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ANXIETY AND MEMORY FUNCTIONING IN CHILDREN: AN INDIVIDUAL DIFFERENCES APPROACH

PhD Thesis Abstract

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An Introduction

In recent years, more researchers turned their attention towards the under-investigated area of potential detrimental effects of anxiety upon memory functioning in children (see Visu-Petra, Cheie, & Miu, in press, for a review). This recent increasing interest can be accounted by several crucial reasons, such as: (1) the need to unravel anxiety's early vulnerability markers that would aid revealing the underpinning mechaninsms of anxiety disorders development (see Hadwin & Field, 2010a); (2) the need to investigate the early precursors of memory impairments (e.g. Visu-Petra, Cheie, Benga, & Alloway, 2011); and (3) the need to investigate high-anxious children's academic underachievement (e.g. Aronen, Vuontela, Steenari, Salmi, & Carlson, 2005).

The present thesis aimed to bring substantial added value to this emerging field, attempting to provide new evidence confirming non-clinical anxiety's detrimental effects upon children's memory functioning. In a series of four studies, research was channeled into two main directions: the first direction line focused on investigating the relationship between individual differences in trait anxiety and memory for non-emotional information (on both retrospective and prospective memory) and their links to academic achievement; the second direction line focused on exploring the role of individual differences in trait anxiety on various aspects of memory for emotional information.

CHAPTER 1

ANXIETY AND MEMORY FUNCTIONING: THEORIES AND EMPIRICAL DATA

1.1. Conceptual clarifications

1.1.1. Development and individual differences in anxiety

Studies from the last decade have shown that anxiety disorders are among the most prevalent psychopathologies in children and adolescents (e.g. Costello, Mustillo, Erkanli, Keeler, & Angold, 2003). This issue has become more pressing, in light of recent findings suggesting that, although it can embrace several forms, anxiety can have a chronic course throughout childhood, and can continue into adolescence and adulthood (e.g. Goodwin, Fergusson, & Horwood, 2004). Moreover, studies have emphasized anxiety's negative consequences on children's well being, as it negatively predicts academic outcome (e.g. Ashcraft, 2002), cognitive performance (e.g. Martin et al., 2007), or long term psychopathology (e.g. Costello et al., 2003; Ferdinand, Dieleman, Ormel, & Verhulst, 2007). Hence, it has become increasingly important to investigate anxiety and its vulnerability marks in the developmental period.

But is there an individual trait that acts as a vulnerability factor for these disorders? So far, most researchers investigating anxiety-related individual trait differences have mainly focused on neuroticism (Arnold & Taillefer, 2011). According to Spielberger (1973), trait anxiety refers to stable individual differences in anxiety proneness, and underlies the differences between children in the tendency to experience anxiety states. Although it is conceptualized as an anxiety vulnerability factor, the concept is often misconceived as an anxiety symptom, and treated as such within developmental research (see also Murris, 2007).

In the present series of studies, despite focusing on individual differences in non-clinical (trait) anxiety, we subscribe to a continuum model of anxiety (see Endler & Kocovski, 2001), where temperamental predispositions, dimensional manifestations (state-trait anxiety), and anxiety disorders all represent phenotypic outcomes of lifelong gene-environment interactions which lead an underlying diathesis to be manifested or remain silent (Pine, 2007). This perspective emphasizes the paramount importance of memory processes in the generation and maintenance of developmental trajectories of anxiety, and this direction was consistently pursued throughout the studies.

1.1.2. Anxiety and retrospective memory

A general distinction in the memory domain is the one between *retrospective* and *prospective memory* (see Baddeley & Wilkins, 1984). Not surprisingly, this distinction has been commonly mentioned in order to define prospective memory by contrasting it to the better known retrospective memory system. Thus, while retrospective memory refers to remembering past events or previously encoded information (maintained in the working memory system or long term memory system), prospective memory is commonly defined as remembering to perform a previously planned action at the appropriate time or in the appropriate context (e.g. remembering to make a phone call after finishing reading a couple of articles; see Einstein & McDaniel, 1996).

Regarding the potential anxiety-related effects in both adults and children's retrospective memory functioning, studies have initially focused on anxiety-related disruptions of WM capacity and processing (Processing Efficiency Theory; PET, Eysenck & Calvo, 1992), and more recently on the impact of anxiety upon attentional control (Attentional Control Theory; ACT, Eysenck, Derakshan, Santos, & Calvo, 2007). The first approach was supported by a large body of - mostly behavioural - evidence, revealing that, especially on difficult and demanding memory tests, performance deficits arise due to anxious individuals' tendency to process task-irrelevant information associated with their worries (Eysenck & Calvo, 1992). The second approach focuses on the functions of the central executive and on goal-related patterns of performance, relying on convergent behavioral, electrophysiological and neuroimaging data (Eysenck et al., 2007) to reveal attentional control failures in high-anxious participants.

Researchers have focused on the contents of the memoranda, investigating whether the introduction of *emotionally relevant* (especially threat-related) information generated anxiety-related memory biases. In order for a memory bias to be ascertained, one would have to look for both between-group differences and within-group discrepancies between processing of neutral versus threat-related information (Mitte, 2008). Evidence revealing such a memory bias has been rather inconsistent (Miu & Visu-Petra, 2010), with results highly dependent upon the population and the memory system (explicit vs. implicit) investigated, the experimental paradigm (recall vs. recognition), or procedural details (stimulus modality, encoding procedure, retention interval). This chapter will focus on studies with non-clinical, *high-anxious participants*, and on *explicit memory biases*, revealed by both recall and recognition paradigms.

Although the number of studies dealing with the impact of anxiety on memory (either short-term memory, WM, or long-term memory) is still disproportionately small compared to the literature on attentional biases, there are more and more investigations claiming that the dynamics of cognitive biases should be studied longitudinally. From this developmental perspective, memory processes are bound to play an important role in the translation of the emotional "capture" of attention into the long-lasting, “looming” cognitive style (Riskind & Williams, 2005) characterizing anxious individuals.

1.1.3. Anxiety and prospective memory

Although research in the prospective memory (PM) domain is growing (Brandimonte, Einstein, & McDaniel, 1996; Einstein, McDaniel, Marsh, & West 2008; Kliegel & Martin, 2003), the number of studies concerning it is rather small if we are to consider the number of scientific papers on RM and the fact that studies reported that up to 80% of our everyday memory problems are PM problems (see Kliegel & Martin, 2003 for a review).

The above mentioned Attentional Control Theory (ACT; Eysenck et al, 2007) also predicts that high levels of anxiety would impair PM performance as it would be a cost of task switching (failing to shift attention to the task when cued). Regarding the anxiety-PM relationship in adults, there is a handful of studies. Cockburn and Smith’s (1994) event-based PM task consisted in participants asking the experimenter about an appointment immediately after an alarm rang. The authors concluded that intermediate levels of state anxiety were associated with PM failure, whereas high and low levels of anxiety were related to PM success. However, their result does not infirm ACT’s prediction, as a ringing alarm can be considered a very salient external cue that could easily redirect attentional resources from the ongoing task. Using a typical laboratory paradigm, Nigro and Cicogna (1999) found that high levels of state anxiety were associated with shorter latencies of the PM responses. However, no data concerning the accuracy of response (PM failures) was provided. Using dual-task procedures, Harris and Menziez (1999) and Harris and Cumming (2003) found that participants with high state anxiety performed significantly worse than those with low state anxiety on event-based PM tasks. Similar results were also reported by Kliegel and Jäger (2006a) for the event-based and time-based PM performance as studied with a laboratory paradigm. Hence, even though none of these studies directly address the anxiety – PM relationship in a task-switching paradigm, they provide suggestive evidence that anxiety impairs PM performance.

1.2. Trait anxiety and cognitive functioning: theoretical approaches

In investigating emotion-cognition interactions, the study of anxiety has played an essential role, considering the preferential processing of threat-related information which characterizes this condition (see Bar-Haim et al., 2007, for a meta-analysis). This "bias" influences an individual’s somatic, emotional, cognitive, and behavioural functioning (Eysenck, 1992). In the cognitive domain, despite the widely acknowledged impact of anxiety on the preferential allocation of *attention* to threat, the presence of an analogous *memory* bias has been a matter of controversy. Although there is consensus with regard to the importance of memory processes for the establishment and maintenance of an anxious cognitive style, and to the emerging implications for psychotherapy (Williams, 1996), both theoretical and empirical work provided mixed support for anxiety-memory interactions (MacLeod & Mathews, 2004). The present chapter aims to review these findings, following several directions which offer promising avenues for their integration, and revealing their implications for cognitive and developmental models of anxiety, and for academic and therapeutic interventions.

There has been a long-standing intuition that anxiety is associated with cognitive performance decrements. Empirical support for this intuition extends back several decades, identifying negative associations between the stable tendency to respond with anxiety in the anticipation of threatening situations (e.g. evaluative), and intelligence (Calvin, Koons, Bingham, & Fink, 1955; but see Kraus, 1965; Kanekar, Neelakantan, & D'Souza, 1976, for negative findings), learning (Spence & Spence, 1966; Weinstein, Cubberly, & Richardson, 1982) or problem solving skills (Sinclair, 1974; Deffenbacher, 1978).

Within the last decade, a substantial increase in the number of studies targeting anxiety influences on cognitive performance has been noted. This surge of interest can be tracked down to at least three factors: (1) the theoretical advances promoted by a unifying theory, focusing on attentional control mechanisms, responsible for anxiety-related effects across neutral and emotionally-relevant contexts; (2) the methodological advances offered by neuroimaging techniques; and (3) the therapeutic advances, consisting in an incorporation of the latest findings into treatment packages targeting cognitive biases, such as the Attentional Bias Modification paradigm (see Mathews & MacLeod, 2002; Bar-Haim, 2010, for reviews). We will review how the first two directions have influenced research targeting the specific influence of anxiety on WM processes. Unfortunately, intervention studies designed specifically to diminish memory biases in anxiety are scarce, probably due to the controversy still surrounding the very presence of such a bias. Finally, we will present two directions which we consider highly relevant (although still under-investigated) for research in this field: the role of memory processes in establishing and maintaining the developmental trajectory of anxiety, and the role of individual differences in WM capacity in modulating the impact of anxiety on memory functions.

1.2.1. The Attentional Control Theory

While incorporating the general framework of PET, the Attentional Control Theory (Eysenck et al., 2007; Derakshan & Eysenck, 2009) extends it in two significant directions. First, a more precise description of the *mechanism* through which anxiety interferes with cognitive performance is provided, by placing this interaction in the context of goal-directed (top-down) and stimulus-directed (bottom-up) attentional systems (Corbetta & Shulmann, 2002). The key assumption is that anxiety disrupts attentional control, an essential function of the central executive component of the WM and PM systems. Anxiety is thereby conceptualized as "a state in which an individual is unable to instigate a clear pattern of behaviour to remove or alter the event / object / interpretation that is threatening an existing goal" (Power & Dalgleish, 1997). By increasing attention to such task-irrelevant stimuli (especially threat-related), anxiety disrupts the balance between the goal-directed and stimulus-directed systems in favor of the latter.

This prediction allows for the incorporation of the literature regarding stimulus emotional valence, with anxious individuals showing enhanced distractibility and difficulties disengaging from threat-related stimuli, either external, present in the task itself, or internally generated by the subjective interpretation of the context. As a corollary, anxiety is also expected to enhance performance, when the required responses primarily involve the stimulus-driven attentional system, and not the goal-directed attentional system. Support for these predictions is beginning to accumulate (see Eysenck et al., 2007; Derakshan & Eysenck, 2009; Eysenck & Derakshan, 2011, for reviews). The meta-analysis by Mitte (2008) provided a comprehensive systematization of the existing evidence of memory enhancement for threat-related information, affecting both recognition and recall processes in high-anxious individuals. It found support for: a within-group trend toward preferred recognition of threat-related pictorial (but not verbal), compared to neutral material; a between-group difference indicating better recall of verbal threatening material and poorer recall of positive material compared to low-anxious individuals; no consistent evidence for an implicit memory bias. Some studies show that there is a degree of content-specificity in the preferential processing of threat, so that the specific worries that an individual has are also the ones most likely to be remembered when found in memory tasks (Calvo, Avero, Dolores Castillo, & Miguel-Tobal, 2003; Reidy, 2004;). Ignoring the personal relevance of threat items could be an important explanation for divergent findings, beside the methodological diversity characterizing the studies (Mitte, 2008).

Second, the homuncular (Cowan, 1988) perspective on the central executive is replaced with a more *functional* approach, provided by the executive functions model of Miyake and collaborators (2000). This model identifies three independent (yet interdependent) executive functions: shifting (flexibly switching between multiple tasks, operations or mental sets), updating (using and monitoring, and refreshing the representations in WM), and inhibition (the ability to deliberately inhibit dominant, automatic or prepotent responses when necessary). ACT predicts that anxiety mainly disrupts the functions of *inhibition* ("negative" attentional control) and *shifting* ("positive" attentional control), and, to a lesser degree, the updating function. Support for the negative effect of anxiety on inhibition is drawn from multiple behavioural, electrophysiological and neuroimaging studies (see Eysenck & Derakshan, 2011, for a recent review). The typical finding is that high-anxious individuals are more susceptible to (especially threat-related) distraction than low-anxious individuals. It is important to stress the fact that several neuroimaging investigations have supported the existence of a general (not just threat-related) impairment of attentional control in high-anxious individuals (Bishop, 2009; Basten, Stelzel, & Fiebach, 2011). Similar to the documented inhibitory failures, high-anxious individuals have also been shown to present more difficulties in flexibly shifting between different mental/task sets (see Eysenck & Derakshan, 2011, for a recent review).

Given our focus on memory functioning, it is of relevance to explore ACT's prediction of a limited effect of anxiety on the *updating* function. There appears to be some discrepancy between the ACT conceptualization of updating as "concerned with the transient storage of information, and so involves short-term memory rather than attentional control per se", (Derakshan & Eysenck, 2009, p. 12), and the original view of this function, since "the essence of Updating lies in the requirement to actively manipulate relevant information in working memory, rather than passively store information" (Miyake et al., 2000, p. 57). Considering that in its traditional sense, updating is an executive process (Smith & Jonides, 1999) which requires attentional control in order to monitor, code, substitute and update incoming information in response to task goals (see Ecker, Lewandowsky, Oberauer, & Chee, 2010, for an experimental decomposition of its sub-processes), it is presumable that anxiety will also affect its functioning, especially in updating contexts that include threat-related distractors. Although not focused on anxiety effects, Schmeichel (2007) investigated the hypothesis that initial efforts at executive control temporarily undermine subsequent efforts at executive control. Using tasks involving simple information storage, or updating, he showed that attempts to maintain and update information in memory were impaired by prior efforts at executive control, whereas attempts simply to maintain information in memory remained relatively unaffected. In our view, the resource depletion approach proposed by this complex investigation is similar to the ACT approach, and could provide a fruitful strategy for analyzing anxiety-related effects on the updating function, in contexts containing neutral or threat-explicit material. It is presumable that anxious individuals' attempts to exert executive control in order to attenuate their task-irrelevant worries could deplete subsequent executive resources required by the updating task itself (see Fales et al., 2008, 2010; or Visu-Petra, Miclea, Cheie, & Benga, 2009; Visu-Petra et al., 2011, for preliminary evidence).

1.3. Memory and the Developmental Trajectory of Anxiety

1.3.1. Anxiety and memory for non-emotional information

Developmental research focusing on the link between anxiety and WM for *emotionally-neutral* information seems to be better documented than the one concerning a content specific memory bias in anxiety. Yet, the existing studies conducted with both clinical and non-clinical high-anxious children have yield mixed evidence of impaired memory for neutral information (see also Miu & Visu-Petra, 2010). The first set of evidence can be derived from studies conducted with clinical populations, in which most of the findings imply a link between anxiety symptomatology and poor WM performance (e.g. Toren et al., 2000; Vasa et al., 2007; but see also Günther, Holtkamp, Jolles, Herpertz-Dahlmann, & Konrad, 2004 for contradictory results). Although evidence of a memory impairment in clinically anxious children clearly exists, the results of these studies are rather inconsistent with regard to stimulus modality effects (verbal vs. visual-spatial). However, part of these inconsistencies are probably accounted for by methodological differences such as: investigating different or restrictive anxiety diagnoses (e.g. Günther et al., 2004; Toren et al., 2000; Vasa et al., 2007), using a large age range (e.g. 8 – 17 years in Günther et al., 2004; 9 – 20 years in Vasa et al., 2007), or the various experimental paradigms and procedural details.

