitive abilities may have an impact. In this respect, working memory (WM) capacity could be of special importance, due to its involvement in the ability to memorize and elaborate stimuli while concurrently rejecting interfering information (De Beni, Palladino, Pazzaglia, & Cornoldi, 1998; Engle, 2002). In this chapter I describe two experiments investigating how WM capacity affect the production of inferential false memories for emotional and neutral events, but first I briefly review the existing literature on the interplay between WM and false memory.

WM has been defined as a multi-component, limited-capacity memory system that enables us to temporarily store and manipulate information (Baddeley, 2000, 2012). WM has been shown to serve a series of higher mental functions and to be strictly related to intelligence (e.g. Engle, Tuholski, Laughlin, & Conway, 1999). Importantly, it has critical implications also for episodic memory. In particular, WM is involved in the binding of different features and parts of presented stimuli, which allows us to create complex representations and to store them in memory without errors (Allen, Baddeley, & Hitch, 2006; Reinitz & Hannigan, 2004). In particular, Reinitz and Hannigan (2004) showed that WM processing is needed in order to avoid false memories deriving from the recombination of studied elements.

In the last decade, a number of studies have shown that individual differences in WM capacity are related to individual differences in the propensity to incur false memories. In particular, it has been found that high WM capacity predicts a reduced occurrence of false memories for the critical lures using the DRM procedure (Bixter & Daniel, 2013; Peters, Jelicic, Verbeek, & Merckelbach, 2007; Watson, Bunting, Poole, & Conway, 2005). Bixter and Daniel (2013) hypothesized that good WM capacity may allow to effectively encode information while at the same time using strategies to avoid false memories (for example identifying the critical element to subsequently reject it at recognition, i.e. the so-called identify-to-reject strategy; see Carneiro et al., 2012); consistently with this hypothesis, some studies have found that WM capacity actually predicts the occurrence of false memories only when participants are given specific warnings about the possibility of committing such memory errors (Bixter & Conway, 2013; Watson et al., 2005). However, other studies found that WM capacity has a significant protective effect against false memories even without providing any warning (e.g., Peters et al., 2007).

A protective effect of WM capacity against false memory was found also using different paradigms. In particular, Jaschinski and Wentura (2002) reported that participants with higher WM capacity were better able at resisting misleading information provided after encoding; furthermore, Gerrie and Garry (2007) found that participants with higher WM capacity were less prone to falsely recognize elements related to crucial aspects of viewed events (while no effects were found in the case of non-crucial elements). One hypothesis is that persons with greater WM capacity are able to create and store a more detailed and coherent mental representation of the encoded material (Jaschinski & Wentura, 2002), which is consistent with the notion that WM serves the ability to bind together different features of an event without committing mistakes (Reinitz & Hannigan, 2004). Finally, testing a very large sample of participants with a misinformation paradigm, Zhu et al. (2010) recently found that, while different variables related to cognitive abilities (including fluid intelligence) negatively predicted false memories occurrence, WM capacity had in fact the strongest effect; this confirms the convenience of focusing on WM in the present study.

To my knowledge, all published studies on the relationship between WM capacity and false memory used non-emotional material. Therefore it is not yet clear how WM capacity may differently affect the production of false memories for neutral vs. emotionally-charged events. However, hypotheses can be made.

The existing literature suggests that negative information may have impairing effects on WM performance (e.g. Kensinger, 2009). For example, it has been found that individuals are slower to respond to a WM task when material is negatively charged (Kensinger & Corkin, 2003), and that negative distracting stimuli interfere with the activity in the brain areas (i.e. in the prefrontal cortex) that are responsible for the executive control of WM – thus ultimately having detrimental effects on WM performance (e.g. Dolcos & McCarthy, 2006); furthermore, Osaka, Yaoi, Minamoto, and Osaka (2013) recently reported that, compared to neutral and positive distracting stimuli, negative ones are more difficult to inhibit during a WM task. Impairing effects on WM were reported using both arousing (e.g. Dolcos & McCarthy, 2006) and non-arousing (e.g. Osaka et al., 2013) negative stimuli.

If negative information has detrimental effects on WM performance, which in turn is crucial to accurately encode stimuli and ward off false memories (e.g. Peters et al., 2007; Reinitz & Hannigan, 2004), then we would expect negative material to give rise to more false memories. However, in most cases the opposite is found (e.g. Kensinger & Schacter, 2005, 2006b, 2008). It could thus be hypothesised that negative material has a twofold effect on the occurrence of false memories; on the one hand, it may interfere with WM processing, thus potentially leading to increased false memories; on the other hand, it may facilitate a detailed and careful encoding of the material at hand, thus protecting against memory errors. Normally, the "protective" effect seems to prevail, but in certain cases the "adverse" effects may emerge –

for example when available WM capacity is reduced. This hypothesis has been explored in Experiments 4 and 5.

4.2 Experiment 4: The role of individual differences in working memory capacity

In Experiment 4, the relationship between WM capacity at the level of individual differences and the propensity to incur inferential false memories for negative, positive, and neutral events was investigated. A relatively large sample of over one hundred young adults was recruited; participants were subjected to the same false memory paradigm as in Experiment 3. However, in the present study no groups were created, and WM capacity of each participants was measured using an active WM task (i.e. the *Categorization Working Memory Span* task, adapted from De Beni et al., 1998) that employs verbal material. The WM task was intended to measure the central executive aspect of WM; the fact that it used verbal material was considered appropriate due to the narrative structure of the encoded scripted material, the comprehension of which may involve verbal processing.

In line with the reasoning presented in the Introduction of this chapter, it was hypothesized that WM capacity could be related to the production of false memories, and that this relationship could be moderated by valence. In particular it was expected that, at medium or high levels of WM capacity, emotional events would be less likely to give rise to false memories (in keeping with the literature showing protective effects of emotional material), while at low levels of WM negative (but not positive) events would no longer be protected against false memories compared to neutral events. This was hypothesized because it is known that negative (and apparently not positive) material interfere with WM performance (e.g. Osaka et al., 2013), which in turn is required to avoid false memories (e.g. Peters et al., 2007);

therefore, in participants with low WM capacity, available WM resources may not be sufficient to counteract the adverse effect of negative material on false memories, which may thus become evident.

As in the previous experiments, the effect of valence was expected to be primarily found on causal errors, due to the fact that they are more strictly related to the emotional (or non-emotional) outcomes. Furthermore, WM capacity was expected to affect causal errors more than gap-filling errors; indeed, it has been shown that WM capacity predicts the occurrence of false memories only when they concern aspects that are crucial of a given event (Gerrie & Garry, 2007). Causal errors are considered to involve crucial aspects of an event (i.e. the antecedent of its specific outcome), while gap-filling errors are non-crucial (i.e. they concern aspects that are consistent with – but not essential for the comprehension of – the event in its entirety).

4.2.1 Method

Participants

The sample consisted of 103 undergraduate students (mean age = 22.50 years, SD = 1.99, females = 83) who attended a psychology course and received course credit in return for their participation. As for all the experiments described in this thesis, no participant had ever participated in any experiment involving the same paradigm or similar versions of it. Both written and oral informed consent was obtained from all participants prior to the study.

Materials and procedure

The pictorial stimuli used for encoding and recognition, as well as the procedure, were exactly the same as in Experiment 3; all participants were tested in a quiet laboratory room.

After the completion of the memory paradigm, participants were administered a verbal WM task (which lasted about 20 minutes) and a short version of the Q-Pad questionnaire (Sica et al., 2011), which included the anxiety, depression, and self-esteem/well-being scales. The presence of anxious and depressive symptoms was assessed since in the previous two experiments it was found that internalizing symptoms – at least when they are particularly pronounced –, are likely to affect emotional false memories. The Q-Pad was used for consistency with the previous experiments and because, as the authors (Sica et al., 2011) pointed out, some of the scales assessing aspects that are not specific to adolescence (as in the case of anxiety and depression), are appropriate also for young adults over 19 years of age. Reliability of both scales was good, with Cronbach's α = .78 for anxiety and α = .89 for depression, confirming the validity of the measure in our sample. Item scores were added to obtain the scores for the two scales.

Working Memory task

The *Categorization Working Memory Span* (CWMS; Borella, Carretti, Cornoldi, & De Beni, 2007, adapted from De Beni et al., 1998) task was used to measure working memory capacity at the level of individual differences. This task consists of lists of unrelated words being presented on a computer screen one after the other. Lists are composed of five words each, and are organized in sequences. Participants are required to read aloud each word and to: 1) remember the last word of each list (primary task); 2) press the space bar every time that a word indicating an animal appears on the screen (secondary task). At the end of each sequence of word lists, the final words had to be recalled in the correct order. The task became increasingly difficult as the number of lists within each sequence, and thus the number of final words to be remembered, increased from a span of 2 to a span of 6. Two sequences of the same length were presented for each span length, for a total of 10 sequences. An example of the stimuli used in the CWMS task is reported in Appendix C.

The primary index of working memory capacity was the number of final words remembered in the correct order, which consequently ranged between 0 and 40. The frequencies of omissions and false alarms at pressing the space bar when reading the name of an animal were also considered to make sure that participants were not neglecting the secondary task. As such frequencies were very low for both omissions and false alarms, and there was no evidence that any participant had neglected the secondary task, omissions and false alarms were not included in the subsequent analysis, and all working memory scores were considered as valid.