Few studies have attempted to validate the existence of a general WM impairment in non-clinical, *high-anxious children*. All of these studies explored this relationship by directly addressing ACT's (Eysenck et al., 2007) main predictions considering anxiety's detrimental effect on both efficiency and accuracy of performance. The first of such developmental studies were carried out with *school age children*. Hadwin et al. (2005) found that while state anxiety was not related to the accuracy of performance on any WM test, high-anxious children took longer to complete the backward digit span task, and more effort to complete the forward digit span task, compared to low-anxious children. Moreover, processing efficiency impairments were also reported in a study that compared the performance of high and low trait test anxiety groups of 10 year olds on a mental arithmetic task, varying in WM demands (Ng & Lee, 2010). Consistent with the PET/ACT's predictions and Hadwin et al.'s previous findings (2005), the adverse effects of anxiety were found on the memory load task efficiency. However, some results were inconsistent with ACT predictions, as the detrimental effects of test anxiety did not increase as the WM demands increased. Owens et al. (2008) also directly tested ACT's predictions, investigating the relationship between trait anxiety, WM, and academic performance in a sample of school-age children (11 – 12 years). Consistent with the abovementioned results and ACT's predictions, trait anxiety was again found to be negatively associated with verbal WM performance, and no association was found between trait anxiety and visuo-spatial WM.

More recently, the trait anxiety – short-term memory relationship was also investigated in *preschoolers*. Visu-Petra et al. (2009) investigated the effects of trait anxiety on simple span accuracy and performance efficiency (response timing) in a sample of 3 to 6 year olds. At the first time point, WM was assessed using a digit span task and a word span task, and 8 months later, children were assessed with the same tasks and a newly introduced nonword span task. As predicted by the ACT, the results showed that trait anxiety was a negative predictor of span effectiveness over time, as well as a concurrent negative predictor for efficiency (in the case of word and non-word span). The microanalysis of response timing (measuring the duration taken to prepare the response, to produce each word, and the pauses between words) indicated that children with high trait anxiety took longer to prepare their answers, as they had longer pauses between words and longer preparatory intervals. In another study, Visu-Petra et al. (2011) investigated both short-term memory and WM performance in relation to trait anxiety, in two samples of preschoolers (3-7 years). Results revealed that while both the visual-spatial storage and updating performance did not differ between the two anxiety groups, their performance differed on the verbal measures. In this respect, when simple verbal storage was required, high-anxious preschoolers displayed efficiency deficits only; but when executive demands were higher (i.e., verbal updating), both efficiency and accuracy of response were impaired.

To sum up, although the number of studies exploring the relationship between non-clinical anxiety and WM in children is limited, a consistent pattern of results, confirming ACT's (Eysenck et al., 2007) predictions, is notable. So far, findings suggest that: (1) there are comparable levels of both accuracy and efficiency of performance between the two anxiety groups on the visuo-spatial short-term memory and WM tasks (see Hadwin et al., 2005; Owens et al., 2008; Visu-Petra et al., 2011); (2) higher levels of anxiety mainly disrupt children's verbal performance efficiency, on both WM tests (see Hadwin et al., 2005; Owens et al., 2008; Ng & Lee, 2010; Visu-Petra et al., 2011), as well as on simple storage tasks (see Visu-Petra et al., 2009; Visu-Petra et al., 2011); (3) high levels of anxiety can also disrupt children's performance effectiveness, mainly as a function of the increase in executive demands involved in the memory task (see Visu-Petra et al., 2011).

1.3.2. Anxiety, working memory and academic performance

The relationship between anxiety and neurocognitive functioning in children has been mainly investigated at the level of the consequences, as it has been well documented that a higher level of anxiety is related to poorer academic achievement (see Ashcraft, 2002; Crozier & Hostettler, 2003; Woodward & Fergusson, 2001). A less documented area concerns the neurocognitive mechanisms underlying this relationship. Within the ACT (Eysenk et al., 2007) framework, the interference between anxiety and WM functioning represents a potential mechanism that may account for anxiety's detrimental effect on academic performance. Some indirect evidence derives from studies showing that a poorer academic achievement and learning difficulties are also associated with a poorer WM capacity (e.g. Alloway & Gathercole, 2005; Gathercole & Pickering, 2000; Gathercole, Pickering, Knight, & Stegmann, 2004; Henry, 2001; Swanson & Sachse-Lee, 2001).

However, there are few studies specifically focusing on the association between anxiety, WM, and academic performance. In their study, Aronen and his collaborators (2005) concluded that teacher-rated anxiety/depression symptoms were negatively related to WM functioning and the ability to concentrate, an outcome that would lead to having a poorer academic performance in school. Nevertheless, the children's academic performance per se was not evaluated, so the authors' conclusions relied solely on teachers' reports.

Directly testing ACT’s predictions, Owens et al. (2008) investigated the relationship between trait anxiety, WM, and academic performance in a sample of school-age children. As mentioned earlier, trait anxiety was found to be negatively associated with verbal WM. But, most importantly, verbal WM was also found to partially mediate the relationship between trait anxiety and academic performance, accounting for 51% of the association. Given these results and the fact that visuospatial WM accounted for only 9% of the anxiety - academic performance relationship, this study suggests that verbal WM is an important neurocognitive mechanism underlying anxiety's negative effect on school outcomes. Moreover, similar results have been recently obtained in independent samples of school-age children (Owens, Stevenson, Norgate, & Hadwin, submitted; as described in Curtis, 2009; Yousefi et al., 2009).

1.3.3. Anxiety and memory for emotional information

Although symptoms of subclinical and clinical anxiety are common even in the preschool period (Cartwright-Hatton, McNicol, & Doubleday, 2006; Egger & Angold, 2006) and persist through the childhood years and into adulthood (Hadwin & Field, 2010a; Weems, 2008), research analyzing the onset of children's anxiety-related cognitive biases has been scarce and often contradictory. In recent years, researchers have struggled to organize evidence supporting the existence of cognitive biases in high-anxious children's processing of emotional information, by adopting an information-processing perspective (e.g., Daleiden & Vasey, 1997; Field & Lester, 2010a; Hadwin, Garner, & Perez-Olivas, 2006; Pine, 2007). This integrative perspective is essential for investigating both distal, and proximal vulnerability markers that contribute to the development and maintenance of child and adolescent anxiety (Ingram & Price, 2010)

Anxious children display distinctive patterns of information processing biases (see Hadwin & Field, 2010b; Field & Lester, 2010b; Pine, 2007). In one of the most comprehensive developmental models of cognitive biases in early information processing in anxiety, Pine (2007) argues that genetic and environmental influences directly operate at the level of the neural circuitry that shapes threat responses, influencing information processing mechanisms. It is hypothesized that there is an interaction between attentional biases which occur in the early stages of information processing and subsequent learning processes, which lead children to classify a broad range of stimuli as dangerous. Providing a similar explanation, Weems and Watts (2005) argued that selective attention, memory biases, and negative cognitive errors could have a very important role in the generation and maintenance of childhood anxiety symptoms.

Existing evidence of early memory biases towards negative information would support the *developmental continuity* framework (Weems, 2008), acknowledging the early onset of information processing biases in high-anxious children. In favor of this perspective, Pine (2007) conjectures that the information processing biases could be even stronger in young children, due to the enhanced plasticity of their threat-processing circuitry. Moreover, based on developmental cognitive research findings, Field & Lester (2010a) argue that early childhood (4–7 years) could be an important developmental period in learning interpretational biases to threat, while attentional biases could develop during early childhood (Pérez-Edgar, Bar-Haim, McDermott, Chronis-Tuscano, Pine, & Fox, 2010).

To date, most of the developmental researchers studying cognitive vulnerability factors in high-anxious children, have been interested in investigating attentional biases towards threat and threat appraisal distortions. Results revealed that, compared to their low-anxious counterparts, high-anxious children display an attentional bias towards threatening information (see Malcarne, Hansdottir, & Merz, 2010; Miu & Visu-Petra, 2010, for recent reviews). However, data regarding high-anxious children's cognitive vulnerability factors, especially with respect to remembering emotional information, remains scarce and inconsistent (see Hadwin, Garner, & Perez-Olivas, 2006, for a review). Developmental research with *clinical populations* has yielded mixed results: in terms of *verbal* short-term memory recall. An overall poorer memory performance, as well as a bias favoring negative information recall were found in children and adolescents with PTSD (Moradi, Taghavi, Neshat-Doost, Yule, & Dalgleish**,** 2000; but see Dalgleish et al., 2003 for no significant effects in samples of PTSD and GAD patients. In the *visual* domain, no significant interference of negative task-irrelevant images (backgrounds) was found on memory performance in the anxiety-only group

(Ladouceur et al., 2005). Again, the scarcity of the existing literature and the inconsistency of the existing results prevent us from drawing any conclusions.

Again, few studies have investigated WM or short-term memory for emotional information in *non-clinical* samples. In the *verbal WM* domain, the first data derived from studies conducted with *school age* children. Daleiden (1998) investigated the effects of trait anxiety on a conceptual and perceptual verbal memory task in a sample of school-age children (11–13 years). The children were presented with two lists of 30 emotional words (positive, negative, and neutral). Results revealed that the recall of negative words (relative to positive and neutral) was better in the high-anxious group, when recall reflected conceptual (relative to perceptual) memory. Another study, conducted by Reid, Salmon, and Lovibond (2006), investigated cognitive biases in a non-clinical sample of school-age children (8-14 years) assessed for anxiety, depression, and aggression symptoms. Regarding memory biases, the authors used a verbal memory task involving self-descriptors (44 positive and negative adjectives) and varied the depth of processing in the encoding stage, from a superficial level (the child had to decide if it's a long or a short word) to a deeper, self-referential level. Their findings revealed a memory bias towards negative information, present only when scores from all types of symptomatology were combined, and no specific association with anxiety.

As for the relationship between non-clinical anxiety and emotional biases in *visual WM*, to our knowledge, there is just one published study. Using a memory updating task in a sample of preschoolers (59 to 88 months), Visu-Petra, Țincaş, Cheie and Benga (2010) found that, compared to their low-anxious counterparts, high-anxious children were both less efficient and less accurate in recognizing happy faces, but more accurate in identifying previously seen angry faces. Also, high-anxious children were less accurate in recognizing happy (relative to neutral) facial expressions, while low-anxious children were less accurate in response to angry (relative to happy and neutral) faces. The results confirm previous findings from research with adults (Moser Huppert, Duval, & Simons, 2008), revealing a negative bias favoring the recognition of threatening faces in children with high levels of anxiety, as well the absence of a positive bias towards positive visual information, for high-anxious participants only.

1.4. Summary and Critical Issues

The main research question investigated throughout the chapter focused on the cognitive outcomes of the interaction between individual differences in trait anxiety and memory functioning. Most of the reviewed literature focused on one direction of this interaction, analyzing whether there is a disruptive effect of trait anxiety (further amplified by anxious state) on cognitive performance, in general, and on memory, in particular. As emphasized throughout the chapter, this rather straightforward prediction should be nuanced in several directions. First, one major distinction relates to the contents of the memory task. Would anxiety interfere with WM and PM processes even when the to-be-remembered contents do not involve an explicit threat? Apparently, the answer is yes, but not without reserve. But what happens when information with emotional valence is introduced? The answer needs to be calibrated according to the relevance of this information for the task at hand, and to the level of threat being experienced, both influencing how motivation and emotion interact to enhance or impair executive control (Pessoa, 2009). When (negative) emotional information is relevant for the goals of the individual, anxiety can enhance cognitive performance by favoring a more rapid detection and encoding of threat-related information. When emotional valence is task-irrelevant, anxiety acts as a distracter and impairs performance, by allocating resources in a stimulus-driven mode toward (task-irrelevant) threatening information.

The following studies aimed to complement the existing literature, addressing several of the prior exposed critical issues, by investigating non-clinical anxiety's detrimental effects upon children's memory functioning.

Research was channeled into two main directions:

(1) aiming to explore the relationship between individual differences in trait anxiety and memory for non-emotional information. Both PM (Chapter 2, Study 1; Chapter 3, Study 2b, Sudy2c) and WM and its links to academic achievement (Chapter 3, Study 2a, Study 2c) were investigated in relation to individual differences in children's trait anxiety;

(2) focusing on exploring the role of individual differences in trait anxiety on various aspects of memory for emotional information. Children's immediate and delayed memory for emotional information was investigated in Chapter 4, Study 3. Memory for emotional stories, and potential emotion-induced memory trade-offs in complex-scenes were investigated in Chapter 5, Study 4.

CHAPTER 2.

STUDY 1. EVENT-BASED PROSPECTIVE MEMORY IN YOUNG CHILDREN: EFFECTS OF AGE, TRAIT ANXIETY, AND MEMORY AIDS

2.1. Introduction

2.1.1. Prospective memory and development

Although we expect young children to remember to deliver messages or to lock the door after entering home, research regarding the developmental path of children's prospective memory (PM) is still limited (see Kvavilashvili, Kyle, & Messer, 2008 for a review). Older children have been shown to outperform younger children on most types of PM tasks (e.g. Kliegel & Jäger, 2007), but the lack of standard methods could account for some of the existing age differences across developmental studies (Kvavilashvili et al., 2008). Using both adult and child versions of Einstein & McDaniel's (1990) *laboratory paradigm*, studies revealed a consistent pattern of PM improvement during the preschool period, 4-to-5-year-old children presenting significantly better PM performances than 3-year-olds (see Guajardo & Best, 2000; Kliegel & Jäger, 2007; Kliegel, Brandenberger, & Aberle, 2010; Wang, Kliegel, Liu, & Yang, 2008). Although underinvestigated, age effects have also been found in some studies using more *ecologically-valid* tasks for evaluating PM performance (e.g. to remember close the door when cued; see Guajardo & Best, 2000).

As the executive functions develop substantially within the preschool and early school years (see Diamond, 2006), age differences are to be expected especially in PM tasks that require more executive control, rather than automatic processing (see Kliegel & Jäger, 2007; Maylor, 2008; for evidence in this direction).

2.1.2. Prospective memory and individual differences in anxiety

The impact of individual differences in dispositional variables on prospective remembering has been underinvestigated. According to the Attentional Control Theory (ACT; Eysenck, Derakshan, Santos, & Calvo, 2007) anxiety-related worrisome thoughts generate cognitive interference, mainly disrupting inhibition and shifting processes (see Derakshan & Eysenck, 2009 for a review). An innovative way to test ACT's prediction would be via a PM task that implies a task-switching procedure, as performance on task-switching paradigms highly loads on the shifting function (Miyake et al., 2000). Eysenck et al. (2007) actually predicted that high levels of anxiety would impair PM performance as it would be a cost of task-switching (failing to shift attention to the PM task when cued). In an unpublished study (see Eysenck & Derakshan, 2008), Eysenck and colleagues confirmed this prediction as they found that high anxious (HA) individuals performed significantly worse than low anxious (LA) ones when the PM cue was nonfocal (category members) as opposed to the focal condition (specific words), and also when the PM target was not cued in advance, as opposed to the condition in which a cue was present. The findings suggest that the detrimental effects of anxiety on PM performance are much diminished when PM cues are more salient, thus attentional control demands are reduced. Aside from this unpublished study, to our knowledge, there is no research directly testing ACT's prediction regarding PM performance.

However, in research with adults, there are a handful of studies regarding the anxiety-PM relationship (see Kliegel & Jäger, 2006, for a review). Although none of these studies directly address the anxiety – PM relationship in a task-switching paradigm, they provide suggestive evidence that high levels of anxiety can impair PM performance. ACT's predictions regarding PM performance have not yet been addressed by developmental research, but evidence from the retrospective memory domain confirms the detrimental effects of nonclinical anxiety on the Central Executive (CE) in young children (e.g. Visu-Petra, Cheie, Benga, & Alloway, 2011).

2.2. Current study

The major goal of the *current study* was to provide an evaluation of even-based PM performance in both task-switching and non-switching contexts during preschool years, and to explore the effects of individual differences in TA upon PM performance in this young age group. Thus, a first aim was to investigate developmental differences preschoolers' PM performance on a task-switching computerized task with two memory-aid conditions: with and without external cueing, respectively; and on a non task-switching, more ecologically-valid task. We expected performance in the task-switching computerized task to increase with age, especially in the no external memory aid condition, as an effect of the more executive-demanding of the target cue. With regards to age effects on the non task-switching, more ecologically-valid task, given the scarcity of the literature, our investigation was rather exploratory.

The second major objective was to test the ACT prediction that a high level of anxiety disrupts PM performance, and that this performance is less impaired when the target cues are very salient. Thus, we expected (1) HA children to be outperformed by their LA counterparts in the task-switching context, especially on the no memory aid condition, as an effect of the more executive-demanding of the target cue; (2) no differences between HA and LA children in the ongoing task performance of the task-switching computerized probe. No specific predictions regarding effects of TA on the more ecologically-valid task could be made, our investigation being exploratory.

2.3. Methods

2.3.1. Participants

A total of 75 preschoolers were recruited from three local kindergartens and all completed the memory tasks. However, two preschoolers failed to recall the task-switching PM instruction at the end of the evaluation, and were therefore excluded from the analysis. Hence, our sample consisted in 73 children (38 girls), with an age range of 45 to 85 months (mean age = 65.23 months, SD = 10.87). The parental ratings of the children's anxiety symptoms on Spence Preschool Anxiety Scale (SPAS; Spence, Rapee, McDonald, & Ingram, 2001) generated a total TA score for each child. Based on the median split (median value was 22) of their total anxiety scores, children were classified as either LA (n = 35) or HA (n = 38). The two groups significantly differed in their anxiety scores, $F(1, 71) = 68.53$, $MSE = 7554.73$, $p < .001$, $\eta_p^2 = .49$, but did not differ in age, $F(1, 71) = .29$, $MSE = 34.72$, or gender distribution, $X^2(1) = 1.08$, $p = .30$.

2.3.2. Materials and procedure

PM performance

In order to evaluate PM performance, two types of measures were used: a *computerized task* (modeled after the modified paradigm for children; Kvavilashvili, et al., 2001) and a more *ecologically-valid task*. The two conditions of the computerized task differed in terms of using an external memory aid aimed to help children to remember the previously planned action.

In the *No-Aid condition*, preschoolers had to name pictures as they individually appeared on the screen (i.e. ongoing task) and to remember to press the space-bar key whenever the PM target cue appeared. The pictures represented familiar images (e.g. clock, bear, carrot) taken from the Snodgrass Inventory (Snodgrass & Vanderwart, 1980) and were displayed for 5s each, with a 1s interval in between. Children received the instructions for the ongoing task (picture naming) and then were engaged in a learning phase, during which they had to name 3 images individually displayed on the screen. The experimenter then introduced the actual PM task by instructing the preschoolers to remember to refrain from picture naming and press the space-bar key (covered with blue tape) whenever they saw the image of an apple. Once the preschoolers understood the instructions for the ongoing and the PM task, the experimenter introduced them to a 2-minute block construction filler task. Before engaging the children in this filler task for the first time, the experimenter took the cube box from a nearby table and gave the ***more ecologically-valid task*** instruction. This instruction consisted in asking the children to remember to put the box back on the table once the experimenter said "*We've finished the computer game*" and closed the laptop lid.

The No-Aid condition consisted in 3 blocks of 10 pictures each, each block being preceded by the 2-minute filler task. After completing the 3 blocks, children who forgot to press the space-bar key on all 3 occasions, were asked successive questions, increasing in specificity (see Kvavilashvili et al., 2008), in order to find out whether or not the lack of PM response was a RM failure. For the With-Aid condition, children were provided with an external reminder of the target image, a 10 X 10 cm card that depicted the PM cue (i.e. a frog), which was placed on the left corner of the screen. Aside from this particularity, the two aid conditions were identical. However, the presentation of the two conditions was not counterbalanced in order to preserve the secondary nature of the PM task and the primary nature of the ongoing task.

After finishing the task-switching PM procedure, the target cue for the more *ecologically-valid task* was introduced. If the preschoolers did not spontaneously perform the PM action, then it was considered a PM failure. RM for the PM instruction was also verified through two successive questions. All children were praised for their good work on the tasks.

Trait anxiety

Trait anxiety was assessed via parental report on the *Spence Preschool Anxiety Scale* (Spence et al., 2001). The scale consists in 28 TA items, 5 nonscored posttraumatic stress disorder items, and another open-ended (nonscored) item.

2.3.3. Scoring.

For the analyses on each condition, we used both a pass–fail evaluation (pass = remembering to carry out the PM action on the 3 trials of the condition), as well as the total score children received on each condition (out of a maximum 3). For the Ongoing task performance, a maximum score of 27 points per condition could be obtained. As for the more ecologically-valid task, we used a pass–fail evaluation.

2.4. Results

First, in order to investigate children's performance on the *two task-switching PM conditions* as a function of age and anxiety, we conducted a repeated measures analysis of covariance (ANCOVA), with PM Condition (No-Aid and With-Aid) as a within-subjects variable, Anxiety Group as between-subjects measure, and Age and Ongoing performance as covariates. Overall PM performance increased with age, as we found a main effect of Age, $F(1, 68) = 4.78$, $MSE = 8.61$, $p < .05$, $\eta_p^2 = .07$, and no effect of Age X PM Condition interaction, $F(1, 68) = .06$, $MSE = .06$. Although a tendency for all children to have better performances on the With-Aid condition can be noticed in Figure 2.1, we found no significant effect of PM Condition $F(1, 68) = 1.28$, $MSE = 1.36$, and a non-significant PM Condition X Anxiety Group interaction, $F(1, 68) = 1.33$, $MSE = 1.41$. However, a main effect of Anxiety Group was found, $F(1, 68) = 6.96$, $MSE = 12.54$, $p < .001$, $\eta_p^2 = .09$, revealing that LA children generally outperformed their HA counterparts on both PM task-switching conditions.

To analyze children's performances on the *ongoing tasks* used in the two aid conditions as a function of age and TA, we conducted a repeated measures ANCOVA, with Anxiety Group (HA vs. LA) as a between subjects measure, PM Condition (No-Aid and With-Aid) as within-subjects variable, and Age (in months) as covariate. We found a main effect of Age, $F(1, 70) = 11.66$, $MSE = 22.96$, $p < .001$, $\eta_p^2 = .14$, ongoing performance significantly increasing with age on both No-Aid, $B = .03$, $SE = .01$. $p < .01$, $\eta_p^2 = .11$, and With-Aid, $B = .04$, $SE = .02$. $p < .01$, $\eta_p^2 = .09$, conditions. We found no effect of PM condition, $F(1, 70) = 3.58$, $MSE = 4.35$, or PM Condition X Age interaction, $F(1, 70) = .63$, $MSE = .76$. Anxiety Group also had no significant effect on the ongoing performance, $F(1, 70) = .09$ $MSE = .11$, and there was a non-significant Anxiety Group X PM Condition interaction, $F(1, 70) = .68$, $MSE = 1.35$.

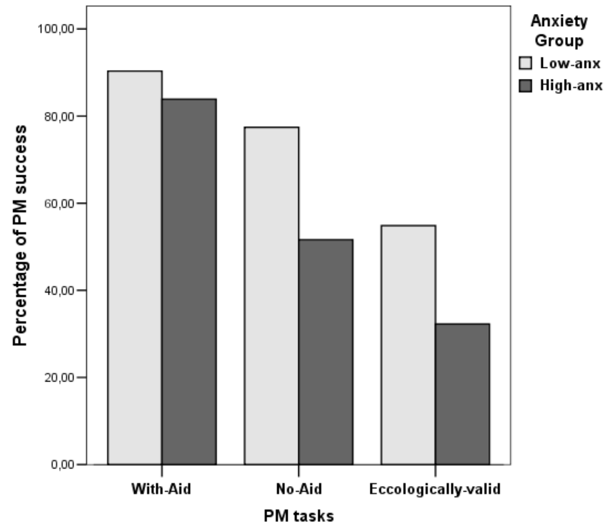


Figure 2.1. Percentage of children passing on the PM task-switching procedure with and without external aid (With-Aid, No-Aid) and on the more ecologically-valid task, as a function of Anxiety Group.

Additional analyses were conducted aiming to determine whether the number of children passing, as opposed to children failing (on all trials), to perform the PM planned actions significantly differed as a function of Anxiety Group. Chi square tests revealed that LA and HA children had comparable performances on the With-Aid condition, $X^2(1) = 1.26$, $p = .26$, but that significantly more HA preschoolers failed to perform the PM task (47.4%; as opposed to 20% of the LA) in the No-Aid condition, $X^2(1) = 5.35$, $p = .02$.

In order to determine whether the number of children failing *the more ecologically-valid PM task* were older or younger, a univariate analysis of variance (ANOVA) was conducted, with PM pass-fail as between factor and age as within factor. Results showed no significant effect, $F(1, 71) = .05$, $MSE = 6.19$. To determine whether the number of children passing, as opposed to children failing to perform the PM task, significantly differed as a function of Anxiety Group, a chi square test was conducted. The results revealed a significant difference, $X^2(1) = 7.14$, $p < .001$, more HA children failing to carry out the previously planned PM action (71.1%), compared to LA preschoolers (40%). All differences, expressed in percentage of children succeeding on all PM tasks, as a function of Anxiety Group, are shown in Figure 1.

2.5. Discussions

The current study addressed several issues related to event-based PM functioning in 4-7 year olds, analyzing the effects of age, TA, and memory aids. Summarizing the main findings, the study revealed that (1) PM performance increased with age, but only on the task-switching procedure, and did not vary as a function of the presence/absence of a memory aid; (2) TA impaired PM performances on both the task-switching procedure, as well as on the more ecologically-valid task; however, the percentage of children failing to perform the PM action on all trials was higher in the HA group (compared to the LA group) only in the no external aid condition.

2.5.1. Age and PM performance

Analyzing the age effects on PM performance, performances in the task-switching procedure increased with age, suggesting that PM abilities substantially improve during this developmental period. These findings are consistent with previous studies of PM performance in young children (e.g. Kliegel, Mackinlay, & Jäger, 2008; Wang et. al., 2008) and could be accounted by the fact that executive functions are found to develop considerably during this period (e.g. Diamond, 2006). This explanation is relevant in our task-switching context, as Miyake et al. (2000) showed that performance on task-switching procedures highly loads on the shifting function. Therefore, the documented age-related effects are consistent with data suggesting that most of the PM improvement during childhood is associated with the development of the shifting component in executive functioning (e.g. Kliegel et al., 2008). Nevertheless, we expected age effects to be more evident on the No-Aid condition, as it would have requested a more executive-demanding processing of the target cue. However, as overall PM performance also did not differ as a function of aid-condition, finding no such age effects could be explained by the fact that the two aid-conditions might not have imposed substantially different amounts of executive demands. These findings are also consistent with the suggestion that a PM aid is most efficient for children's prospective remembering when, apart from the PM target, it also cues the specific action that needs to be realized when the PM target-cue is encountered (see Guynn, McDaniel, & Einstein, 1998; Kliegel & Jäger, 2007).

No age effects were found on the *more ecologically-valid tasks* and these findings confirm previous data suggesting that age differences are specifically evident in task-switching PM procedures (Kliegel, et al., 2008; Wang et al., 2008). Aside for not being a task-switching procedure, another element that might have aided to the age invariance, would be the fact that the cube box might have acted like a distinctive aid, cueing for the PM action (i.e. putting the cube box on the table). However, this hypothesis should be regarded with caution, as the instructed event-based PM cue (i.e. the experimenter closing the laptop lid while giving the verbal cue) was different from the supposed PM action aid.

2.5.2. Trait Anxiety and PM performance

Regarding *TA's effects on PM performance*, we predicted based on the ACT (Eysenck et al., 2007) that TA would impair performance in a task-switching context, since a task-switching procedure would highly load on the shifting function (Miyake et al., 2000). In this respect, our findings are consistent with studies showing anxiety's impairment of the shifting function (e.g. Derakshan, Smyth, & Eysenck, 2009) and with the only (unpublished) study we found which specifically tested this prediction in the context of a PM task (see Eysenck & Derakshan, 2008). Moreover, we found that significantly more HA children failed to carry out the PM action (on all trials) on the No-Aid condition, than their LA counterparts. Therefore, we can imply that the use of an external memory aid could have diminished the detrimental effect of anxiety on PM performance, resulting in a comparable accuracy between the two groups. These findings are also consistent with adult data regarding the effects of anxiety on the shifting function, as this type of manipulation (reducing the attentional control demands) was found to diminish performance differences between HA and LA individuals (e.g. Derakshan et al., 2009).

However, surprisingly, results also revealed that significantly less HA children succeeded to perform the previously planned action in *the more ecologically-valid task*. Given that the detrimental effect was also found in a non-switching context, an impairment of the shifting function could not account for this finding. However, it confirms one of the ACT's predictions, according to which the negative effects of anxiety should be observed on tasks perceived as secondary (Eysenck et al., 2007). Moreover, this result further stresses the possibility of true PM failure, as HA preschoolers seem to fail to keep in mind the previously planned action.

Importantly, we found no differences between the two anxiety groups in their ongoing task performance. This finding confirms one of ACT's predictions, according to which the negative effects of anxiety should not be observed on the primary task (i.e. ongoing task), but on the concurrent one, perceived as secondary (i.e. PM task; Eysenck et al., 2007).

2.6. Concluding remarks

Apart from supporting previous results regarding PM development, this study stresses out the potential importance of executive functioning development in PM abilities improvement during the preschool years, as well as the importance of PM's early personality correlates. As results show that the level of TA accounts for differences in PM performance, it should be taken into consideration and controlled for when investigating PM development. From an applied perspective, the study provides data suggesting ways to improve prospective remembering for HA preschoolers, as failure to perform a previously planned action seems to be less frequent when a specific memory aid is present.

CHAPTER 3

STUDY 2. ADVERSE EFFECTS OF TRAIT-ANXIETY UPON CHILDREN'S WORKING MEMORY AND PROSPECTIVE REMEMBERING: IMPLICATIONS OF PROCESSING LOAD AND SECONDARY EXECUTIVE DEMANDS

3.1. Introduction

In the majority of the situations, information related to intention realization needs to be maintained and updated constantly until it is appropriate to perform the planned action (see West & Bowry, 2005). In other words, WM (Baddeley, 1986; 1990) might play a crucial role in PM success. Moreover, most of our everyday activities require a large amount of attentional resources to be allocated in order to solve particular tasks; information needs to be updated continuously, making PM failure more likely to occur when we are engaged in a highly demanding concurrent activity (McDaniel & Einstein, 2005). Hence, it is theoretically plausible that the previously found PM impairment in HA children (see Study 1) would be greater when their attentional resources are occupied, in response to the ongoing WM tasks' goals. Furthermore, as ACT states that anxiety's deleterious effects on the main task would be greater when the secondary or load task imposes high demands on inhibition and / or shifting, it is also plausible that HA children's WM performance (the main, ongoing task) would be greatly impaired when a PM task is concurrently performed.

3.1.1. Trait anxiety, working memory, and academic performance

Although the ACT (Eysenck et al., 2007) makes a series of predictions regarding anxiety's deleterious effects on the central executive functions, it also states that updating does not directly involve attentional control, and thus it is not impaired by high levels of anxiety (unless under stressful situations). However, updating is an executive function that requires active manipulation of relevant information in WM (Miyake et al., 2000), thus requires attentional control in order to monitor, code, substitute, and update incoming information in response to task goals (Ecker et al., 2010). Furthermore, given updating's evident role of consistently predicting performance on higher level and everyday cognitive tasks, a direct relation to the goal-directed attentional control system is highly probable (see Engle, 2010), making it thus susceptible to anxiety-related impairments.

Importantly, even though the number of empirical studies exploring the relationship between non-clinical anxiety and WM in children is limited, a consistent pattern of results, confirming anxiety's deleterious effects on updating, is notable (see *Chapter 1).* As presented in *Chapter 1*, there is also substantial indirect evidence that WM could mediate the higher levels of anxiety - poorer academic performance relationship. Notably, Owens and collaborators (2008) found that verbal WM partially mediated the relationship between TA and academic performance, accounting for approximately 51% of the association. The study's findings strongly suggest that verbal WM is an important neurocognitive mechanism underlying the high anxiety – academic underachievement relationship. Given the scarcity of the literature directly testing WM's role in the anxiety – academic outcome relationship, our investigation was rather exploratory. However, given the substantial indirect evidence towards the potential mediating role of WM, we expected to replicate Owens et al.'s (2008) findings.