The CWMS material was presented using E-Prime software (Psychology Software Tools, Inc., Pittsburgh, PA, USA). Words were presented on the computer screen for 1000 ms each, and were divided by a 500 ms blank screen as the interstimuli; lists were divided by a screen showing a square for 2000 ms; the end of each sequence – and thus the moment to recall the final words of each list – was signalled by a triple question mark, and was self-paced (i.e. it lasted until the participant had responded and the experimenter had subsequently pressed a key). Two sequences were administered as practice trials before the test.

4.2.2 Results

Data analysis was conducted in a way similar to that of the previous experiments: causal errors, gap-filling errors and hits were analysed using logistic mixed-effects models (Jaeger, 2008), significance of the effects was assessed through likelihood ratio tests for nested models (Pinheiro & Bates, 2000), and evidence ratio was reported for fixed effects (Wagenmakers & Farrell, 2004). Participants and Photographs were treated as random effects. Anxiety and depression scale scores obtained using the Q-Pad questionnaire, as well as their interaction with Valence, were controlled for by including them as fixed effects in all models. Fixed effects of WM capacity (which was treated as a continuous predictor), Valence, and their interaction, were tested.

Causal errors

For causal errors, no main effect of WM capacity was found, $\chi^2(1) = .11$, $p = .74$ (model with WM capacity: AIC = 1103.71; model without WM capacity: AIC = 1101.82; evidence ratio = 0.39). A significant main effect of Valence was found, with very strong evidence, $\chi^2(2) = 21.98$, $p < .001$ (model with Valence: AIC = 1101.57; model without Valence: AIC = 1119.56; evidence ratio = 8034.5); analysis of the parameters (see Table 4.1) confirmed that, in a normal population of young adults who encode material in basic conditions, both positive and negative events are less likely to lead to causal memory errors than neutral events. Crucially, a significant WM capacity x Valence interaction was found, with evidence that was positive although not strong, $\chi^2(2) = 6.91$, $p = .03$ (model with interaction: AIC = 1100.80; model without interaction: AIC = 1103.71; evidence ratio = 4.28); consideration of regression parameters (Table 4.1) and observation of probability slopes (Figure 4.1) seem to suggest that, while probability of committing causal errors for neutral and positive events is relatively unaffected by WM capacity, probability of committing causal errors for negative material is negatively predicted by WM capacity. Both random effects were significant: for Participants, $\chi^2(1) = 49.71$, $p < .001$ (full model: AIC = 1100.80; model without Participants: AIC = 1148.51); for Photographs, $\chi^2(1) = 67.92$, $p < .001$ (model without Photographs: AIC = 1166.72). The estimated probabilities of producing causal errors as a function of WM capacity in the three conditions of valence are shown in Figure 4.1. Detailed information on the models, including estimated parameters and odds ratios, is reported in Table 4.1.

Figure 4.1. Estimated probability of causal error as a function of WM capacity in the three condition of Valence for Experiment 4. Shaded areas represent 95% confidence bands.

Gap-filling errors and accuracy

No significant fixed effects were found for gap-filling errors. For WM capacity, $\chi^2(1)$ = .03, *p* = .86 (model with WM capacity: AIC = 2227.81; model without WM capacity: AIC = 2225.85; evidence ratio = 0.37). For Valence, $\chi^2(2)$ = .47, *p* = .79 (model with Valence: AIC = 2222.20; model without Valence: AIC = 2218.66; evidence ratio = 0.17). For the WM capacity x Valence interaction, $\chi^2(2)$ = 3.10, *p* = .21 (model with interaction: AIC = 2228.71; model without interaction: AIC = 2227.81; evidence ratio = 0.64). As no significant fixed effects were found, significance of random effects was not calculated. Estimated probabilities of producing gap-filling errors as a function of WM capacity in the three conditions of valence (Figure 4.2), and details on statistical models (Table 4.1) have however been reported.

Also for hits no significant fixed effects emerged. For WM capacity, $\chi^2(1)$ = .15, *p* = .70 (model with WM capacity: AIC = 2693.72; model without WM capacity: AIC = 2691.87; evidence ratio = 0.40). For Valence, $\chi^2(2)$ = 1.23, *p* = .54 (model with Valence: AIC = 2688.96; model without Valence: AIC = 2686.20; evidence ratio = 0.25). For the WM capacity x Valence interaction, $\chi^2(2)$ = .70, *p* = .71 (model with interaction: AIC = 2697.03; model without interaction: AIC = 2693.72; evidence ratio = 0.19). As for gap-filling errors, significance of random effects was not calculated; estimated probabilities of hits as a function of WM capacity in the three conditions of valence (Figure 4.3), and details on statistical models (Table 4.1) have been reported.

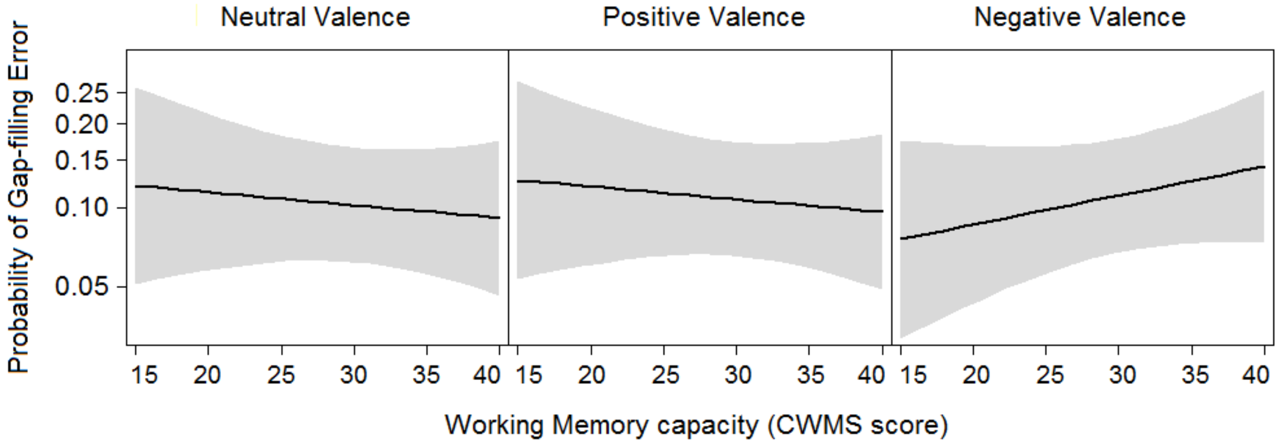

Figure 4.2. Estimated probability of Gap-filling Error as a function of WM capacity in the three condition of Valence for Experiment 4. Shaded areas represent 95% confidence bands.

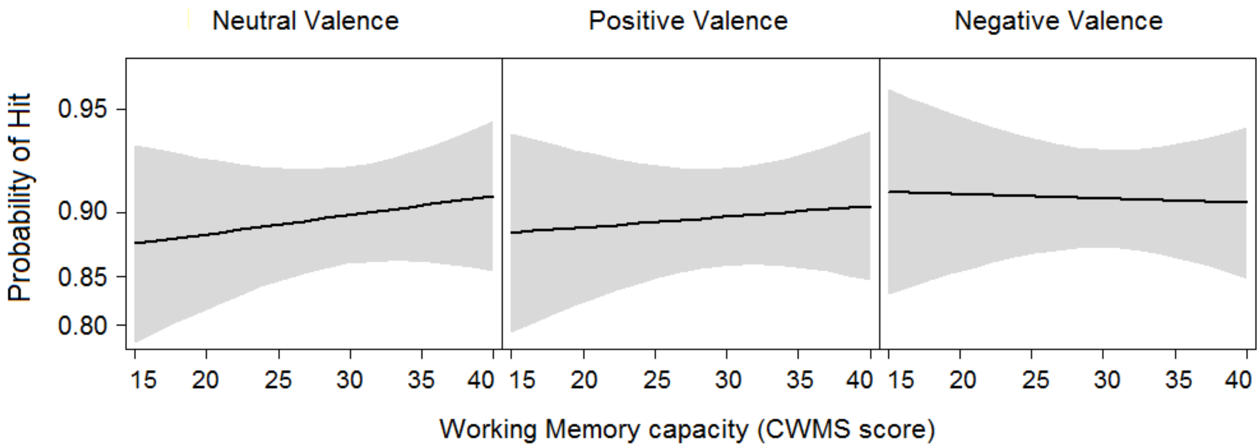

Figure 4.3. Estimated accuracy (i.e. estimated probability of hits) as a function of WM capacity in the three condition of Valence for Experiment 4. Shaded areas represent 95% confidence bands.

Table 4.1. Fixed effects of WM capacity, Valence, and their interaction on causal errors, gap-filling errors and hits, in Experiment 4, using logistic mixed-effects models.

Fixed effect	*B*	*SE*	*Odds ratio*	χ^2*(df)*
Dependent variable: Causal errors				
WM capacity	-.01	.02	.99	.11 (1)
Valence				21.98*** (2)
Positive	-.90	.19	.41***	
Negative	-.52	.19	.59**	
WM capacity x Valence				6.91* (2)
WM capacity x Positive	.03	.04	1.03	
WM capacity x Negative	-.07	.03	.93	
Dependent variable: Gap-filling errors				
WM capacity	< .01	.02	1.00	.03 (1)
Valence				.47 (2)
Positive	.05	.14	1.06	
Negative	.10	.14	1.10	
WM capacity x Valence				3.10 (2)
WM capacity x Positive	< .01	.03	1.00	
WM capacity x Negative	.04	.03	1.04	
Dependent variable: Hits				
WM capacity	.01	.02	1.01	.15 (1)
Valence				1.23 (2)
Positive	-.01	.12	.99	
Negative	.12	.12	1.13	
WM capacity x Valence				.70 (2)
WM capacity x Positive	-.01	.02	.99	
WM capacity x Negative	-.02	.02	.98	

Note. Baseline category for Valence was “neutral”. Random effects were Participants and Photographs. Number of observations was 927 for causal errors, 2781 for gap-filling errors, and 3708 for hits. Number of photographs was 9 for causal errors, 54 for gap-filling errors, and 63 for hits. Number of participants = 103. **p* < .05, ***p* < .01 ****p* < .001.

4.2.3 Discussion

The main result of Experiment 4 was that the effect of WM capacity on the production of inferential false memories varied as a function of the valence of encoded material. In particular, while for neutral and positively charged episodes the occurrence of causal errors did not seem to be affected by WM capacity, an inverse relationship between the two variables was observed for negatively charged episodes. This pattern of results is consistent with the hypothesis that WM resources are required to ward off false memories for negative events. Indeed, it was hypothesized that, while emotional material would normally protect against false memories (e.g. Kensinger & Schacter, 2005; Palmer & Dodson, 2009; but see also the previous three experiments in this dissertation), negative material would interfere with the ability to control WM (Osaka et al., 2013) which should lead to more false memories (e.g. Peters et al., 2007; Zhu et al., 2010) – and this adverse effect would become evident at lower baseline WM capacity. The results confirmed the hypothesis. Interestingly, the estimated probability of committing negative causal errors in participants with the lowest level of WM capacity was roughly equal to the estimated probability of committing neutral causal errors (see Figure 4.1); on the contrary, positive valence emerged to be always protected against causal errors, i.e. for any given level of WM capacity.

Results from Experiment 4, however, have a series of limitation. First, the effect of WM capacity on the production of false memories is limited to the negative condition. While it is still disputed whether WM capacity at the level of individual differences affects false memory production at all (Bixter & Daniel, 2013; Watson, et al., 2005), most evidence indicates this is the case, although with modest effect size (e.g. Gerrie & Garry, 2007; Peters et al., 2007; Zhu et al., 2010). One could thus have expected WM capacity to have an inverse relationship with the occurrence of false memories across the board, and this relationship to be stronger for negative than for positive or neutral material – but this was not found. Even the interaction between valence and WM capacity, albeit significant, was supported by a limited amount of evidence (the model with the interaction was only 4.28 more likely to be the best model compared to the model without the interaction). One possibility is that individual differences in WM capacity were too limited in range – because of the relative homogeneity of a sample of young undergraduate students – for an across-the-board effect to emerge. However, also previous studies (e.g. Zhu et al., 2010) tested undergraduate students. Furthermore, while it was expected that any effect involving valence (thus including the interaction between valence and WM capacity) would be primarily found on causal errors, WM capacity was not found to affect neither gap-filling errors nor hits at all. This may indicate that the memory paradigm consisting of the presentation of scripted everyday events – such as the paradigm that I used – does not involve WM processing to a large extent. To try to overcome these limitations, and to strengthen the evidence brought by Experiment 4, in the next experiment the effect of WM capacity was examined using an experimental manipulation.

4.3 Experiment 5: The effect of induced reduction of available working memory capacity

Experiment 5 aimed to extend the results emerged in Experiment 4 by examining the effect of an artificial, temporary reduction of available WM resources during the encoding phase. This condition was obtained by mean of a concurrent request (counting backwards by two). Indeed, it is known that performing a dual task reduces the available WM resources, and specifically that it affects the central executive component of WM (Baddeley, 2000; Baddeley, Allen, & Hitch, 2011). The concurrent task was of verbal nature for consistency with the previous experiment, in which participants had their WM capacity assessed using an active task that was focused on the verbal component (De Beni et al., 1998).

4.3.1 Method

Participants

A group of 77 undergraduate students took part in the experiment and received course credit in exchange for their participation. Participants were randomly assigned to either one of two conditions: WM-load condition (N = 39, mean age = 20.62 years, SD = 1.57, females = 29) or control condition (N = 38, mean age = 21.18 years, SD = 2.71, females = 29). Written and oral informed consent was obtain from all participants prior to the study.

Materials and procedure

For participants in the control condition, materials and procedure were exactly the same as in Experiment 4. Participants in the WM-load condition were administered the same materials and procedure, the only difference being that they were required to do a concurrent double task while encoding the pictorial stimuli. The concurrent task consisted of counting backward by two starting from 800 (such that participants had to say aloud, while viewing the photographs, "798, 796, 794, ..."); a manipulation that was intended to directly affect the central executive component of the WM system (Baddeley, 2000; Baddeley et al., 2011). Prior to the study it was conducted a pilot test on three participants (who were not subsequently included in the experiment) to evaluate whether the concurrent task would be sufficiently demanding given the present memory paradigm; it was found that counting backward by three was excessively demanding, as to make it nearly impossible to encode any narrative of the scripts, while counting backward by two seemed appropriate.

As in Experiment 4, all participants were administered the CWMS task (De Beni et al., 1988) and the depression, anxiety, and self-esteem/well-being scales of the Q-Pad (Sica et al., 2011) after the completion of the false memory paradigm. This was done to ensure that the two groups were actually comparable in terms of both baseline working memory capacity and presence of internalizing symptoms, as both these aspects were found to potentially affect production of inferential false memories for emotional events (see Experiments 2-4).

4.3.2 Results

Preliminary analysis showed that the two groups were indeed equivalent in terms of both baseline WM capacity and presence of internalizing symptoms at the level of individual differences. For CWMS scores, WM-load group: $M = 31.36$, $SD = 6.30$, 95% CI [29.38, 33.34]; control group: $M = 30.92$, $SD = 6.02$, 95% CI [29.01, 32.83]. For anxiety scores, WM-load group: $M = 21.05$, $SD = 5.19$, 95% CI [19.42, 22.68]; control group: $M = 21.58$, $SD = 4.84$, 95% CI [20.04, 23.12]. For depression scores, WM-load group: $M = 12.49$, $SD = 3.79$, 95% CI [11.30, 13.68]; control group: $M = 12.76$, $SD = 3.82$, 95% CI [11.55, 13.97].

Data analysis on causal errors, gap-filling errors and hits was conducted as in Experiment 4, with the difference that participants were categorized by Group, which was used as the predictor instead of WM capacity. Logistic mixed-effects models were used (Jaeger, 2008), and significance of the effects was tested using likelihood ratio tests for nested models (Pinheiro & Bates, 2000); evidence ratio was reported for fixed effects (Wagenmakers & Farrell, 2004). Participants and Photographs were treated as random effects. As in Experiment 4, scores on the anxiety and depression scales and their interaction with Valence were controlled for by including them as fixed effects in all models.

Causal errors

A significant main effect of Group on the probability of committing causal errors was found, and evidence was very strong, $\chi^2(1) = 15.33$, $p < .001$ (model with Group: AIC = 867.99; model without Group: AIC = 881.32; evidence ratio = 784.46); analysis of the parameters (Table 4.2) showed that the probability of committing causal errors was higher in the WM-load group and in the control group. A significant main effect of Valence was also found, with clear evidence, $\chi^2(2) = 12.13$, $p = .002$ (model with Valence: AIC = 864.77; model without Valence: AIC = 872.90; evidence ratio = 58.26); analysis of the parameters (Table 4.2) and observation of the estimated probabilities (Figure 4.4) indicated that this main effect was due to causal errors being less frequent for positive than for neutral scripts, and that this was qualified by a Group x Valence interaction. Indeed, a significant Group x Valence interaction emerged, with positive although not strong evidence, $\chi^2(2) = 6.92$, $p = .03$ (model with interaction: AIC = 865.07; model without interaction: AIC = 867.99; evidence ratio = 4.31); as it is shown in Figure 4.4, this implied that while both positive and negative events led to fewer causal errors compared to neutral events in the control group, only positive events led to fewer causal errors in the WM-load group. Both random effects were significant: for Participants, $\chi^2(1) = 11.57$, $p < .001$ (full model: AIC = 865.07; model without Participants: AIC = 874.63); for Photographs, $\chi^2(1) = 53.42$, $p < .001$ (model without Photographs: AIC = 916.49). The estimated probabilities of producing causal errors in the two groups and in the three conditions of valence are displayed in Figure 4.4. Detailed information on the models, including estimated parameters and odds ratios, is reported in Table 4.2.

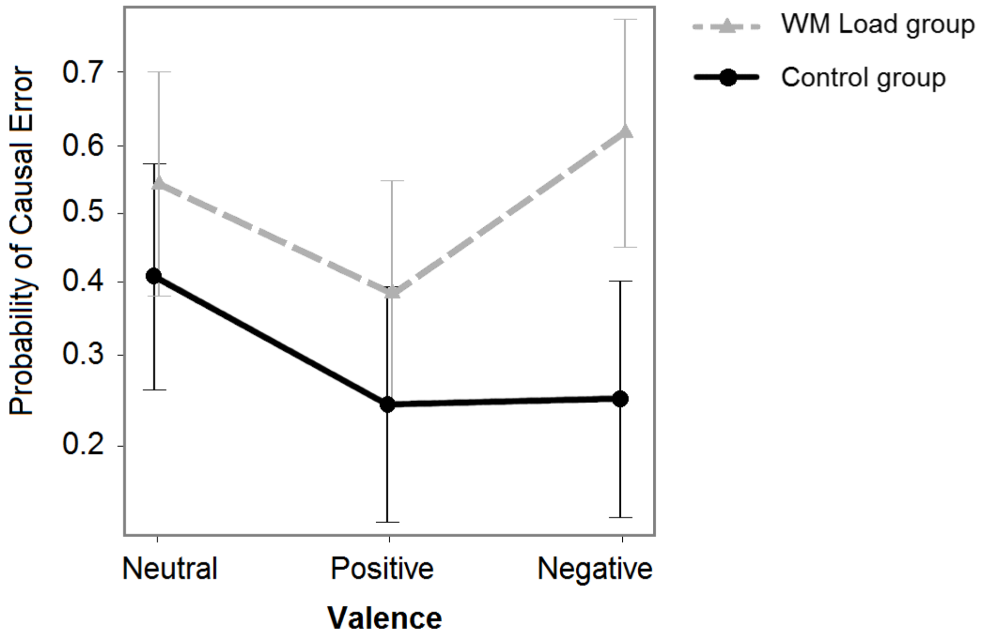

Figure 4.4. Estimated probability of causal error by Group and Valence for Experiment 5. Error bars represent 95% confidence intervals.