3.1.2. Trait anxiety and prospective memory

So far, the study presented in Chapter 2 is, to our knowledge, the only study investigating TA's deleterious effects on PM in children. The study's findings show that TA impairs prospective remembering in preschoolers, and it suggests that this impairment could be more detrimental as more attentional demands are required during task unfolding (Cheie, Visu-Petra, & Miclea, submitted). Several studies suggested that PM success critically depends upon executive functions (e.g. Kliegel et al., 2008; McDaniel et al., 1999) which are steadily developing until young adulthood (see De Luca et al, 2003; Zelazo, Craik, & Booth, 2004). Furthermore, prior research suggests that age differences in PM development, are modulated by the involvement of executive control (e.g. Atance & Jackson, 2009; Kliegel et al, 2008; Kvavilashvili et al, 2001; Rendell et al., 2009; Wang et al., 2008).

These findings are particularly important in corroboration with the ACT's predictions concerning anxiety's deleterious effects on tasks tapping shifting and/or inhibition. ACT (Eysenck et al., 2007) states that anxiety's negative effects should be most evident on tasks tapping shifting and / or inhibition, and less on tasks involving the updating function. Furthermore, it also predicts that anxiety's impairment on inhibition and/ or shifting should be greater, as overall task demands increase. As previously shown in Study 1, a typical laboratory PM task is a task-switching probe, that mainly taps the shifting function (see Miyake et al., 2000). Given ACT's predictions, as well as the previously found PM impairment in preschoolers with high levels of TA (see Study 1), it becomes theoretically plausible that TA deleterious effects upon children's PM performance should become greater as overall task demands increase. Study 2.B. has focused on testing this hypothesis.

3.1.3. The interplay between working memory, prospective memory, and trait anxiety: evidence from research with adults and children

What are the effects of WM load on PM retrieval?

As previously shown in Chapter 1, the executive functions are involved in various aspects of event-based PM tasks. Success in carrying out a PM task is thought to depend upon the degree of relevance of the intention (Hicks et al., 2005), length of the delay (McDaniel, Einstein, Graham, & Rall, 2004), complexity of the ongoing task, or salience of the PM cue (McDaniel & Einstein, 2005). The adverse effects of WM load on PM retrieval have been demonstrated in several studies manipulating the ongoing task's cognitive processing demands (Marsh & Hicks, 1998; Marsh, Hancock, & Hicks, 2002; McGann, Ellis, & Milne, 2002; West, Bowry, Krompinger, 2006). Findings suggest that occupying the central executive functions of the WM system, or dividing attention with a demanding concurrent task, impairs PM performance (mainly in terms of efficiency; see West et al., 2006). Furthermore, studies reveal that PM retrieval is also disrupted when the ongoing activity requires manipulating verbal information (e.g. Herrmann & Gruneberg, 1999), thus when occupying the phonological loop. These findings suggest that engaging in a demanding ongoing activity makes it highly unlikely for individuals to actively maintain the intended action in WM during the delay period.

In children, several studies have shown that WM predicts PM success (e.g. Kerns, 2000; Mahy & Moses, 2011; Wang et al., 2008). However, to our knowledge, only Wang and collaborators (2008) actually tested the prediction that WM influences event-based PM performance, by varying WM load during the ongoing task. In their study, preschoolers were asked to either memorize or not memorize the cards as they named them during the ongoing task unfolding. Findings suggested that WM load impaired PM performance, as children had longer response times in the load condition.

What are the costs of PM demands on WM functioning?

But is there a reversed effect? Can PM induce a cost on WM functioning? Possible answers derive from prior research investigating the role of task switching on WM performance. Liefooghe, Barrouillet, Vandierendonck, and Camos (2008) suggest that evidence for such cost effects could be better explained by the procedure used, as clear evidence for a direct relation between WM and task-switching derives from studies using selective interference (e.g. Baddeley, Chincotta, & Adlam, 2001; Emerson & Miyake, 2003). These studies have manipulated the cost of task switching by requiring the participants to concurrently perform the primary and secondary tasks (e.g. task switching with letter span; Baddeley et al., 2001). It is assumed that within such a complex probe, the primary and the secondary tasks necessitate to compete with each other, requiring more control resources from the central executive (Liefooghe et al., 2008). It has been generally shown that in such demanding tasks, WM in adults is disrupted as a cost of task switching (e.g. Baddeley et al., 2001; Liefooghe et al., 2008; Mayr & Kliegl, 2003), but that additional WM load does not increase the size of the switch cost (e.g. Kane et al., 2007; Logan, 2007). Nevertheless, investigating these cost effects in children has been largely overlooked.

How would TA interact with WM costs on children's prospective remembering? How would TA interact with PM costs on children's WM functioning?

The previously presented findings suggest that WM and PM costs occur as a consequence of high executive control demands being imposed by the concurrent tasks. Particularly, as individuals are required to perform both tasks concurrently (i.e. virtually at the same time), their performance is ought to be impaired by the competition between the primary and secondary task, which demands for more executive control resources to be allocated. According to the ACT, anxiety's deleterious effects should be more evident when overall task demands on the central executive are greater, particularly when using the loading parading, in which two tasks are performed concurrently (Eysenck et al., 2007; Derakshan & Eysenck, 2009). Hence, it would be theoretically plausible that TA would impair WM functioning in a processing load paradigm when a task-switching concurrent interference (i.e. a PM task) would be present. Equally plausible would be for TA to impair prospective remembering in a processing load paradigm when a WM concurrent demand would be present.

3.1.4. Current study

We report on a series of three studies in which the relationship between different levels of processing demands, different aspects of children's memory functioning (WM, PM, WM in relation to PM), and TA were investigated. The main goal was to provide empirical evidence regarding TA's deleterious effects upon children's executive functioning as tasks become more resource-demanding, with consequences upon their WM and PM performances. Additionally, we also wanted to investigate whether WM plays a crucial role in HA children's documented academic underachievement. Hence, the study successively treated the following research topics:

(1) TA, processing load, and WM; TA, WM, and academic performance (Study 2a);

(2) TA, processing load, and PM (Study2b);

(3) TA and the interplay between WM and PM: effects of TA and concurrent WM load on PM performance; effects of TA and concurrent PM demands on WM performance (Study 2c).

3.2. General Methodology

Common Processing task

In each of the three studies, children were requested to perform an arithmetic addition task that would vary with regard to its complexity level. The task was constructed so that:

a) it would involve sentence reading in order not to allow verbal rehearsal and grouping of items, and thus provide a purer measure of the updating function for *Study 2a* and *Study 2c*;

b) it would allow generating different levels of processing demands on the same structure of item lists;

c) it would be more suitable for school age children; making it more appealing than the classic Operation Span (that only requires operating with numbers) and preventing boredom and fatigue;

d) its primary arithmetic task could be used as the invariant processing procedure concurrently performed with working memory span demands (*Study 2a*), prospective memory demands (*Study2b*), and both working memory and prospective memory demands conjointly (*Study 2c*).

The task requirements for each of the three studies are presented in Table 3.1.

Trait Anxiety

The Revised Child Anxiety and Depression Scale (RCADS; Chorpita et al., 2000) was used in all three studies in order to assess trait anxiety in children. The RCADS contains 47 items referring to the frequency of occurrence of different anxiety and depression symptoms. Children's symptoms were assessed via children and parent report. However, preliminary results have indicated questionable internal consistency values for children's reports in trait anxiety, Crombach's α values between 0.62 and 0.67 for the three samples. Because the equivalent parental reports had good internal consistency (Crombach's α values between 0.86 and 0.89 for the three samples), we decided to only use the parent version of the scale for measuring trait anxiety.

Table 3.1.

Studies' methodology illustration

Study	**Task requirements**		**Item example**
Study 2a, 2b, 2c	**Low demanding processing condition**	**2 elements arithmetics**	For her birthday, Ana received *two shirts* and *a ball*. The number of things she received is…
	Medium demanding processing condition	**3 elements arithmetics**	For her birthday, Ana received *three shirts*, *a ball*, and *two sweaters*. The number of things she received is…
	High demanding processing condition	**3 elements arithmetics + categorization**	For her birthday, Ana received *two shirts*, *a ball*, and *a sweater*. The number of *clothes* she received is…
Study 2a	**WM task**	**Recall the last (2 / 3 / 4) results.**	
Study 2b	**PM task**	**Refrain from saying the result and press the space-bar whenever the word "*ball*" appears**	
Study 2c	**WM task + PM task**	**Recall the last (2 / 3 / 4) results. + Refrain from saying the result and press the space-bar whenever the word "*ball*" appears**	

3.3. Study 2a. Trait anxiety, increased processing demands, and working memory in children.

3.3.1. Current Study

The general aim of the present study was to investigate TA's effects on children's WM, in a task varying in processing demands. At the same time, using a WM task highly reliant on the updating function, we also wanted test whether the ACT's predictions regarding anxiety's disruptive effects on performance could also be extended to the updating function (in absence of an explicit stressful condition). Additionally, the role of WM in understanding academic underachievement in anxiety was investigated.

In order to assess TA's effects on children's WM, we developed an operation span combined with reading for the following reasons: (1) according to Miyake and collaborators (2000) operation span tasks are found to mainly tap the updating function, and (2) WM tasks that involve reading provide a purer measure of WM capacity, as their demands do not allow covert verbal rehearsal and grouping of items (Cowan et al., 2005). Thus, an operation + reading span task would make an ideal choice for our investigation, as it would provide a purer measure of the updating function (see the Measures subsection for a detailed presentation of the task).

The study's hypotheses were:

(1) TA impairs performance (efficiency and / or accuracy) on the primary processing task (i.e. arithmetic problems);

(2) TA impairs actual WM recall (efficiency and / or accuracy);

(3) Performance impairment in HA children is greater when task requirements are more resource demanding (i.e. TA's deleterious effects are most evident on the highest resource demanding task condition);

(4) TA also impairs academic performance, and WM mediates the TA – academic underachievement relationship.

3.3.2. Methodology

3.3.2.1. Participants

For this study, we evaluated a total of 69 children (40 girls) with an age range of 8.8 years to 11.5 years (mean age = 123.37 months, *SD* = 7.30), recruited from two schools. The children were selected after their parents gave their written consent and completed the *RCADS* (Chorpita et al., 2000).

3.3.2.2. Measures

Trait anxiety.

The total anxiety score was used as a measure of each child's trait anxiety level. In our sample, the trait anxiety scale had a good internal consistency, Crombach's α of .87, while the internal consistency of the depression scale was α = .74.

WM task.

A self-paced *modified WM Operation Span task* was created. The task consists in reading aloud sentences containing several elements that need to be added in order to generate a sum. Children were requested to solve each of the problems and retain each result. After a list of two (List

Length 2; LL2), three (List Length 3; LL3), or four problems (List Length 4; LL4), children were requested to recall the last (2/ 3 /4) results. Each LL contained six recall trials.

Additionally, in order to emphasize the effects of increased processing demands on HA children's WM, we created three processing demands conditions. These consist in addition of two elements (Low Processing Demands), addition of three elements (Medium Processing Demands), and addition of three elements + categorization (High Processing Demands).The task requirements are presented in Table 3.1.

Academic performance

For the academic performance measure, we relied on children's school outcome indicators per se.The educational system in Romania allows for a four point scale grading convention in primary school. Accordingly, children can obtain "Very good", "Good", "Sufficient", "Insufficient" grades. The present study used the annual average academic outcome indicators for maths, Romanian (language), and a general indicator that subsumes their academic outcomes in all study areas.

3.3.2.3. Procedure and scoring

During task unfolding, children were instructed to read aloud, at their own pace, each arithmetic problem that appeared on the screen. Pressing the space bar allowed us to measure response times (RTs). Indexes of efficiency were generated by measuring RTs (mean RTs across LL/condition).

Two types of accuracy scores were generated (1) a total *processing accuracy score*, determining children's performance on the tasks' arithmetical problems, and (2) a *WM accuracy score*, revealing children's ability to retain information in task conditions with different levels of processing demands. In order to obtain the *WM accuracy score*, we followed the procedure used by Cowan and collaborators (1994; 2003) and calculated an aggregate span score that would reflect WM performance effectiveness across lists.

3.3.3. Results

3.3.3.1. Arithmetic processing performance, processing load, and anxiety

Arithmetic processing accuracy, load, and TA

In order to investigate TA's influence on children's *accuracy* performance on the Arithmetic Processing Task conditions, a repeated measures analysis of covariance was conducted (ANCOVA), with Arithmetic Processing Condition (i.e. Low Demanding, Medium Demanding, and High Demanding) as within-subjects measure, and TA and WM accuracy as covariates. A main effect of Arithmetic Processing Condition was found, $F(2,132) = 11.66$, $p < .001$, $\eta_p^2 = .26$, Pairwise Comparisons indicating that children performed better (generating 2.88 more accurate results on average, $p < .001$) on the Low Demanding condition than on the Medium Demanding one, but also significantly better on the Medium Demanding condition than on the High Demanding one (generating 1.92 more accurate results on average, $p < .001$). Significant mean differences in Arithmetic Processing Condition accuracy scores are displayed in Figure 3.1 (A).

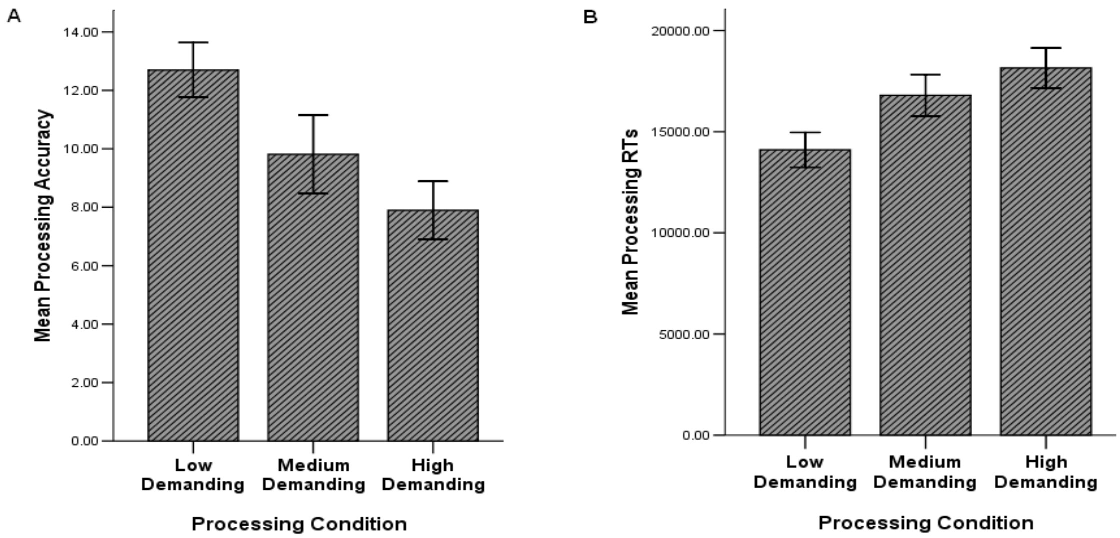


Figure 3.1. Mean accuracy scores (A) and mean response times (B) for Arithmetic processing performance on all three processing conditions. Standard errors are represented by the error bars attached to each column.

A significant effect of WM Accuracy was found, $F(1,66) = 79.72$, $p < .001$, $\eta_p^2 = .55$, results indicating that overall Arithmetic processing scores were greater when better WM performance was achieved as well. Moreover, tests of within subjects revealed a significant Arithmetic Processing Condition X WM Accuracy, $F(2,132) = 6.35$, $p = .002$, $\eta_p^2 = .09$, parameter estimates suggesting that although the aforementioned positive association was held true on each of the conditions, it had decreased as processing demands were greater. Hence, the association was most powerful on the Low Demanding condition, $B = .66$, $SE = .08$, $t(66) = 8.04$, $p < .001$, $\eta_p^2 = .50$, followed by the Medium Demanding condition, $B = .94$, $SE = .12$, $t(66) = 7.76$, $p < .001$, $\eta_p^2 = .48$, and least powerful on the High Demanding condition, $B = .66$, $SE = .09$, $t(66) = 7.18$, $p < .001$, $\eta_p^2 = .44$.