Gap-filling errors

For gap-filling errors, Group had a significant main effect, and evidence was very strong, $\chi^2(1) = 12.71$, $p < .001$ (model with Group: AIC = 2040.51; model without Group: AIC = 2051.23; evidence ratio = 212.72); analysis of the parameters (see Table 4.2) showed that participants in the WM-load group were more likely to commit gap-filling errors than participants in the control group. No significant main effect of Valence was found, $\chi^2(2) = 1.55$, $p = .46$ (model with Valence: AIC = 2033.46; model without Valence: AIC = 2031.00; evidence ratio = 0.29). Further, no significant Group x Valence interaction was found, $\chi^2(2) = .24$, $p = .89$ (model with the interaction: AIC = 2044.28; model without the interaction: AIC = 2040.51; evidence ratio = 0.15). Both random effects were significant: for Participants, $\chi^2(1) = 102.52$, $p < .001$ (full model: AIC = 2044.28; model without Participants: AIC = 2144.80); for Photographs, $\chi^2(1) = 293.26$, $p < .001$ (model without Photographs: AIC = 2335.53). The estimated probabilities of producing gap-filling errors in the two groups and in the three conditions of valence are reported in Figure 4.5. Detailed information on the models is reported in Table 4.2.

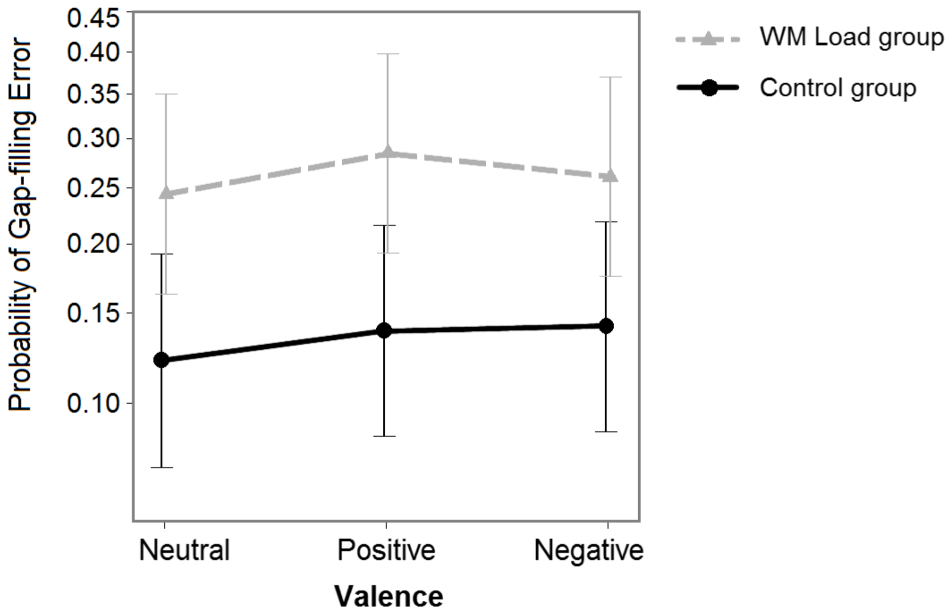

Figure 4.5. Estimated probability of Gap-filling Error by Group and Valence for Experiment 5. Error bars represent 95% confidence intervals.

Accuracy

Also for hits, Group had a significant main effect, and evidence was extremely strong, $\chi^2(1) = 31.60$, $p < .001$ (model with Group: AIC = 2873.39; model without Group: AIC = 2902.99; evidence ratio > $2*10^6$); analysis of parameters (Table 4.6) indicated that the frequency of hits was lower in participants in the WM-load groups than in participants in the control group. No significant main effect of Valence was found, $\chi^2(2) = .35$, $p = .84$ (model with Valence: AIC = 2870.86; model without Valence: AIC = 2867.21; evidence ratio = 0.16). Finally, although the Group x Valence interaction did not reach the conventional level for statistical significance, there was some degree of evidence in favour of it, $\chi^2(2) = 5.03$, $p = .08$ (model with interaction: AIC = 2872.36; model without interaction: AIC = 2873.39; evidence ratio = 1.68); observation of the estimated probabilities seems to suggest that while in the control group hits are more frequent in the negative condition, the opposite happens in the WM-load group. Both random effects were significant: for Participants, $\chi^2(1) = 52.46$, $p < .001$

(full model: AIC = 2872.36; model without Participants: AIC = 2922.82); for Photographs, $\chi^2(1) = 174.26$, $p < .001$ (model without Photographs: AIC = 3044.62). The estimated probabilities of hits in the two groups and in the three conditions of valence are displayed in Figure 4.6. Detailed information on the models is reported in Table 4.2.

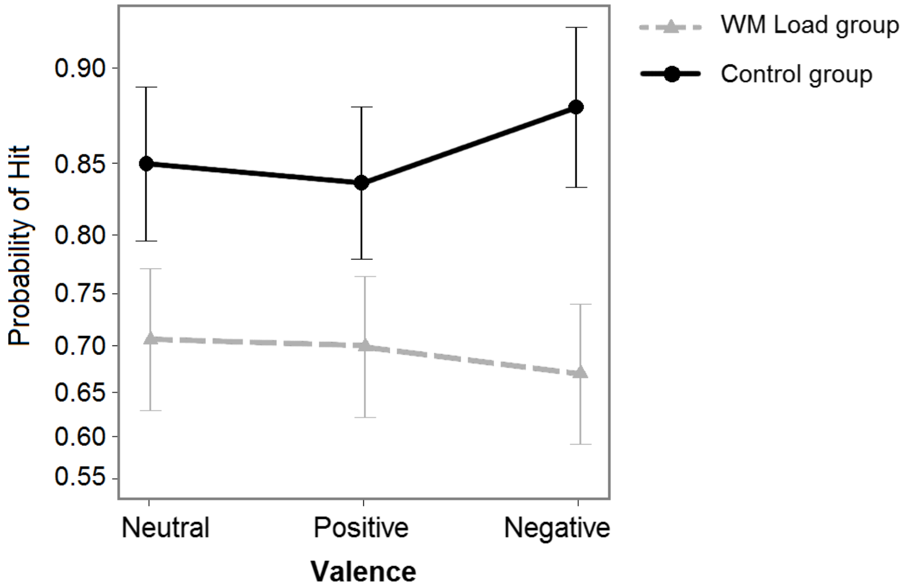

Figure 4.6. Estimated accuracy (i.e. estimated probability of hit) by Group and Valence for Experiment 5. Error bars represent 95% confidence intervals.

Table 4.2. Fixed effects of Group, Valence, and Group x Valence on causal errors, gap-filling errors and hits, in Experiment 5, using logistic mixed-effects models.

Fixed effect	*B*	*SE*	*Odds ratio*	χ^2*(df)*
Dependent variable: Causal errors				
Group				15.33*** (1)
WM-load	.91	.23	2.48***	
Valence				12.13** (2)
Positive	-.71	.95	.49***	
Negative	-.18	.94	.84	
Group x Valence				6.92* (2)
WM-load x Positive	.11	.42	1.12	
WM-load x Negative	1.04	.43	2.83*	
Dependent variable: Gap-filling errors				
Group				12.71*** (1)
WM-load	.84	.23	2.31***	
Valence				1.55 (2)
Positive	.18	.14	1.19	
Negative	.11	.14	1.12	
Group x Valence				.24 (2)
WM-load x Positive	.06	.29	1.06	
WM-load x Negative	-.08	.29	.92	
Dependent variable: Hits				
Group				31.60*** (1)
WM-load	-.97	.16	.38***	
Valence				.35 (2)
Positive	-.06	.11	.94	
Negative	< .01	.12	1.00	
Group x Valence				5.03 (2)
WM-load x Positive	.06	.23	1.06	
WM-load x Negative	-.44	.24	.64	

Note. Baseline category for Group was "control group", baseline category for Valence was “neutral”. Random effects were Participants and Photographs. Number of observations was 693 for causal errors, 2079 for gap-filling errors, and 2772 for hits. Number of photographs was 9 for causal errors, 54 for gap-filling errors, and 63 for hits. Number of participants = 77. *p < .05, **p < .01, ***p < .001.

4.3.3 Discussion

Results from Experiment 5 confirmed evidence for an interplay between valence and available WM resources on the production of false memories. However, there were also novel findings. Unlike in Experiment 4, in the present study a general increase in false memories as a consequence of low available WM capacity was also found; this may be due to the fact that the depletion of WM resources in a dual task condition is much more taxing than having low WM capacity at the level of individual differences, at least within the range of normality for young adults (as it was in Experiment 4). In fact, previous research showed that a comparable dual task condition reduced the propensity to incur associative false memories using the DRM procedure (Knott & Dewhurst, 2007; although the opposite was also found, see for example Dehon, 2006; Otgaar, Peters, & Howe, 2012); the authors hypothesized that divided attention induced by the dual task – i.e. generating random numbers – reduced semantic processing of the word lists, thus decreasing the activation of the critical lure and consequently the propensity to falsely recognize it. In other words, participants in the dual task condition may have been too distracted to grasp the core aspect of the lists (Knott & Dewhurst, 2007); however, this effect may heavily depend on the difficulty of the dual task, as Otgaar and colleagues (2012), using an apparently easier secondary task, found that adult participants were more likely to rely on the semantic core of the lists, thus incurring more DRM false memories. In fact, in the present paradigm memorizing the viewed material may have been not critically dependent on semantic processing, also because such material is graphic and depicts easily comprehensible everyday events. In this context, WM resources appeared to have been crucial to accurately store all aspects of the events without errors, rather than to create a complex representation of the material as a whole. Furthermore, our secondary task was likely less demanding than that used by Knott and Dewhurst (2007). To be noted, however, the general effect of the WM-load condition on causal and gap-filling errors may not be due to a genuine increase in propensity to false memories, but rather to a general decrease in the ability to discriminate old-new photographs; indeed, also hits were affected by the dual task.

Despite some questions remaining open, a crucial finding emerged, and it shows that reduced WM resources affects the production of negative causal errors more than the production of neutral or positive ones. This is consistent with results from Experiment 4, and confirms that good WM resources are a necessary condition for the protective effect of negative emotion against inferential false memories to be observed. The strength of the evidence was positive, although not large, just as in the previous experiment. Another important point that emerged in Experiment 5 was that the interplay between WM and valence seems to take place during the encoding phase. This was left unclear in the previous experiment, where participants with low WM capacity were obviously characterized by their condition in all phases of the memory process (i.e. encoding, consolidation, and retrieval). In Experiment 5, instead, participants in the WM-load condition could rely on their full WM resources during the retrieval phase, and yet negative material did not protect them against false memory. This is consistent with the notion that WM processing is critically involved in creating a solid complex representation of the events when they are first viewed, thus avoiding memory distortions (e.g. Gerrie & Garry, 2007; Reinitz & Hannigan, 2004). Nonetheless, it cannot be excluded that any similar effect could be found also if WM resources were depleted at retrieval; this could be matter for future investigation. Finally, in Experiment 5 it was confirmed that, in control condition, both positive and negative events are less likely to give rise to causal errors than neutral events.

5. CONCLUSIONS

5.1 Summary of the findings and their implications

Through five experiments, I explored two general questions concerning the occurrence of false memories for emotional material. The first question was whether emotional events are protected against inferential false memories (i.e. memory errors consisting of falsely remembering scenes as a consequence of inferential processes; they include causal and gap-filling errors) compared to non-emotional events, in line with the notion that emotional material improves reality monitoring and reduces memory distortions (Kensinger & Corkin, 2004; Kensinger & Schacter 2005, 2006b, 2008; Pesta et al., 2001). To this end, a false memory paradigm based on pictorial scripted material was created, following the method suggested by Hannigan and Reinitz (2001) and Lyons and colleagues (2010). Results showed that emotional events were indeed associated to a reduced probability of committing inferential false memories compared to neutral events; the finding specifically concerned causal errors, (which are indeed temporally contiguous and logically related to the specific event that is either emotional or non-emotional), while no effect of valence was found on gap-filling errors, except in one experiment. The second and most important question was whether there are conditions that moderate the effect of valence on the probability of incur false memories; it was found that such conditions exist, and include both encoding/post-encoding manipulations and individual differences.

Experiment 1 examined the effect of post-encoding elaboration of neutral vs. negative material on false memory production. Rehearsing material after encoding is known to enhance the subsequent probability of committing false memory, due to the tendency to rely on the gist of the material when recollecting (Roediger & McDermott, 1995; Gallo, 2006). Thus, it was hypothesized that this would also happen for scripted events. Crucially, it was hypothesized that negative events would be especially susceptible to false memory after re-elaboration (i.e. to a higher extent compared to neutral events), due to the fact that emotionally charged events are more likely to be the focus of re-thinking and elaborative processes (e.g. Walker et al., 2009); furthermore, it is known that emotional elaboration of events leads to higher false memories (Drivdahl et al., 2009). Results from a sample of undergraduate students were consistent with the hypotheses; in particular, while participants who were distracted during a 15 minutes retention interval were less likely to incur causal errors for negative than neutral events, participants who were encouraged to think back and reconstruct what they had just seen showed the opposite pattern. Furthermore, consistently with hypotheses, an overall increase in gap-filling errors was observed in the experimental group. Finally, negative events were indeed more likely to be mentioned in written reports during the post-encoding elaboration phase. Accuracy was not affected. Implications for the forensic field could be derived; in particular, it was suggested that free, unguided re-elaboration of witnessed events should be prevented, and even repeated forensic interviews should be treated with caution, especially for emotionally charged events.

Experiments 2 and 3 were focused on the effects of symptoms of emotional disorders at the sub-clinical level. Previous research had shown that individuals suffering from emotional disorders are more likely to incur false memories for negative material (e.g., Howe & Malone, 2011; Joormann et al., 2009); this was explained in terms of a higher baseline activation of negative concepts in depression (Howe & Malone, 2011). However, it was still unclear what would happen at the sub-clinical level, in the case of anxiety, and with positive material; furthermore, only the DRM paradigm had been previously used. In experiments 2 and 3 participants were selected through wide screenings among 17-to-19-years-old high school students; using the Q-Pad questionnaire (Sica et al., 2011) I selected participants who were high (i.e. over the 80th percentile) on both the anxiety and depression scales (Experiment 2) or were high on the anxiety scale but around or below the median (as reported for the standardization sample) in the depression scale (Experiment 3); in both cases, control groups consisted of youths who were around or below the median in both the depression and the anxiety scales. In Experiment 2, it was shown that participants with strong internalizing traits are more likely to misremember the causal antecedent (i.e. to incur an inferential false memory) when the outcome is negative than when it is neutral, while control participants show the opposite pattern (i.e. they are protected by negative material). In Experiment 3, the previous result was replicated, and it was shown that it may be specific for anxiety (i.e. also when concurrent depression levels are low), and that it is only found for negative (but not positive) material.

Experiments 2 and 3 importantly indicated that a) also symptoms of emotional disorders at the sub-clinical level imply increased false memories for negative material, b) that this phenomenon could also be found in the case of trait anxiety, and c) that it is specific for negative material. Furthermore, it is interesting to note that, as the critical element in this paradigm is not emotional itself (but it is linked to an emotional event) the hypothesis of a pre-activation of negative concepts in emotional disorders (Howe & Malone, 2011) could not be applied to the present case. Rather, an explanation based on the over-elaboration of negative material in individuals with high levels of anxiety and depression (see Gotlib & Joormann, 2010) could be more appropriate; indeed, it is interesting to note that the pattern of results in Experiments 2 and 3 was somehow similar to that of Experiment 1 (i.e. individuals with internalizing traits behave similar to individuals who have re-elaborated the viewed material). Finally, these experiments suggested that individuals suffering from high levels of internalizing symptoms could create distorted memories of the events, especially if they are negatively charged; persons with internalizing symptoms may thus be increasingly tangled up in an illusory representation of the reality, which may have critical implications when they are invited to re-think of and describe past events, for example when receiving clinical support.

In Experiment 4 and 5 the focus was on the role of working memory (WM) capacity. WM is known to be crucial for memory binding, which allows to create vivid representations of events (Mitchell, Johnson, Raye, & Greene, 2004), and thus to avoid false memories (e.g. Peters, Jelicic, Verbeek, & Merckelbach, 2007; Reinitz & Hannigan, 2004). However, it was still unclear what role WM has in the case of emotional material. It is known that negative material interferes with WM control, reducing performance (Osaka, Yaoi, Minamoto, & Osaka, 2013). Therefore, negative material should lead to increased memory errors; however, the opposite is typically observed, as widely reviewed. It was thus hypothesized that negative material could have both “protective” (via higher distinctiveness, verbatim encoding, and so on), and “adverse” (via interference with WM control) effects on the production of false memories. While normally the protective effects of negative material is observed, the impairing effects could emerge when baseline WM capacity is reduced. In Experiment 4, a large group of undergraduates was administered the false memory paradigm in basic conditions, and their WM capacity was subsequently measured using an active WM task (De Beni et al., 1998). Results showed a significant interaction between WM capacity and emotionality of the material on the production of causal errors, such that while causal errors were relatively unaffected by WM in the positive and neutral conditions, in the negative condition they tended to be relatively fewer as WM increased. To further clarify this pattern of results, Experiment 5 was conducted. In this experiment, half of the participants (WM-Load group) encoded the scripted material while concurrently doing a double task, which was intended to interfere with the central executive component of their WM system (Baddeley, 2000). Results showed that occurrence of false memories was overall higher in the WM-Load group than in the control group (matched by a decrease in accuracy). However, this increase in false memories was larger in the negative than in the neutral and positive conditions, thus confirming the importance of good WM capacity to protect against inferential false memories for negative events. Finally, Experiment 5 suggested that the role of WM in warding off (negative) false memories is crucial during the encoding phase, i.e. when the event is first processed and stored in memory, rather than at retrieval.

As for the general conclusions, it was shown that emotional scripted events (both negative and positive) are normally protected against inferential false memories (and especially against causal errors) compared to neutral scripted events. Importantly, however, this does not hold true in any condition; indeed, especially in the case of negative events, the "protective" effect is disrupted – and sometimes even reversed – under certain conditions, which include post-encoding elaboration of viewed material, strong presence of internalizing symptoms at the sub-clinical level (and especially of trait anxiety), and low or reduced capacity of WM during the encoding.