The results suggest no significant influence of TA, as non significant effects of TA, $F(1,66) = .18$, $p = .68$, $\eta_p^2 = .00$, *ns*, and Arithmetic Processing Condition X TA interaction, $F(2,132) = .88$, $p = .42$, $\eta_p^2 = .01$, *ns.*, were found.

Arithmetic processing efficiency, load, and TA

A similar repeated measures ANCOVA was conducted in order to investigate the relationship between children's performance efficiency (i.e. response times) on the Arithmetic Processing Task conditions and TA. The ANCOVA was conducted controlling for WM mean RTs and TA scores. A main effect of TA, $F(1,58) = 6.75$, $p = .012$, $\eta_p^2 = .27$, indicated that TA influenced overall performance efficiency, scatterplots revealing that RTs were longer when TA levels were greater. Positive significant associations were found on the Low Demanding condition, $B = 99.78$, $SE = 38.90$, $t(58) = 2.48$, $p = .016$, $\eta_p^2 = .10$, on the Medium Demanding condition, $B = 96.52$, $SE = 46.71$, $t(58) = 2.07$, $p = .043$, $\eta_p^2 = .07$, and on the High Demanding condition, $B = 118.51$, $SE = 44.25$, $t(58) = 2.68$, $p = .010$, $\eta_p^2 = .11$ (see Figure 3.2. for a detailed illustration).

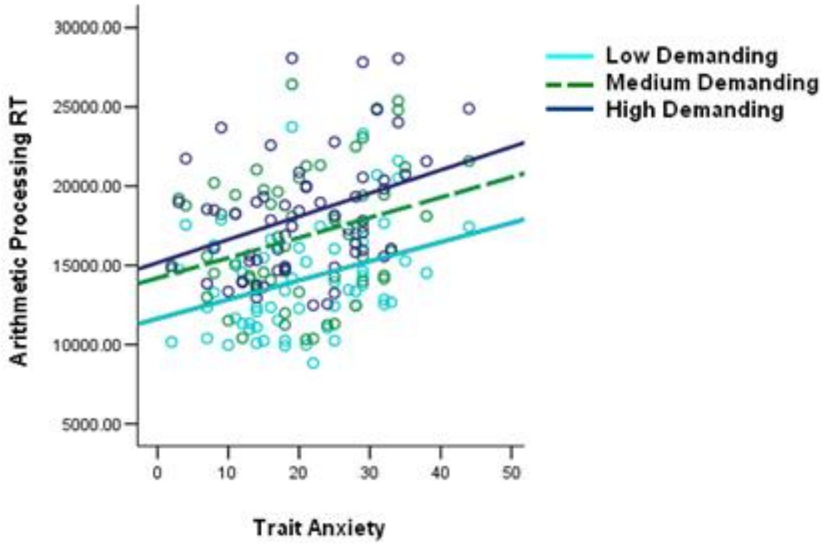


Figure 3.2. Scaterrplot depicting the relationship between Arithmetic Processing efficiency scores (response times; RTs) on all three processing conditions (Low, Medium, and High Demanding) and Trait Anxiety. RTs are longer as levels of TA are higher.

3.3.3.2. WM Accuracy, Processing Load, and anxiety

As in the case of Arithmetic Processing Performance, a repeated measures ANCOVA was conducted in order to investigate the relationship between anxiety (covariate) and WM *accuracy* on the three processing conditions (Low, Medium, High Demanding; within subjects measure). Results revealed a marginally significant effect of Arithmetic Processing Condition on WM accuracy, $F(2,132) = 2.83$, $p = .06$, $\eta_p^2 = .04$, *ns.*

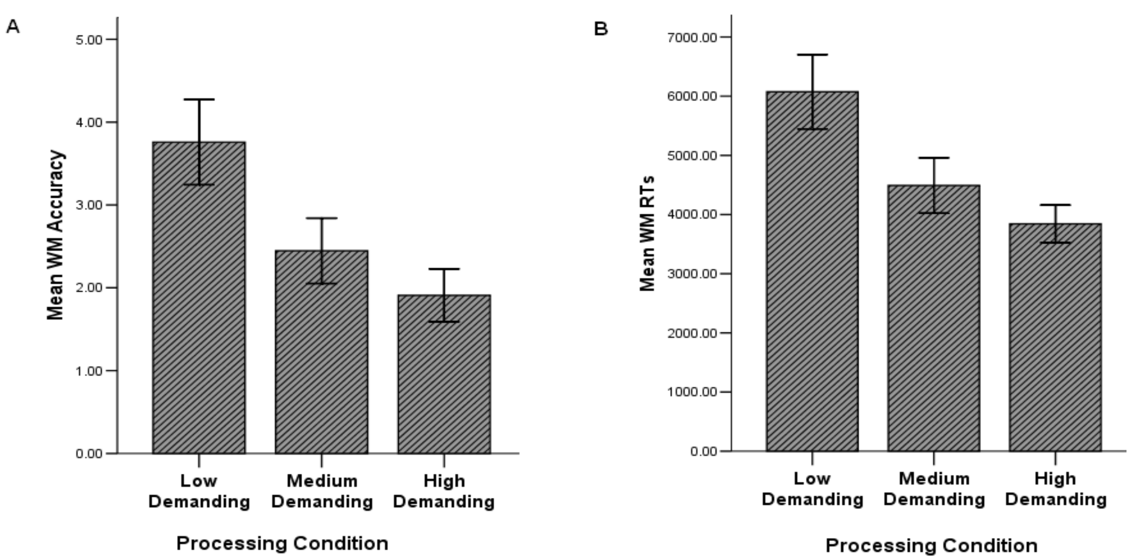


Figure 3.3. Mean accuracy scores (A) and mean response times (B) reflecting performance on the WM task, on all three processing conditions. Standard errors are represented by the error bars attached to each column.

Mean WM accuracy scores, across processing conditions, are illustrated in Figure 3.3 (A).

A significant WM Condition X Arithmetic Processing Accuracy interaction was found, $F(2,132) = 22.57$, $p < .001$, $\eta_p^2 = .26$. Parameter estimates revealed that children's WM scores were positively associated with Arithmetic Processing Performance on all three conditions, but that this association decreased as the Processing Condition became more difficult ($p < .001$). Tests of between subject effects indicated a significant effect of TA on overall WM accuracy performance, $F(1,66) = 5.74$, $p = .019$, $\eta_p^2 = .08$. Parameter estimates revealed that there was no significant relationship between TA scores and WM accuracy scores on the Low Demanding Processing Condition, $B = -.009$, $SE = .02$, $t(66) = -.52$, $p = .60$, $\eta_p^2 = .01$, *ns*. However, this relationship became significant on the Medium Demanding Processing Condition, $B = -.03$, $SE = .02$, $t(66) = -2.02$, $p = .047$, $\eta_p^2 = .06$, and proved to be stronger on the High Demanding Processing Condition, $B = -.04$, $SE = .02$, $t(59) = 2.87$, $p = .005$, $\eta_p^2 = .11$, suggesting that there was at least a tendency for WM scores to be reduced when levels of both TA and cognitive demands were greater.

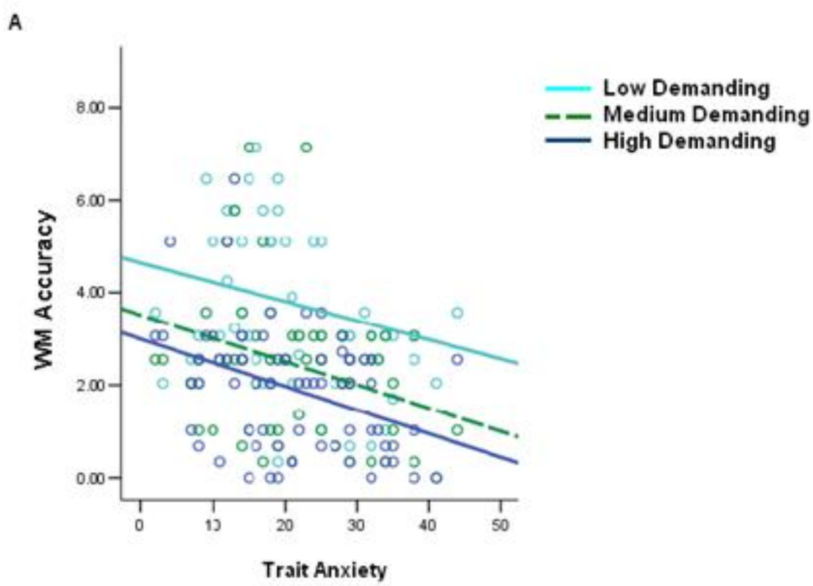


Figure 3.4. Scaterrplot depicting the relationships between WM accuracy scores on all three processing conditions (Low, Medium, and High Demanding) and Trait Anxiety.

3.3.3.3. WM efficiency, processing load, and TA

Results of a similar ANCOVA conducted for WM RTs indicated no significant effects of Condition, $F(2,106) = .20$, $p = .82$, $\eta_p^2 = .01$, *ns.* There was, however, a significant WM Mean RT X Processing Mean RT interraction, $F(2,106) = 3,91$, $p = .023$, $\eta_p^2 = .07$, as well as a significant main effect of Processing Mean RT, $F(2,106) = 23.93$, $p < .001$, $\eta_p^2 = .31$, revealing that WM efficiency and processing efficiency were highly related. Tests of between subjects effects revealed no significant effect of TA on WM efficiency, $F(1,53) = .33$, $p = .57$, $\eta_p^2 = .01$, *ns.* Also, the TA X Processing Condition interaction failed to reach significance, $F(2,106) = 2.40$, $p = .10$, $\eta_p^2 = .04$, *ns.*.

3.3.3.4. TA, WM, and academic performance

We conducted a mediation analysis in order to see whether WM performance could mediate the relationship between TA and academic outcome in mathematics. Our analysis indicated that:

(1) TA was a significant negative predictor of Maths academic performance (path *c*);

(2) TA was also a significant negative predictor of WM performance (path *a*); but

(3) the relationship between TA and Math academic outcome became non-significant when WM was added in the analysis (path *c*'). The analysis results are detailed in Table 3.2.

Table 3.2.
Regression coefficients for testing WM mediation of the TA –Maths Academic Performance relationship

Path	*B*	*SE (B)*	*β*	*p*
(c) TA – Maths Academic Performance	-.02	.01	-.28	.02
(b) WM – Maths Academic performance	.06	.02	.32	.01
(a) TA – WM	-.14	.05	-.33	.01
(c') TA – (WM) – Maths Academic Performance	-.02	.01	-.19	.12
(WM) – Maths Academic Performance	.05	.02	.26	.04

Note. TA = Trait anxiety; WM = working memory.

Research indicated that bootstrapping is one of the most valid and powerful methods for testing intervening variable effects (MacKinnon, Lockwood, & Williams, 2004; Williams & MacKinnon, 2008). Hence, a bootstrapping technique (of 5000 bootstrapped re-samples, as recommended by Hayes, 2009) was used to empirically estimate the *ab* indirect effect, with bias-corrected 95% confidence intervals. The bootstrap results (as calculated using Preacher and Hayes macro for SPSS, 2008) indicated a non-zero indirect effect (bias-corrected 95% confidence interval: -.019, -.001; *SE* = .004; *p* = .008), thus WM significantly mediated the TA – mathematics academic performance.

3.3.4. Discussions

In this first study, several findings were attained:

(1) Children's arithmetic performances (regarding both accuracy and efficiency) varied as a function of arithmetic task condition, decreasing as the processing demands increased;

(2) WM performance significantly interacted with arithmetic processing performance, results indicating that WM scores were positively associated with arithmetic processing performance on all three conditions, but that this association decreased as the Processing Condition became more difficult;

(3) there were positive associations between WM efficiency and arithmetic processing efficiency, effects between conditions generally following the trend found with regard to accuracy of performance;

(4) TA significantly impaired arithmetic performance efficiency, mean response duration being greater for children with higher TA scores;

(5) TA significantly impaired WM accuracy; findings suggest this effect might be most powerful when processing demands imposed are greater;

(6) TA negatively influenced academic performance in Maths; however this relationship was mediated by WM.

These findings are further discussed in detail.

Arithmetic task performance and WM

First, results regarding the main effects of Processing Condition on both performance accuracy, and performance efficiency, indicate that the three load conditions varied in the expected direction. Children achieved lower arithmetic processing scores and took longer RTs as processing demands became higher, displaying poorer processing efficacy and efficiency on the Medium Demanding condition as compared to the Low Demanding one, and on the High Demanding Condition as compared to the Medium Demanding one. Hence, we can conclude that the three load conditions were, in fact, different in terms of processing demands requirements.

Secondly, WM performance positively predicted arithmetic processing, both accuracy and efficiency of performance. These findings are consistent with literature regarding the implications of WM development (see Cowan & Alloway, 2009, for a review). It has been established that WM plays an important role in arithmetic skills in 7 year-olds (Bull & Scerif, 2001; Gathercole & Pickering, 2000) and it is also a predictor for math disabilities in the first year of schooling (Gersten, Jordan, & Flojo, 2005). However, results have shown that the degree of influence WM manifested on the arithmetic task performance significantly decreased as the Processing Condition became more difficult. One possible explanation derives from developmental studies that show that verbal WM plays a strong role for basic arithmetic only. As children get older, it has been shown that their performance in maths does not significantly rely anymore on WM (e.g. Reuhkala, 2001), but more on number knowledge and strategies (e.g. Thevenot & Oakhill, 2005). Hence, even if results suggest WM has a crucial role in arithmetic performance, it is possible for its role to have diminished as children were required to perform more strategy-dependent complex operations (i.e. more than simple two elements addition exercises on the Medium Demanding condition; addition plus categorization on the High Demanding condition).

Arithmetic task performance, WM, and TA

With regards to TA's impairment of the *arithmetic performance efficiency,* our findings confirm a main prediction of the ACT (Eysenck et al., 2007). As children with higher TA scores were found to take longer to respond to the arithmetic task, our results confirm ACT's hypothesis that anxiety impairs processing efficiency to a greater extent than performance effectiveness. The results are also in line with previous findings in children (e.g. Hadwin et al. 2005; Ikeda et al., 1996; McDonald, 2001; Ng & Lee, 2010) showing that WM mediates the effects of anxiety on task performance.

Notably, these findings also contradict ACT's prediction that anxiety impairs performance on tasks involving the updating function only under stressful conditions. However, as earlier described, based on empirical data regarding anxiety's deleterious effects on children's performance on tasks involving the updating function (e.g. Owens et al., 2008; Visu-Petra et al., 2011), we expected TA to significantly impair both processing and recall performances on the WM task.

TA significantly impaired overall *WM accuracy,* and findings suggest this effect might be most powerful when the imposed processing demands are greater. According to ACT, anxiety's deleterious effects on performance should be more evident on task efficiency, as high-anxious individuals would exert greater effort in achieving accuracy performances comparable to those of their low-anxious counterparts. However, when such a compensatory strategy is not available, impairments are prone to be evident in performance accuracy as well (Eysenck et al., 2007). Previous developmental findings indicate that WM performance accuracy is particularly impaired when the task imposes high demands on the updating function as opposed to situations when simple storage is exclusively required (see Hadwin et al., 2005; Visu-Petra et al., 2011). Our results replicate these findings, in showing that high anxious children's performance efficiency in WM recall was preserved, but at the cost of impaired WM recall per se. Moreover, ACT's prediction that such an impairment should be more evident on tasks imposing higher demands on the central executive, could also be sustained by finding deleterious effects on the arithmetic task performance efficiency, while finding accuracy impairments on the WM recall task. Although the interaction between task condition and TA was non-significant, a load effect should not be excluded. TA's impairment was only evident on conditions involving medium and high processing demands, suggesting that there was at least a tendency for WM scores to be reduced when levels of both TA and cognitive demands were greater.

TA, WM, and math academic performance

The main prediction regarding the links between TA, WM, and academic performance, was that TA was associated to academic underachievement and that this relationship would be partially mediated by WM. The findings first showed that TA negatively associated to both WM and math academic performance, while there was also a positive association between WM and math academic performance. These findings were consistent with previous research showing the link between high levels of anxiety and academic underachievement (e.g. Ashcraft, 2002; Crozier & Hostettler, 2003; Breslau, Lane, Sampson, & Kessler, 2008; van Ameringen, Mancini, & Farvolden, 2003), as well as with prior studies revealing that verbal WM was positively related to school outcome (e.g. Cain, Oakhill, & Bryant, 2004; Gathercole et al., 2004; Lehto, 1995). Moreover, WM was found to partially account for the initially found relationship between TA and math underachievement. These findings are consistent with previous research showing that verbal WM partially accounted for the TA – performance underachievement relationship (Johnson & Gronlund, 2009; Owens et al., 2008).