5.2 Limitations and suggestions for future research

Although the present dissertation offers novel evidence with important theoretical and applied implications, and highlights the opportunity of using a new, highly ecological paradigm to study inferential false memories, several limitations emerged, and a series of other aspects might be addressed in future research. While some of the issues were presented in the Discussion section of each single experiment, here I focus on more general aspects.

First, the single roles of valence and arousal, as well as other potentially relevant properties of the stimuli, were not systematically explored. In particular, the emotional outcomes (both negative and positive) were always associated to high arousal. This was primarily decided in order to keep the paradigm simple, but also to resemble real life as well as potentially forensic-relevant emotional events (particularly in the case of negative events). However, it is inherently difficult to create pictorial material in the form of brief episodes that include specific cause-effect patterns conveying low-arousal emotions, such as quiet sadness, melancholy, or serenity. Nonetheless, such an effort would be worthwhile, as it has been reported that valence and arousal may act upon memory through different mechanisms (e.g. Kensinger, 2004). Another limitation lies in that positive outcomes, although more arousing than the neutral ones, were not as arousing as the negative outcomes; therefore, one could not completely rule out that some of the reported effects concerning interactions with valence (specifically in Experiments 3–5) were in fact driven, at least in part, by arousal. Furthermore, other important stimuli properties should also be considered in future research. In particular, the role of distinctiveness should be taken into account. One hypothesis is that emotional material reduces the occurrence of false memories because its distinctiveness allows for a better encoding (e.g. Kensinger & Corkin, 2004; Kensinger & Schacter, 2006b; Palmer & Dodson, 2009). Therefore, to better understand why this “protective” effect is sometimes nullified or even reversed (as it has been shown in the present dissertation), it would be important to include outcomes that are distinctive but non-emotional along with the positive and negative ones; only then it will be possible to draw firm conclusions about the actual role of emotionality.

Another general issue is that the degree of evidence supporting the reported effects was not always large. Indeed, in Experiments 1, 4 and 5, evidence was positive but not strong, and the effects were modest in size, possibly indicating that the paradigm is still to be refined, but also that a large portion of the variability in the propensity to incur inferential false memories remains unexplained.

With regard to the type of false memory, while it was expected that valence would mainly (if not only) affect causal errors, adjusting the paradigm in order to systematically examine the effect of valence on gap-filling errors would importantly extend the scope of the research. Indeed, causal and gap-filling errors are thought to stem from partially different reconstructive processes (Hannigan & Reinitz, 2001; Lyons et al., 2010), which could be differently affected by valence. One option would be to vary valence of the episodes thematically, following a procedure similar to that of Laney and colleagues (2004); indeed, these authors showed a nearly identical sequence of slides to all participants, and manipulated valence by presenting a verbal description of the episode (either negatively arousing or neutral) during the slide show at the encoding phase. Adapting this procedure to the present paradigm, could facilitate the study of how valence affects not only memory errors concerning specific events (i.e. causal errors) but also memory errors deriving from the understanding of the episode in its entirety (i.e. gap-filling errors). More in general, as all the experiments reported in the present dissertation have novel aspects in terms of both the paradigm that was used and the evidence that they offer, it would be important to systematically examine the similarities and differences that could be found with false memories elicited by traditional procedures (for example, by conceptually replicating the experiments presented in the current thesis but using the DRM paradigm); doing so would have important theoretical implications, as it would shed light on how valence affects the specific mechanisms that underlie each type of false memory.

Finally, all the experiments in the present dissertation were conducted on young adults. This is a specific population that may have particular characteristics. In fact, the same applies to most of the research on emotional false memories; however, studies on children (Howe, 2007) and older adults (Kensinger & Corkin, 2004) were also conducted. Examining inferential false memories in a larger age range would be important. For example, Lyons and colleagues (2010) found that causal errors increase with development during childhood, arguing that this increase is due to the fact that the memory processes underling causal errors formation develop throughout the school years. However, it is not known what happens with emotional events;

importantly, WM resources are not fully developed in children, and they have been found critical in the case of negative false memories (Experiments 4 and 5). On the same line, inferential false memories for emotional events in older adults could be examined. Indeed, older adults are known to have an overall deficit in WM abilities (e.g. Borella, Carretti, & De Beni, 2008), which may predict increased negative false memories; on the other hand, however, older adults are known to have a bias towards positive material (and away from negative one; see e.g. Charles, Mather, & Carstensen, 2003; Mather & Carstensen, 2005), which may predict increased elaboration and false memories for positively charged events.

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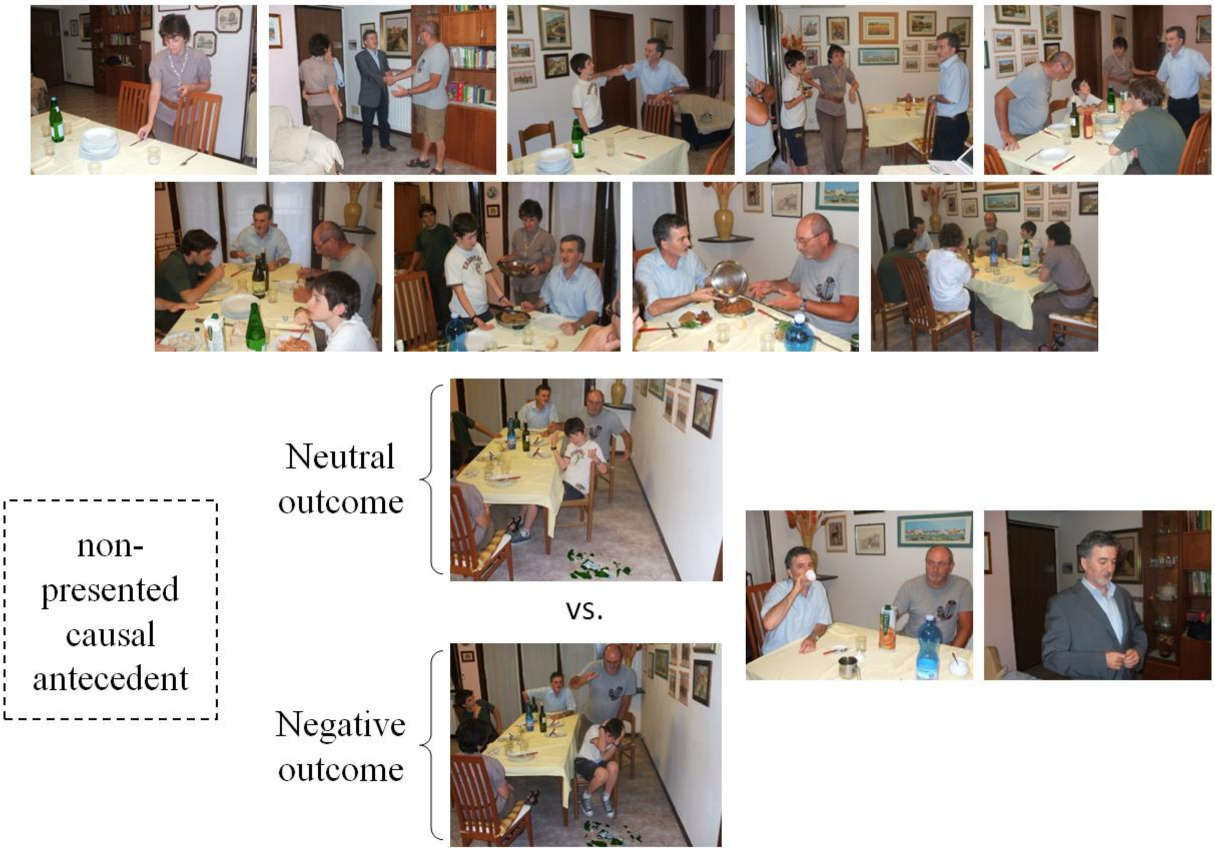
APPENDIX

Appendix A – Examples of scripts used for the false memory paradigm

1. Example of the "dinner script"

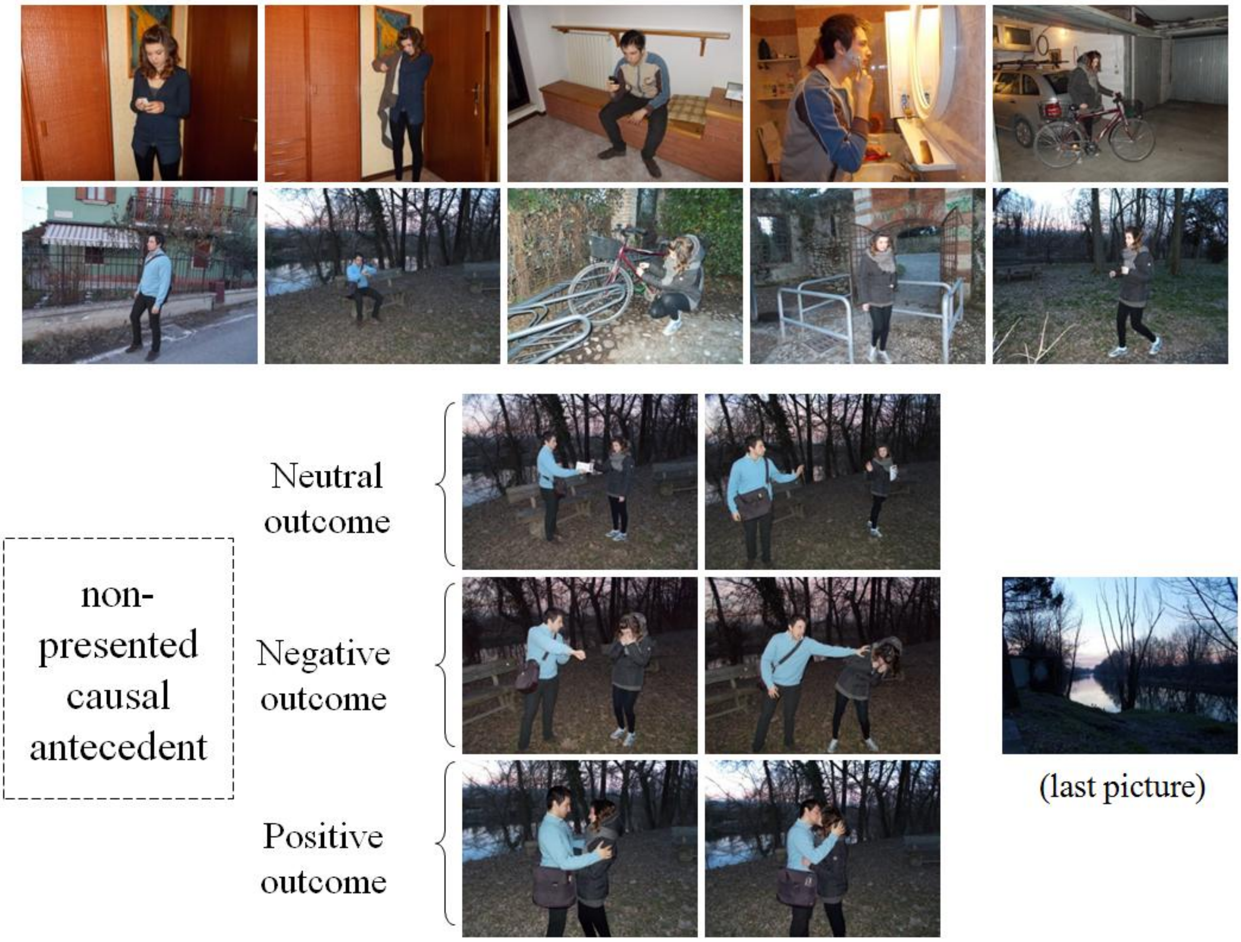
<u>Encoded photographs</u>



<u>Tested photographs</u>

2. Example of the "dating / meeting a friend script"

Encoded photographs



Tested photographs

Appendix B – Questionnaire used for assessing internalizing symptoms

The following items were used (in the original Italian version) to assess levels of internalizing symptoms in Experiments 2–5. They correspond to the anxiety and depression scales of the Q-Pad questionnaire (Sica, Chiri, Favilli, & Marchetti, 2011); responses are given on a Likert scale ranging from 1 to 4 based on the extent to which each sentence describes one's own situation.

Anxiety scale

"I often feel tense."

"When I am tense, I have difficulty breathing."

"I am almost always worried about something."

"I am often so nervous that I can feel my heart pounding."

"I am worried about things that most people are not worried about."

"I think that I show signs of much stress."

"Lately I have found it difficult to sleep because of my worries."

"I often feel worried and I do not know why."

"I am bothered by thoughts I cannot get rid of."

Depression scale

"Lately I have been feeling sad for most of the time."

"I have lost interest in things that I used to like."

"Things went from bad to worse."

"Lately I have felt like time does not flow."

"Sad thoughts keep me awake at night."

“I no longer get pleasure from activities as I used to.”

“It does not matter what I do, things will not improve.”

“I feel like I cannot get rid of my sadness.”

Appendix C – Example of the stimuli used for assessing working memory capacity

The following list of words (translated from Italian) are taken from the Categorization Working Memory Span task (Borella et al., 2007, adapted from De Beni et al., 1998), which was used as a measure of individual working memory capacity in Experiment 4.

Participants were required to read aloud each word, to press the space bar when they read the name of an animal, and to remember the last word in each list (which was followed by a square). Participants were then asked to repeat the to-be-remembered words when a "???" appeared.

Example – SPAN = 3

WOLF ASH COUCH WAVE **PLATE** [square]
GERANIUM BOX *RABBIT* CHAIR **CHERRY** [square]
HOUSE *COW* DYKE CUBE **JACKET** [square]
???

Example – SPAN = 4

SNAKE SHOVEL PENCIL PLANT **CAKE** [square]
MUM LILY *GOAT* LEATHER **SEED** [square]
WIND *SPIDER* SKULL TRAIN **PAN** [square]
SHIELD WIFE CUP WALNUT ***CATERPILLAR*** [square]
???

Note. Only for illustrative purposes in the current example, the words indicating animals have been highlighted in italics, and the final word in each list has been highlighted in bold; however, all words were presented in plain text to participants. The original Italian words are all bi- to tri-syllabic and of medium-to-high frequency in the Italian language.

SUMMARY IN ITALIAN / RIASSUNTO IN ITALIANO

Come nota Daniel Schacter (1999), gli errori di memoria non sono solo “errori”. Essi vanno piuttosto considerati come effetti collaterali di caratteristiche altrimenti utili e adattive della nostra memoria. La memoria umana è infatti costruttiva e ricostruttiva, immagazzina schemi (Alba & Hasher, 1983; Bartlett, 1932) piuttosto che semplici sensazioni, coglie il “succo” degli eventi, ed è continuamente impegnata ad attribuire un significato a ciò che accade (Schacter, 2012). Ciò implica che la nostra memoria immagazzina più di quanto le venga effettivamente presentato. In effetti, come è stato ampiamente dimostrato dalla ricerca, le distorsioni della memoria e i falsi ricordi —spesso vividi e dettagliati— sono un fatto piuttosto comune nella vita quotidiana (per es. Loftus, 2005; Schacter, 2001).

Le emozioni influenzano potentemente la memoria, spesso con effetti contrapposti. Di solito, il ricordo degli eventi emotivi è più duraturo e accurato rispetto al ricordo di eventi ordinari (Christianson, 1992; Kensinger & Schacter, 2008). Tuttavia ciò non è necessariamente vero in qualsiasi condizione. Per esempio, in condizioni di forte attivazione emotiva *(arousal)*, o quando un elemento attivante ed estremamente saliente appare nella scena (ad esempio un’arma), il ricordo può restringersi agli aspetti centrali, trascurando i dettagli periferici (Christianson & Loftus, 1991; Reisberg & Heuer, 2004). Anche nel caso dei falsi ricordi le emozioni hanno effetti complessi (Kaplan, Van Damme, Levine, & Loftus, 2015). Per quanto il materiale emotivo, specialmente negativo, in molti casi faciliti il monitoraggio di realtà, riducendo di conseguenza il rischio di falsi ricordi (Kensinger & Corkin, 2004; Kensinger & Schacter 2005, 2006; Pesta, Murphy, & Sanders, 2001), è possibile anche che le emozioni abbiano l’effetto opposto, causando più ricordi scorretti (Brainerd, Stein, Silveira, Rohenkohl, & Reyna, 2008; Gallo, Foster, & Johnson, 2009).

Negli ultimi due decenni sono stati studiati soprattutto i falsi ricordi di tipo associativo, facendo ampio uso del paradigma Deese-Roediger-McDermott (DRM; Roediger & McDermott, 1995; si veda Gallo, 2010, per una rassegna), che è basato su liste di parole semanticamente relate. Alcuni studi recenti sui falsi ricordi col DRM hanno mostrato che le liste di parole negative generano più falsi ricordi di quelle neutre (per es., Brainerd et al., 2008). Tuttavia, ciò sembra dovuto alla più forte densità semantica posseduta dalle liste emotive (l'emozione stessa è un "collante" che unisce semanticamente gli stimoli), il che causerebbe un aumento dei falsi ricordi di tipo associativo studiati dal DRM (Talmi & Moscovith, 2004). In effetti, quando la forza associativa che lega le parole all'interno di diverse liste è uguale, il fatto che siano emotive (sia positive che negative) sembra proteggerle dai falsi ricordi rispetto alle liste neutre (Palmer & Dodson, 2009). Esistono comunque anche altri tipi di falsi ricordi. In particolare, i falsi ricordi basati sulle inferenze sono di grande interesse per la comprensione dei processi ricostruttivi della memoria, ma anche per le loro applicazioni potenzialmente immediate allo studio della testimonianza oculare (Hannigan & Reinitz, 2001). Due tipi di falsi ricordi inferenziali sono gli errori di "gap-filling" e gli errori di inferenza causale. I primi si riferiscono al ricordo erroneo di un elemento – o eventualmente di un intero evento – che è tipico di un dato contesto, mentre i secondi si riferiscono al falso ricordo del preciso antecedente causale di un fatto del quale, in realtà, è stata vista solo la conseguenza (Hannigan & Reinitz, 2001).

Nella mia tesi ho investigato per la prima volta gli effetti delle emozioni sulla produzione di falsi ricordi inferenziali, ponendo particolare attenzione alle condizioni che moderano questi effetti. Per condurre la ricerca ho creato del materiale pittorico organizzato in forma di "script", adattando un paradigma precedentemente usato da Hannigan e Reinitz (2001; si veda anche Lyons, Ghetti, & Cornoldi, 2010, and Mirandola, Paparella, Re, & Ghetti, 2012, per applicazioni più recenti). Nello specifico, ho creato sequenze di fotografie che rappresentano eventi tipici della realtà quotidiana (o appunto “script”), ciascuno dei quali presenta alla fine diverse conseguenze, mutuamente esclusive, che differiscono per valenza e attivazione emotiva. La fotografia che rappresenta lo specifico antecedente causale di tutte le conseguenze non viene mostrato nella fase di codifica, ma successivamente presentato in una prova di riconoscimento. Sono stati esaminati anche gli errori di tipo “gap-filling” e l’accuratezza complessiva.