However, as we only tested verbal WM under resource-demanding conditions, it is difficult to establish the roles of updating function and of the phonological loop (from Baddeley's model of the WM system, 1985; 1990) in the aforementioned mediation effect. Owens et al. (2008) tested the mediation effects of both verbal and visuo-spatial WM and found that while verbal WM accounted for approximately 50% of the TA –academic performance relationship, visual WM accounted for only 9%. Even so, the verbal and visual WM tests also differed in terms of task complexity (i.e. the verbal WM task was more difficult, thus implied more attentional control resources), hence the roles of updating and of the phonological loop could not be disentangled. Johnson & Gronlund (2009) found that individuals low in WM capacity were particularly vulnerable to anxiety's negative effect in an auditory span task, whereas those high in WM capacity were buffered against anxiety's effect. Corroborated, these findings could suggest that WM's crucial role is prone to be elicited by verbal tasks that also require a fairly greater amount of attentional control resources. In this respect, we suggest that future research should further investigate WM's role in the TA – academic underachievement relationship, by directly comparing verbal and visual spatial WM task performances, in different complexity conditions.

3.4. Study 2b. Trait anxiety, increased processing demands, and prospective memory in children.

3.4.1. Current study

The aim of the current study was to investigate TA's effects on school children's event-based prospective remembering, in a task varying in processing demands. Using a laboratory task-switching procedure, we also wanted to test ACT's predictions that (1) anxiety's deleterious effects should be evident on a tasks tapping the shifting function; and (2) anxiety's adverse effects should be greater as the task imposes greater overall demands on the shifting function (Eysenck et al., 2007). Our hypotheses were:

(1) TA impairs children's performance (efficiency and / or accuracy) on the primary processing task;

(2) TA impairs children's PM performance (efficiency and /or accuracy);

(3) TA's performance impairment is greater when task requirements are more resource demanding (i.e. TA's adverse effects are most evident on the highest resource demanding condition).

3.4.2. Methodology

3.4.2.1. Participants

A total of 76 school children participated in this study. All children completed the task; however, two children failed to recall the PM instruction at the end of the evaluation even after specific prompting, and were therefore excluded from the analysis. Our final sample consisted in 74 children (30 boys), with an age range between 9.2 years and 11 years of age (mean age = 120.37 months, *SD* = 5.47). The children were recruited from two schools in North-West Romania.

3.4.2.2. Measures

Trait anxiety.

In the same manner as for Study 2a, parents' ratings on the RCADS-P (Chorpita et al., 2000) generated the total TA score. For this sample, the TA scale again had a good internal consistency, Crombach's α of .89, while the internal consistency of the depression scale was α = .75.

PM performance.

The PM task was identical to the WM Operation Span task (used in Study 2a), in terms of Processing Conditions and procedure. The only difference between the two tasks consisted in distinct memory requirements. Hence, children were required to solve the arithmetical problems (identical with the ones used in Study 2a), but there was no additional WM task. Instead, participants were instructed to solve all arithmetical problems appearing on the screen, but to remember to refrain from saying the digit result and to press the space bar whenever the word "*ball*" appeared within a sentence (i.e. PM task; see Table 3.1. for task illustration). The PM cue (i.e. "ball") was embedded within sentences of the second, third, or forth trial of each LL.

3.4.2.3. Procedure and scoring

The procedure was similar to the one used in Study 2a. All children completed all task conditions. After finishing the task, retrospective memory for the PM instruction was verified (through two successive questions, increasing in specificity) for children who did not perform the PM action when cued on all trials. Children were awarded 1 point for each PM action, thus the maximum score they could have received was of 3 per Condition. A mean RT Index per Condition was also generated, but RTs could only be measured for children who remembered to carry on the PM action when cued.

3.4.3. Results

3.4.3.1. Arithmetic Processing Performance, Processing Load, and TA

Processing accuracy, load, and TA

In order to analyze TA's influence on children's *accuracy* performance on the Arithmetic Processing Task conditions, we conducted a repeated measures ANCOVA with Arithmetic Processing Condition as within-subjects measure, and TA as covariate. There was a main effect of Arithmetic Processing Condition, $F(2,142) = 3.64$, $p = .029$, $\eta_p^2 = .05$, children's accuracy performance being significantly worse on the Medium and High Demanding conditions (with an average of 1.01 correct answers, $p < .001$, and 1.48 respectively, $p < .001$).

A

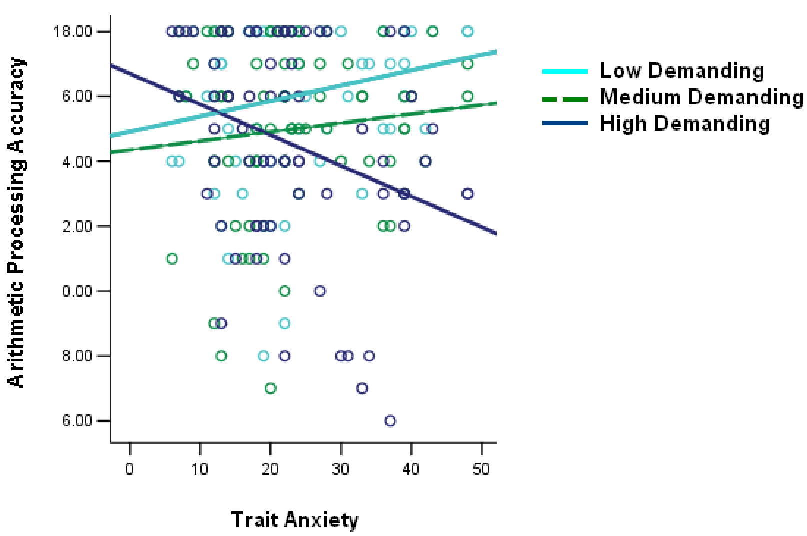


Figure. 3.5. Scaterrplot depicting the relationships between Arithmetic Processing accuracy scores on all three processing conditions (Low, Medium, and High Demanding) and Trait Anxiety.

A significant Arithmetic Processing Condition X TA interaction was found, $F(2,142) = 9.06$, $p < .001$, $\eta_p^2 = .11$, parameter estimates indicating that the detrimental effects of anxiety were only significant on the most complex condition. Hence, while participants had comparable results on the Low Demanding ($B = .047$, $SE = .03$, $t(71) = 1.78$, $p = .08$, $\eta_p^2 = .04$, *ns*.) and Medium Demanding (B

= .028, *SE* = .03, *t*(71) = .93, *p* = .26, η_p^2 = .01, *ns*.) conditions, children displaying higher levels of TA, also performed significantly worse on the High Demanding condition, *B* = -.095, *SE* = .04, *t*(71) = -2.67, *p* = .009, η_p^2 = .09. The directions of results are depicted in Figure 3.5.

Processing efficiency, load, and TA

A similar ANCOVA, controlling for TA, was conducted in order to analyze children's processing efficiency performance on the Arithmetic Processing Task conditions. A main effect of Processing Condition was found, *F*(2,128) = 6.28, *p* = .002, η_p^2 = .09, children's response durations taking longer as the conditions were more demanding (*p* <.001). The TA X Processing Condition interaction was non-significant, *F*(2,128) = 1.22, *p* = .30, η_p^2 = .02, *ns*., as high TA seemed to impair children's processing efficiency irrespective of condition, *F* (1,64) = 3.97, *p* = .05, η_p^2 = .06. However, TA seemed to have a greater impact on the High Demanding Processing Condition, response durations being longer on this condition for children with higher levels of TA, *B* = 103.35, *SE* = 50.27, *t*(64) = 2.06, *p* = .04, η_p^2 = .06.

3.4.3.2. Prospective Memory Performance, Processing Load, and TA

PM accuracy, processing load, and TA

In order to analyze the relationship between prospective remembering, processing load, and TA, we conducted an ANCOVA with PM performance on the three loading conditions (Low, Medium, and High Demanding) as within-subjects measure, arithmetic processing performance accuracy and TA as covariates. No main effect of Condition was found, *F*(2,138) =.02, *p* = .98, η_p^2 = .00, *ns*. (see Figure 3.6), and there were no significant interactions between load Condition and Arithmetic Processing, *F*(2,138) = .07, *p* = .93, η_p^2 = .00, *ns*., or PM Condition X TA, *F*(2,138) = .31, *p* = .74, η_p^2 = .01, *ns*.

However, there was a main effect of TA, *F*(1,69) = 4.43, *p* = .04, η_p^2 = .06, indicating that overall PM performance was influenced by TA. Nevertheless, the impairment was not significant for the Low Demanding Condition, *B* = -.03, *SE* = .02, *t*(69) = -1.67, *p* = .10, η_p^2 = .04. Significant negative relationships between TA and PM were found on the Medium Demanding Condition, *B* = -.03, *SE* = .02, *t*(69) = -2.05, *p* = .04, η_p^2 = .06, and on the High Demanding one, *B* = -.03, *SE* = .02, *t*(69) = -2.14, *p* = .04, η_p^2 = .06.

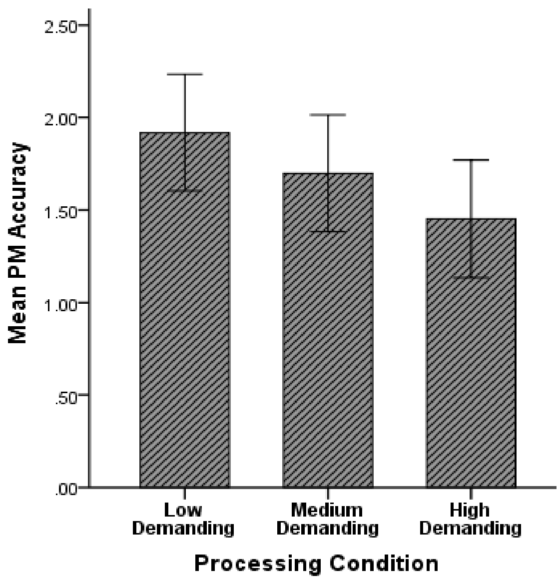


Figure 3.6. Mean accuracy scores reflecting performance on the PM task, on all three processing conditions. Standard errors are represented by the error bars attached to each column.

PM efficiency, processing load, and TA

A similar ANCOVA was conducted for analyzing the children's PM efficiency (response times) on the three processing conditions. The effects were analyzed controlling for Arithmetic Processing RTs and TA. No significant main effect of TA was found to influence PM processing efficiency, $F(1,41) = .02$, $p = .89$, $\eta_p^2 = .00$, *ns*., and there was a non-significant Condition X TA interaction, $F(2,82) = 1.22$, $p = .30$, $\eta_p^2 = .03$, *ns*. However, results are to be regarded with caution as the analysis was performed only for the children who remembered to perform the PM action.

3.4.4. Discussions

From this study, several findings have emerged:

(1) Children's arithmetic performances (regarding both accuracy and efficiency) varied as a function of arithmetic task condition, decreasing as the processing demands increased;

(2) TA significantly impaired arithmetic performance accuracy, mean accuracy being smaller for children with higher TA scores, but only on the most demanding processing condition; TA also significantly impaired arithmetic performance efficiency;

(3) TA significantly impaired PM accuracy; findings suggest this effect might be most powerful when imposed processing demands are greater;

(4) PM performance efficiency decreased as a function of condition; and significantly interacted with arithmetic processing efficiency;

These findings are further discussed in detail.

Arithmetic task performance and TA

First, the results concerning the main effects of Processing Condition on both performance accuracy, and performance efficiency, are similar to those found in Study 2a. The three load conditions varied in terms of processing demands requirements, as children performance accuracy and efficiency steadily decreased as conditions were more difficult.

Secondly, the results pointed out a detrimental effect of TA upon arithmetic *processing accuracy*. However, TA's detrimental effect was only significant on the most demanding condition. The results are in line with the ACT's prediction that anxiety's adverse effects become more evident when task demands are much increased (Eysenck et al., 2007). Specifically, the theory states that when greater overall task demands are imposed on the central executive, accuracy impairments can be elicited in HA individuals, as it becomes decreasingly possible for them to compensate for impaired efficiency through increased effort and resource use (Eysenck et al, 2007). Such detrimental effects of nonclinical anxiety upon performance accuracy have been revealed by prior research with children, as WM accuracy of recall was found to vary as function of anxiety level (e.g. Visu-Petra et al., 2011). Moreover, as also found in Study 2a, TA impaired children's *arithmetic performance efficiency*. As children with higher TA scores were found to have longer RTs, our results confirm again the ACT's prediction that anxiety impairs performance efficiency.

PM, Arithmetic task performance, and TA

As predicted, overall prospective remembering was significantly impaired by children's TA. Our findings are consistent with studies showing anxiety's impairment in task-switching procedures (e.g. Derakshan, Smyth, & Eysenck, 2009), but also with the previously found detrimental effect of anxiety on preschoolers' PM performance (Study 1; Cheie et al, submitted). Importantly, the study's findings contribute to the small group of studies providing evidence that anxiety impairs performance on the PM tasks (Cockburn & Smith, 1994; Harris & Cumming, 2003; Harris & Menzies, 1999). Hence, the results again confirm ACT's prediction regarding anxiety's negative effect on tasks involving the shifting function (Eysenck et al., 2007). Similar to the results found on the WM task (Study 2a), the results indicate that task efficiency was preserved, but at the cost of prospective remembering per se. This finding might also indicate that according to the ACT, the overall task imposed enough demands on shifting so that the compensatory strategies (i.e. putting more effort and engaging more resources, thus taking more time to complete give an accurate response) were highly unlikely to be engaged. As previously shown, such detrimental effects of nonclinical anxiety upon performance accuracy have been found in studies with children, as performance accuracy was found to be impaired in a complex span task (Visu-Petra et al., 2011). The within-subjects pattern of results indicates that such the detrimental effects of anxiety could be more evident on higher-order task-switching procedures. Interestingly, this pattern of results was identical to the one found on the WM task conditions (see Study 2a), TA's impairment being significant only on the medium and high demanding conditions.

Results regarding PM performance efficiency are to be regarded with caution, as it could only be measured for children actually remembering to carry out the prospective task when cued (i.e. hitting the space bar whenever the word "ball" appeared embedded within the ongoing arithmetic task). It has been generally shown that performance on the primary task can be disrupted when the secondary task-switching task imposes heavy demands that forces selective resource allocation (see Baddeley et al., 2001; Liefooghe et al., 2008). In line with this suggestion, we found that children's arithmetic performance was disrupted when task demands were higher, but the concurrent PM performance was not. Hence, it is possible for this task to have elicited a performance trade-off effect. Future studies should further investigate this, by directly comparing performances on the two concurrent tasks, in conditions varying in processing demands.

3.5. Study 2c. Working memory and prospective memory in children: effects of trait anxiety, processing load, and secondary executive demands

3.5.1. Current study

As Study 2a and Study 2b revealed anxiety's detrimental effects on children's WM and PM functioning, the present study's goals were to investigate whether the adverse effects on PM functioning are further modulated by WM demands, and whether the adverse effects on children's WM functioning are further modulated by PM demands. Again, we relied on ACT's hypotheses (Eysenck et al., 2007) predicting greater aversive effects of anxiety on tasks with higher demands on the central executive. Although ACT's predictions concern only effects of anxiety on task performances subjected to a shifting cost, based on previous results (see Study 2a), we expected effects of anxiety to be evident on performances subjected to an updating cost as well.

In Study 2a and Study 2b, although we found performance impairment to be stronger on conditions imposing greater processing demands, we could not find significant interactions between TA and demands conditions upon WM recall, and PM recall, respectively. Hence, this study's hypothesis was that additional central executive demands would elicit a steadily decreasing performance on both WM and PM remembering, as a function of processing demands condition. Thus, we expected:

(1) children's WM performance to be significantly diminished as a function of higher TA and increasing processing demands in the conjoint WM-PM task;

(2) children's PM performance to be significantly diminished as a function of higher TA and increasing processing demands in the conjoint WM-PM task.

3.5.2. Methodology

3.5.2.1. Participants

For this study, 71 children were recruited from three local schools. As three of them failed to recall the PM instruction at the end of the evaluation after specific prompting, our final sample consisted in 68 children (34 girls). The age range was between 8.7 years and 11.3 years (mean age = 117.59 months, *SD* = 9.29). Parental informed consent was obtained prior to the evaluation and informed verbal consent from the child was requested before proceeding with the testing. All children completed the task.

3.5.2.2. Measures

Trait anxiety.

Parents completed the RCADS-P scale and its general score of anxiety generated the trait-anxiety score. For this sample, the trait anxiety scale again had a good internal consistency, Crombach's α of .86, while the internal consistency of the depression scale was α = .71.

PM – WM task.

In order to evaluate the interplay between WM and PM in children, we combined the two memory tasks participants completed in Study 2a and Study 2b (see Table 2.1. for task illustration). Hence, aside from solving the arithmetical problems (identical with the ones used in Study 2a and 2b), children were requested to recall the last 2/ 3 /4 results (i.e. the WM task), but also to remember to refrain from saying the result and to press the space-bar whenever the word "*ball*" appeared within an arithmetical problem (i.e. the PM task).

3.5.2.3. Procedure and scoring

The procedure was similar to the one used in Study 2a and Study 2b. All children completed all task conditions. Retrospective memory for the PM instruction was verified for children who did not perform the PM action when cued on all trials. Scoring the WM task was identical to the scoring used for the WM Operation Span task (Study 2a), while scoring the PM task was identical to the scoring used for the corresponding task in Study 2b.

3.5.3. Results

3.5.3.1. Arithmetic Processing Performance, Processing Load, and TA

Arithmetic Processing Accuracy, Processing Load, and TA

A repeated measures ANCOVA was conducted on children's arithmetic accuracy of response. Processing Condition was designated as within-measure variable (Low, Medium, High Demanding), while Age, WM, PM, and TA were analyzed as covariates. We decided to control for both Age and overall WM accuracy, as both of these variables were previously found to be significantly correlated with children's arithmetic processing accuracy. In order to get a more accurate image of Arithmetic Processing performance when WM and PM requirements interfere, we also controlled for performance on the PM task.

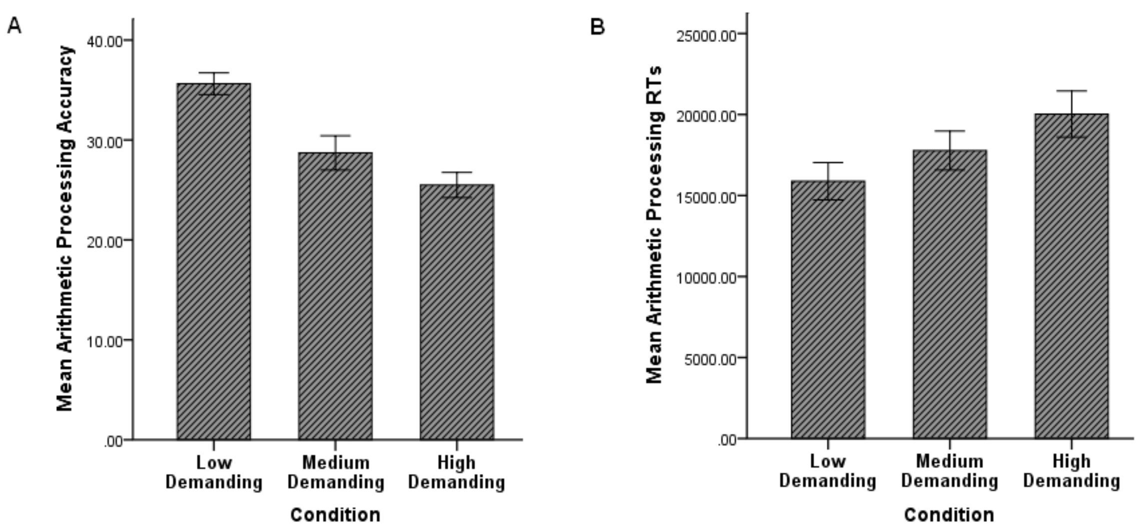


Figure 3.7. Mean scores reflecting performance accuracy (A) and performance efficiency (RTs; B) on the Arithmetic Processing task, on all three conditions (Low, Medium, High Demanding). Standard errors are represented by the error bars attached to each column. RTs = response times. Performance accuracy significantly decreased as conditions were more demanding (A); RTs significantly increased as conditions were more demanding (B).

The results pointed out several significant effects. First, tests of within-subjects effects revealed a significant effect of Processing Condition, $F(2,124) = 6.04$, $p = .003$, $\eta_p^2 = .09$, adjusted Bonferonni comparisons revealing that children were significantly more accurate ($p < .001$) on the Low

Demanding Condition (M = 35.63, SE = .44) than on the Medium Demanding one (M = 28.71, SE = .64), and significantly more accurate on the Medium Demanding Condition (p < .001) than on the High Demanding one (M = 25.49, SE = .48). The differences are represented in Figure 3.7 (A).

Second, main effects of WM and TA were also found, revealing that overall Arithmetic Processing Accuracy significantly increased as WM performance was better, $F(1,62) = 55.38$, $p < .001$, $\eta_p^2 = .47$, and it significantly increased as TA levels were higher, $F(1,62) = 10.76$, $p = .002$, $\eta_p^2 = .15$. Moreover, TA's influence on Arithmetic Processing Accuracy seemed to be further affected by processing task difficulty, as significant Condition X TA interaction was found, $F(2,124) = 4.82$, $p = .010$, $\eta_p^2 = .07$. Parameter estimates surprisingly revealed that not only overall Arithmetic Accuracy improved as TA got higher, but it was further modulated by Condition, performance being superior as processing loads were greater. TA's influence was most powerful on the High Demanding Condition, B =.19, SE = .05, $t(62) = 3.87$, $p < .001$, $\eta_p^2 = .19$, followed by the Medium Demanding Condition, B =.20, SE = .07, $t(62) = 3.00$, $p = .004$, $\eta_p^2 = .13$. TA's effect on children's Arithmetic accuracy on the Low Demanding Condition did not reach significant levels, B =-.05, SE = .05, $t(62) = -1.11$, $p = .27$, $\eta_p^2 = .02$, *ns*.

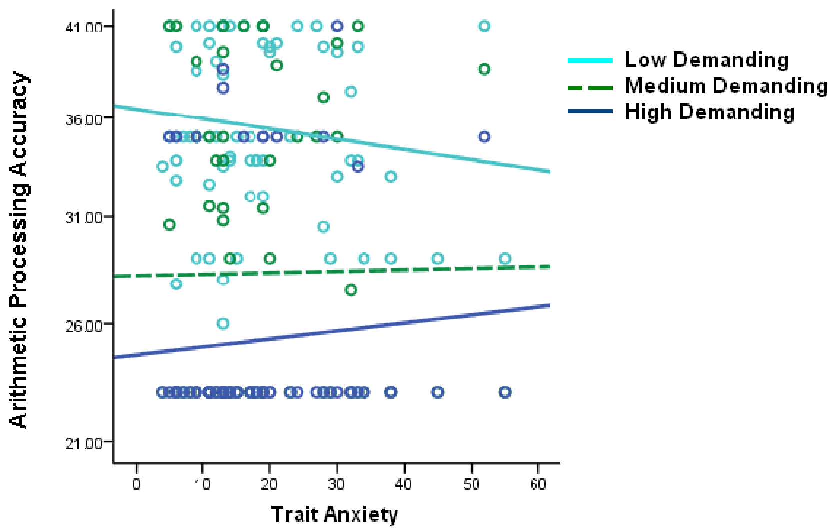


Figure.3.11. Scaterrplot presenting the relationship between Arithmetic Processing accuracy scores on all three processing conditions (Low, Medium, and High Demanding) and Trait Anxiety. Trait Anxiety significantly increased accuracy performance on the Medium and High Demanding conditions.

Arithmetic Processing Efficiency, Processing Load, and TA

A similar repeated measures ANCOVA was conducted in order to analyze children's processing efficiency on the Arithmetic task. Condition was designated as within-measure variable, while Age, WM RTs, PM RTs, and TA were analyzed as covariates. The analysis revealed a main effect of Condition, $F(2,80) = 4.05$, $p = .021$, $\eta_p^2 = .09$, Bonferonni adjusted mean differences revealing that children's RTs significantly increased (p < .001) across conditions. Children responded more rapidly on the Low Demanding Condition (M = 16359.01, SE = 561.55), increasing their RT's on the Medium Demanding Condition (M = 18362.19, SE = 579.23) and even more on the High Demanding one (M = 19937.29, SE = 638.66). These differences are represented in Figure 3.10 (B).

There was also a significant Condition X Age interaction effect, $F(2,80) = 4.02$, $p = .022$, $\eta_p^2 = .09$, parameter estimates indicating that children's RTs generally decreased with age across conditions, it's influence becoming significant on the High Demanding Condition, $B = -.162.98$, $SE = 70.72$, $t(40) = -2.31$, $p = .026$, $\eta_p^2 = .12$. Non-significant interactions were found regarding Condition X TA, $F(2,80) = 1.17$, $p = .31$, $\eta_p^2 = .03$, *ns.*, Condition and WM RTs, $F(2,80) =.13$, $p = .88$, $\eta_p^2 = .00$, *ns.*, or Condition X PM RTs, $F(2,80) = .03$, $p = .97$, $\eta_p^2 = .00$, *ns*. However, there was a main effect of PM RTs, $F(1,40) = 14.66$, $p < .001$, $\eta_p^2 = .27$, parameter estimates indicating positive relationships between this variable and Arithmetic Processing RTs on all processing conditions ($p < .001$). No other main effects were found. However, these results should be regarded with caution, as it only involved a subsample of $n = 40$, due to the PM RTs covariate which consisted in data gathered only from children who remembered to hit the PM key when cued.

3.5.3.2. WM Performance, Processing Load and PM demands, and TA

WM Accuracy, Processing Load and PM demands, and TA

In order to analyze the interplay between WM and PM in relation to TA and executive load, two separate repeated measures ANCOVAs were conducted: one accounting for WM performance on the three processing conditions (Low, Medium, and High Demanding) with overall PM, overall Arithmetic Accuracy performance, Age, and TA as covariates; the other one accounting for PM performance, on the three processing conditions, and having overall WM accuracy performance, Age, and TA as covariates. These analyses were duplicated in order to also investigate efficiency of responses on both WM, and PM respectively.

The analysis regarding WM performance as a function of condition, in relation with PM, Arithmetic Accuracy, Age, and TA revealed several significant effects. First, there was a significant main effect of PM, $F(1,63) = 4.98$, $p = .029$, $\eta_p^2 = .07$ and a non-significant effect of Condition X PM, $F(2,126) = 1.87$, $p = .16$, $\eta_p^2 = .03$, *ns.* The results suggest an overall positive effect of PM on WM performance, irrespective of processing condition. Next, the analysis revealed a main effect of Arithmetic Accuracy performance, $F(1,63) = 45.62$, $p < .001$, $\eta_p^2 = .42$, but also a significant Condition X Arithmetic Accuracy interaction, $F(2,126) = 14.25$, $p < .001$, $\eta_p^2 = .19$. Parameter estimates indicated that WM accuracy increased as Arithmetic Accuracy performance increased as well, but that this association was less powerful as the task conditions were more difficult.

The analysis revealed non-significant effects of Condition, $F(2,126) = .84$, $p = .43$, $\eta_p^2 = .01$, *ns*., as well as non significant Condition X Age interaction, $F(2,126) = .72$, $p = .49$, $\eta_p^2 = .01$, *ns*., or Condition X TA interaction, $F(2,126) = .29$, $p = .75$, $\eta_p^2 = .01$, *ns*. However, tests of between-subjects effects revealed a main effect of TA, $F(1,63) = 14.91$, $p < .001$, $\eta_p^2 = .19$. As also suggested by the representation of this result in Figure 3.12, parameter estimates revealed that this effect was detrimental, as WM accuracy was impaired when TA levels were higher. The results indicated significant detrimental effects on each of the processing conditions, with a more powerful effect on the High Demanding one, $B = -.06$, $SE = .02$, $t(63) = -3.14$, $p = .003$, $\eta_p^2 = .14$.

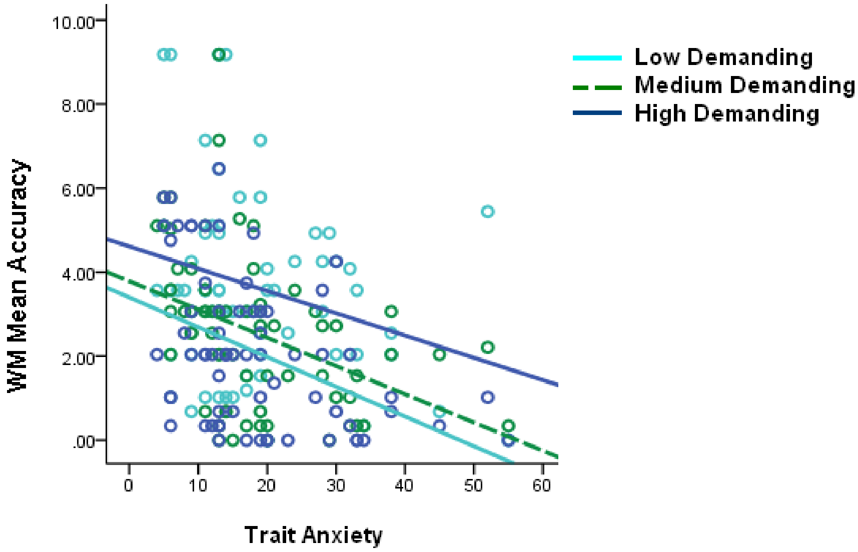


Figure.3.12. Scaterrplot representing the relationship between WM mean accuracy scores on all three processing conditions (Low, Medium, and High Demanding) and Trait Anxiety scores. TA significantly impaired WM Accuracy on all three conditions.

3.5.3.3. PM Performance, Processing Load and WM demands, and TA

The same type of analysis was conducted in order to measure prospective remembering as a function of processing load condition (with WM demands) in relation to TA. In order to obtain a more valid measure of PM performance under several executive demanding conditions (Arithmetic Processing + WM demands), we also controlled for children's WM Accuracy and Age.

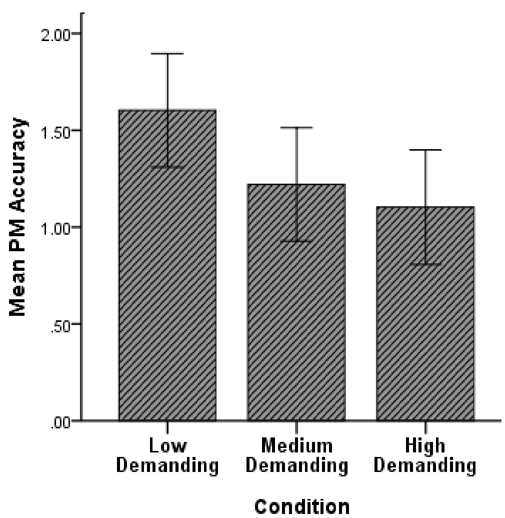


Figure 3.13. Mean accuracy scores reflecting performance on the PM task, on all three processing conditions. Standard errors are represented by the error bars attached to each column.

Tests of between-subjects revealed significant effects of both WM, $F(1,64) = 8.70$, $p = .004$, $\eta_p^2 = .12$, and TA, $F(1,64) = 7.02$, $p = .010$, $\eta_p^2 = .10$, on prospective remembering. Parameter estimates revealed that, across conditions, overall PM performance increased when WM performance was greater (*p* values between .003 and .05). With respect to the effect of TA, results indicated a detrimental effect of TA across conditions, PM performance decreasing as TA levels were higher. The detrimental effect of TA seemed to increase as the PM condition involved more processing demands; the effect was most evident on the High Demanding Condition, $B = -.04$, $SE = .01$, $t(64) = -2.65$, $p = .010$, $\eta_p^2 = .10$, followed by the Medium Demanding, $B = -.03$, $SE = .01$, $t(64) = -2.28$, $p = .026$, $\eta_p^2 = .08$, and the Low Demanding one, $B = -.03$, $SE = .01$, $t(64) = -2.10$, $p = .040$, $\eta_p^2 = .07$.