La mia ricerca è motivata da due quesiti di fondo. Primo, se anche i falsi ricordi inferenziali siano generalmente meno frequenti nel caso di eventi emotivi che di eventi non-emotivi, coerentemente con l’evidenza prevalente che il materiale emotivo riduca le distorsioni di memoria (Kensinger & Schacter 2005; Kensinger, 2007). Secondo e più importante quesito, ho esaminato se questo eventuale effetto “protettivo” venga moderato da particolari condizioni, considerando sia differenze individuali che l’effetto delle manipolazioni sperimentali.

Nell’Esperimento 1 mi sono concentrato sugli effetti della rielaborazione del materiale dopo la codifica. È noto che ripetere più volte il materiale dopo la codifica aumenta la probabilità di commettere falsi ricordi, a causa della tendenza a “ricostruire” il ricordo basandosi sul “nucleo” del significato del materiale studiato (Roediger & McDermott, 1995; Gallo, 2006). Ho ipotizzato che ciò sarebbe accaduto anche per gli eventi presentati in forma di script, specialmente nel caso degli errori di “gap-filling”. Inoltre, ho ipotizzato che gli eventi emotivi sarebbero stati più suscettibili all’aumento di falsi ricordi dovuto alla rielaborazione, dato che essi, per la loro salienza, vengono richiamati alla mente più facilmente e più spesso (Christianson & Engelberg, 1999; Walker, Skowronksi, Gibbons, Vogl, & Ritchie, 2009); si sa inoltre che la rielaborazione degli aspetti emotivi degli eventi conduce a maggiori falsi ricordi (Drivdahl, Zaragoza, & Learned, 2009). I risultati ottenuti su un campione di studenti universitari hanno mostrato che, mentre i partecipanti che venivano distratti durante l’intervallo di ritenzione (partecipanti di controllo) erano relativamente protetti dagli errori causali per eventi negativi rispetto agli eventi neutri, i partecipanti che venivano invitati a ripensare e a ricostruire ciò che avevano visto (partecipanti sperimentali) presentavano il pattern opposto. Inoltre, coerentemente con le ipotesi, si è osservato un aumento generalizzato degli errori di "gap-filling" nel gruppo sperimentale. L'accuratezza invece non differiva.

Negli Esperimenti 2 e 3 mi sono concentrato sugli effetti dei sintomi di disturbi emotivi a livello sub-clinico. Precedenti ricerche hanno mostrato che le persone che soffrono di disturbi emotivi in generale commettono più falsi ricordi per materiale negativo (per es. Howe & Malone, 2011; Joormann, Teachman, & Gotlib, 2009). Un'ipotesi è che ciò sia dovuto a una maggiore attivazione di base dei concetti negativi nelle persone con depressione (Howe & Malone, 2011). Tuttavia, un limite dei precedenti studi è che hanno utilizzato il paradigma DRM, per cui non è chiaro se lo stesso accada anche per altri tipi di falsi ricordi. Inoltre, non è chiaro cosa accada a livello sub-clinico (è infatti possibile che disturbi sufficientemente intensi da raggiungere una soglia clinica presentino effetti specifici, diversi da quelli del corrispondente tratto nella popolazione generale), cosa accada nel caso di sintomi d'ansia (un'altra condizione che comporta un *bias* di memoria e un'elaborazione preferenziale per il materiale emotivo; Mitte, 2008), e con il materiale positivo. Negli Esperimenti 2 e 3 i partecipanti sono stati selezionati tramite ampi screening su studenti di scuola superiore tra i 17 e i 19 anni d'età, utilizzando il questionario Q-Pad (Sica, Chiri, Favilli, & Marchetti, 2011). Nell'Esperimento 2 ho selezionato partecipanti che avevano elevati punteggi (oltre l'80esimo percentile) sia nella scala di ansia che in quella di depressione, mentre nell'Esperimento 3 ho selezionato partecipanti che avevano elevati punteggi di ansia ma punteggi di depressione attorno o sotto la mediana. In entrambi gli esperimenti, i gruppi di controllo erano composti da giovani che si collocavano attorno o sotto la mediana sia nella scala di ansia che in quella di depressione. Nell'Esperimento 2 si è mostrato che i partecipanti con forti tratti internalizzanti hanno maggiore probabilità di commettere falsi ricordi per gli antecedenti causali quando la conseguenza è negativa rispetto a quando è neutra, mentre i partecipanti di controllo presentavano l'effetto opposto (erano quindi protetti dal materiale negativo). Nell'Esperimento 3 sono stati replicati i risultati precedenti, e si è mostrato che l'effetto è specifico per l'ansia (cioè si trova anche quando i livelli di depressione corrispondono alla media della popolazione o sono al di sotto). Inoltre, si è mostrato che l'effetto è specifico per il materiale negativo (e non si trova per il materiale positivo). Gli Esperimenti 2 e 3 hanno mostrato che anche i sintomi internalizzanti a livello sub-clinico implicano elevati livelli di falsi ricordi per materiale negativo, che questo fenomeno si può trovare anche nel caso specifico dell'ansia di tratto, e che è ristretto al materiale negativo. Inoltre, è interessante notare che l'elemento critico, cioè l'antecedente causale, non è emotivamente carico di per sé, ma è collegato ad eventi emotivi. Per questo l'ipotesi della pre-attivazione dei concetti negativi nel caso dei disturbi emotivi (Howe & Malone, 2011) in questo caso non può essere applicato. La spiegazione potrebbe piuttosto avere a che fare con una sovra-elaborazione del materiale negativo negli individui con alti livelli di ansia e di depressione (si veda Gotlib & Joormann, 2010). In effetti, è interessante notare che il quadro dei risultati negli Esperimenti 2 e 3 assomiglia a quello dell'Esperimento 1 (con i partecipanti con forti tratti internalizzanti che si comportano in modo simili a quelli che hanno rielaborato il materiale).

Negli Esperimenti 4 e 5 mi sono concentrato sul ruolo della Memoria di Lavoro (ML; Baddeley, 2000, 2012). Si sa che la ML ha un ruolo cruciale nel "binding", cioè nell'unire assieme i diversi aspetti di un ricordo, il che che permette di creare delle rappresentazioni vivide di un evento (Mitchell, Jonhson, Raye, & Greene, 2004), e dunque di evitare i falsi ricordi (Peters, Jelicic, Verbeek, & Merckelbach, 2007). Tuttavia, non è chiaro cosa succeda nel caso del materiale negativo. Si sa che il materiale negativo tende a interferire con la capacità di controllo della ML, riducendone la prestazione (Osaka, Yaoi, Minamoto, & Osaka, 2013). Di conseguenza, il materiale negativo dovrebbe portare a maggiori falsi ricordi, tuttavia di solito si osserva l'opposto (Kensinger, 2007). È dunque possibile che il materiale negativo abbia sia effetti "protettivi" (dati da una maggiore distintività e da una più accurata codifica; Kensinger & Corkin, 2004) che effetti "avversi" (interferendo con il controllo della ML) nei confronti dei falsi ricordi. Anche se normalmente prevalgono gli effetti protettivi, gli effetti avversi potrebbero emergere quando le capacità di base di ML sono ridotte. Nell'Esperimento 4 un ampio gruppo di studenti universitari è stato sottoposto al paradigma dei falsi ricordi inferenziali emotivi in condizioni di base, e la loro capacità di ML è stata misurata tramite un apposito compito attivo (De Beni, Palladino, Pazzaglia, & Cornoldi, 1998). I risultati hanno mostrato una interazione significativa tra capacità di ML e valenza del materiale sulla produzione di falsi ricordi. In particolare mentre i falsi ricordi per eventi positivi e neutri non erano particolarmente legati alla ML, quest'ultima sembrava avere un effetto protettivo sui falsi ricordi per eventi negativi. Per chiarire meglio il quadro dei risultati è stato condotto l'Esperimento 5. In questo esperimento metà dei partecipanti (gruppo sperimentale) doveva visionare il materiale mentre conduceva un doppio compito inteso ad interferire con la componente dell'esecutivo centrale della loro ML (Baddeley, 2000). I risultati hanno mostrato che la probabilità di commettere falsi ricordi era complessivamente più alta nel gruppo sperimentale rispetto a quello di controllo (si notava anche una generale caduta nell'accuratezza). Tuttavia, questo incremento nei falsi ricordi era più grande nel caso negli eventi negativi che in quello degli eventi positivi o neutri, confermando così l'importanza di avere una buona capacità di ML per essere protetti contro gli errori inferenziali nel caso degli eventi negativi.

Per quanto riguarda le conclusioni generali, attraverso cinque esperimenti ho mostrato che, in genere, gli eventi emotivi (sia positivi che negativi) sono protetti contro gli errori inferenziali (specialmente contro gli errori causali) a confronto con gli eventi neutri. Ciò è coerente con la letteratura. La cosa più importante, però, è che questo non succede in qualsiasi condizione. Esistono condizioni, specialmente nel caso degli eventi negativi, nelle quali questo effetto "protettivo" è annullato, se non capovolto. Tali condizioni includono la rielaborazione del materiale visto, la forte presenza di sintomi internalizzanti, anche a livello sub-clinico (e specialmente di ansia di tratto), e basse o ridotte capacità di ML al momento della codifica.

(Please see the section "5.1 Summary of the findings and their implications" for a corresponding summary in English.)