3.5.4. Discussions

In this final study, several findings were revealed:

(1) Children's arithmetic performances (both accuracy and efficiency) varied as a function of arithmetic task condition, decreasing as the processing demands increased;

(2) TA significantly improved arithmetic processing accuracy, and this improvement was further modulated by the processing demands imposed by the task; Children with higher TA scores displayed improved performance as the task demanded more executive resources to be allocated;

(3) Children's arithmetic processing performance improved as a function of age and processing condition; efficiency improved with age on the highest demanding arithmetic condition; Children's arithmetic processing efficiency seemed to improve as PM efficiency was also present;

(4) WM performance significantly interacted with arithmetic processing performance, results indicating that WM scores were positively associated with arithmetic processing performance on all three conditions, but that this association decreased as the Processing Condition became more difficult; WM recall was also positively associated to overall PM recall;

(5) TA significantly impaired WM accuracy; findings suggest this effect might be most powerful when processing demands imposed are greater;

(6) TA significantly impaired PM accuracy; findings suggest this effect might be most powerful when processing demands imposed are greater.

Arithmetic task performance, WM and PM demands, and TA

Both accuracy and efficiency of arithmetic performance decreased as the level of task demands was greater. The results replicate findings in Study 2a and Study 2b, suggesting that the load conditions varied in the expected direction.

Surprisingly, and in contrast to previous findings on arithmetic processing accuracy (see Study 2a and Study 2b), results reveal that children's performance improved as a function of TA and increasing processing demands. It seemed that HA children benefited from having extra executive demands imposed on the task, displaying improved performance as the task demanded more executive resources to be allocated. These findings contradict ATC's predictions regarding anxiety's deleterious effects on cognitive performance subjected to increased central executive demands (Eysenck et al., 2007; Derakshan & Eysenck, 2009), as well as previous results regarding HA children's performance that are generally in line with the abovementioned theory (e.g. Hadwin et al., 2005; Ng & Lee, 2010; Visu-Petra et al., 2011). However, another recent theory proposed by Bishop (2009) suggests that when the processing requirements of the primary task (i.e. ongoing processing) is high, it fully occupies the attentional resources, leaving thus no room for further processing distractors, such as the inner worrisome thoughts. Consequently, according to this theory, individuals with high levels of TA are expected to have better performances on the primary task in these circumstances (Bishop, 2009). Hence, it is possible that having an arithmetic processing task with both updating (WM) and shifting (PM task-switching procedure) concurrent demands, occupied most of the children's attentional resources and lead to a better performance as the processing demands increased.

Age was found to influence performance efficiency on the arithmetic processing task, but efficiency seems to have improved with age only on the highest demanding arithmetic condition. This result could be explained by age related executive functioning, as its development is also reflected by processing efficiency improvement (e.g. DeLuca et al., 2003). The same explanation could also be attributed to results suggesting that processing efficiency is also be influenced by PM efficiency, as PM success in children depends on executive functioning development (e.g. Attance & Jackson, 2009; Rendell et al., 2009).

Similar to findings revealed by Study 2a, WM performance positively predicted arithmetic processing accuracy and this effect significantly decreased as the Processing Condition became more difficult. As explained in Study 2a, although results suggest WM has an important role in arithmetic performance, it is possible for its role in our arithmetic task solving to have diminished as children were required to perform more strategy-dependent complex operations. Another possible explanation is that this effect could be the consequence of resource allocation competition, as the two tasks were concurrently performed (see Baddeley et al., 2001; Liefooghe et al., 2008). In line with this suggestion, we found that children's arithmetic performance was disrupted when task demands were higher in all three studies, but the concurrent WM / PM performances were not.

WM, processing load, and TA: effects of additional task-switching demands

As results on Study 2a and Study 2b revealed non-significant interactions between TA and demands conditions on WM recall, and PM recall, respectively, we expected the additional central executive demands to elicit a steadily decreasing performance on both WM and PM remembering, as a function of processing demands condition.

Results revealed a stronger effect of TA on WM accuracy, as 19% of the total variation on WM performance has been accounted by TA (as opposed to 8% in Study 2a where no additional executive demands were employed). However, the interaction between TA and processing demands condition was again non-significant, revealing that WM accuracy decreased as a function of higher levels of TA, and apparently irrespective of level of processing demands. Nevertheless, although differences among mean WM scores on conditions were not significant, TA's adverse effect was evident on each processing demand condition. Hence, findings suggest that although TA's deleterious effects on children's WM performance could be stronger when an additional central executive demands are imposed (i.e. on the shifting function), these demands do not further modulate TA's effects as a function of the processing demands. However, as we investigated these phenomena separately, on different samples, no clear-cut conclusions can be derived regarding magnitude differences of such effects. Future research should investigate these effects by directly comparing effects of increasing processing demands versus effects of increasing executive demands in HA's children WM performance.

PM, processing load, and TA: effects of additional updating demands

Findings regarding TA's effects on the concurrent PM task, as a function processing demands variation, reveal a similar pattern. Again, there was an apparent slightly stronger effect of TA on PM accuracy, as TA accounted for 10% of the total PM performance variation (as opposed to 6% in Study 2b where no additional updating demands were employed). However, the interaction between TA and processing condition was again non-significant, and TA exerted its adverse effects on all conditions.

Similarly to the results found in WM's case, results suggest that although TA's negative effects on children's PM performance could be stronger when an additional central executive demands are imposed (i.e. on the updating function), these demands do not further modulate TA's effects as a function of the processing demands. Again, future research should consider investigating these effects by directly comparing effects of increasing processing demands versus effects of increasing executive demands in HA's children prospective remembering.

3.6. Concluding remarks

In sum, findings on *Study 2a* confirmed anxiety's deleterious effects on cognitive performance, and suggest that high-anxious children's memory performance might be greatly impaired when the tasks imposes high central executive demands. Nevertheless, our findings regarding TA's deleterious effects on performance on a task tapping the updating function, only partially sustain ACT's views concerning anxiety's negative effects on cognitive performance, as it specifically states that such effects should not be evident, unless under stressful conditions (Eysenck et al., 2007). However, as previously shown, there is a growing body of developmental empirical evidence highlighting such effects (e.g. Ng & Lee, 2010; Owens et al., 2008; Visu-Petra et al., 2009; Visu-Petra et al., 2011) and this study's findings contributes to the literature confirming the existence of such a pattern in children. Finally, *Study 2a* also revealed that TA predicted academic underachievement in maths, and that this relationship was partially mediated by verbal WM.

In addition to the findings revealing TA's adverse effect on children's verbal WM elicited in Study 2a, findings in *Study 2c* suggested that children's WM performance could be further impaired when there is also a concurrent task (i.e. a PM task-switching procedure), tapping other executive functions (i.e. shifting and/ or inhibition). Additionally, Study 2c also revealed that when the processing requirements of the primary task are high, children with high levels of TA can have better performances. As long as these processing demands occupy the attentional resources, no processing distractors (like the inner worrisome thoughts) can be processed (Bishop, 2009).

Findings in *Study 2b* confirm ACT's predictions (Eysenck et al., 2007) regarding anxiety's adverse effects on cognitive performance when high demands are imposed on the shifting function. In this respect, children with higher levels of TA were found to have worse arithmetic performances when greater demands were imposed, as well as worse prospective remembering performances. Other than confirming ACT's predictions in children, the study's findings also confirm prior documented anxiety elicited cognitive impairments in children (e.g. Hadwin et al., 2005; Ng & Lee, 2010; Owens et al., 2008; Visu-Petra et al., 2009; 2011), as well as prior documented anxiety elicited PM impairments in adults (Cockburn & Smith, 1994; Harris & Cumming, 2003; Harris & Menzies, 1999). Importantly, the study also replicates Study 1's findings of PM impairment in HA preschoolers (Cheie et al., submitted), by finding the same pattern of results in school children. In addition to these findings, *Study 2c* revealed that the deleterious effects of TA on prospective remembering could be greater in situations where children are also engaged in a concurrent task (i.e. a task requiring WM), where additional executive demands are imposed (i.e. on the updating function).

CHAPTER 4

STUDY 3: RELATING INDIVIDUAL DIFFERENCES IN TRAIT-ANXIETY TO MEMORY FUNCTIONING IN YOUNG CHILDREN: AN INVESTIGATION USING TASK-IRRELEVANT EMOTIONAL STIMULI

4.1. Introduction

An information-processing perspective has been explicitly adopted by several researchers in order to organize the extensive (and often controversial) evidence supporting anxious children's cognitive biases in processing emotional information (Daleiden & Vasey, 1997; Pine, 2007). Such integrative approaches are essential in order to investigate vulnerability markers that contribute to the development and maintenance of child and adolescent psychopathology (Ingram & Price, 2010).

According to the Attentional Control Theory (ACT; Eysenck et al., 2007), cognitive performance is influenced by stimulus valence, anxiety's deleterious effects being greater when task stimuli themselves are threat-related. It is presumed that anxious individuals' impaired cognitive performance on tasks involving threat related stimuli is explained by the combination of impaired attentional control and preferential processing of threat related stimuli (Eysenck et al., 2007). Although no direct predictions are made concerning long-term recall of emotion-related stimuli, the above mentioned presumption might suggest a preferential recall of threat-related stimuli.

4.1.1. Developmental evidence

Looking at developmental research, the evidence regarding HA children's memory for emotional information is scarce and inconsistent (see Hadwin, Garner, & Perez-Olivas, 2006, for a review). Only two studies looked at short-term *verbal recall* for emotional information in non-clincal samples (Daleiden, 1998; Reid et al., 2006). Findings are inconclusive, but suggest a tendency for a negative bias in HA children's word recall.

Looking at *visual recognition* of emotional information, developmental researchers used emotional facial expressions as ecologically valid, salient stimuli even for very young children (McClure, 2000), although the ability of affective pictures to elicit discrete emotions has been questioned (Thibodeau, Jorgensen, & Jonovich, 2008). In a visual search task with memory updating demands (testing immediate recognition), Visu-Petra, Țincaș, Cheie, & Benga (2010) found that compared to LA children, HA children were slower and less accurate in recognizing previously seen identities displaying happy expressions, but more accurate in responses to identities expressing anger. Looking at within-group differences according to stimulus valence, LA children were less accurate in response to identities expressing anger (relative to identities displaying happy, and neutral expressions), while HA children were less accurate in response to identities displaying happy (relative to neutral) expressions. These results confirm previous findings from research with adult participants (Moser, Huppert, Duval, & Simons, 2008; Silvia, Allan, Beauchamp, Masehauer, & Workman, 2006), revealing a positive recognition bias for LA participants, and a negative bias in HA children, favoring the recognition of identities expressing anger.

4.1.2. Current study

The aim of the present study was to investigate the relationship between trait-anxiety and explicit memory for task-irrelevant emotional information by focusing on an under-researched developmental period (3-7 years). There is evidence to show that the preschool years represent a period of intensive development in terms of executive functions (see Zelazo, Carlson, & Kesek, 2008), verbal and visual STM (e.g. Alloway, Gathercole, & Pickering, 2006), and memory strategies (e.g. Schneider, Kron, Hunnerkopf, & Krajewski, 2004). Moreover, evidence suggests that during this period, there is also an intensive development of emotion understanding and use of emotional labels (e.g. Widden & Russell, 2003), as well as of memory for emotional information (see *Paz-Alonso, Larson*, Castelli, Alley, & Goodman, 2009 for a review). To our knowledge, this is the first study looking at both immediate and delayed verbal recall, along with delayed visual recognition of identities varying in emotional facial expressions in HA preschoolers. Furthermore, the current investigation is particularly relevant for understanding the developmental trajectory of anxiety, as evidence of early memory biases towards negative information would support the developmental continuity framework (Weems, 2008), that acknowledges the early onset of information processing biases in high-anxious children.

There were several issues of interest. First, we wanted to investigate whether anxiety would impact effectiveness (accuracy) and/or efficiency (response time) performance measures, irrespective of stimulus valence. Our hypothesis, based on ACT predictions, was that overall accuracy would not significantly differ between HA and LA participants, considering that both tasks have low levels of executive demands, requiring simple information storage. However, HA children would have longer response times (efficiency costs) in order to ensure this comparable level of accuracy. Second, we wanted to investigate whether performance accuracy on the recall and recognition tests would differ between HA and LA participants as a function of stimulus emotional valence across both stimulus modalities (verbal and visual). We expected enhanced memory for negative information and diminished memory for positive information in the HA sample, relative to LA participants on both conceptual (verbal) and perceptual (pictorial) tasks. The impact of verbal (task-irrelevant) emotional information was also investigated as a function of retention period (immediate or delayed). Although the comparison between immediate and delayed effects is exploratory, we relied on the theoretical assumption (and the few empirical proofs) that the preferential attentional processing and/or difficulty disengaging from threat-related stimuli would generate both immediate, and delayed memory enhancements for negative information.

4.2. Method

4.2.1. Participants

A total of 76 preschoolers (37 girls) recruited from three kindergartens in the north-west Romania participated in this study. The age range was between 45 and 85 months (mean age = 65.48 months, *SD* = 10.94). Parental informed consent was obtained before testing for all the children involved, as well as informed verbal assent from each child. From the total sample, 71 preschoolers completed the verbal memory tasks, while 76 completed the visual recognition task.

4.2.2. Measures

Trait anxiety were assessed via parental report on the Spence Preschool Anxiety Scale (Spence et al., 2001), described in Chapter 2.

In order to assess *immediate and delayed recall of affective words*, we used a task modified from the List Learning task included in the NEPSY battery (Korkman, Kirk, & Kemp, 1998). The task contains two conditions: the Immediate List Learning condition, and the Delayed List Learning condition, assessing 30-minute delayed recall. The NEPSY List Learning task was modified so that it would: (a) be suitable for preschool children – the number of words included in the list was reduced to 9, while the number of times the list was repeated before the interference list (trials) was reduced to three; (b) contain words with different emotional valences: 3 negative, 3 positive, and 3 neutral words; (c) contain words with a maximum two syllables length. In order to generate the 9 word list, we gave 25 primary school children a list of 56 words extracted from the ANEW (Affective Norms for English Words; Bradley & Lang, 1999) in order to classify them as pleasant, unpleasant or neutral. For the List Learning, as well as for the interference one, we used the top most frequently classified words as belonging to one of the three valence categories.

A modified version of the Memory for Faces task (NEPSY; Korkman et al., 1989) was used in order to assess *delayed recognition of facial expressions*. We modified the NEPSY task so that it would: (1) contain 9, instead of 15 faces; (2) contain 3 different emotional expressions: angry, happy, and neutral; (3) be administered in a computerized format for standardization purposes. We only used the *Delayed* condition, since the Immediate condition resulted in ceiling effects in a pilot study. Therefore, the child sees 9 facial expressions and after a 30-minutes delay he/she had to recognize the previously seen facial identities from 3 displays, each containing 3 more distracters. All stimuli in a display had the same emotional valence (angry, happy, or neutral) in order not to introduce competition among valence-related processes. For both the target items and the distracters, we used faces from the NimStim database (Tottenham et al., 2009) and Pictures of Facial Affect (POFA, Ekman & Friesen, 1976). Regarding the actual presentation of the target stimuli, 2 constraints were employed: (1) the valence of a stimulus was not repeated immediately; (2) an identical number of each stimulus valence occurred (3 angry, 3 happy, 3 neutral).

4.2.3. Procedure and scoring

Trait-anxiety scores.

The Spence scale was rated by children's mothers, and a total trait-anxiety score was subsequently generated. For this sample, the scale had good internal consistency, Cronbach's alpha= .82. We performed a median split of children's total trait anxiety scores (median at 22). As a result, the children in our sample were classified as either high-anxious (HA; N = 38; mean Spence score = 34.11, SD = 13.66) or low-anxious (LA; N = 38; mean Spence score = 13.47, SD = 4.85). While the two anxiety groups did not differ in age, $F(1, 74) = .79$, *n. s.* (mean age for HA = 66.61 months, SD = 12.41; mean age for LA = 64.37 months, SD = 9.28), or gender $F(1, 74) = .46$, *n. s.* (20 girls in the HA group, 17 in the LA group, respectively), the difference between their trait anxiety scores was highly significant, $F(1, 74) = 76.96$, $p < .01$, partial $\eta 2 = .51$.

Immediate and delayed recall of affective words.

All tasks were individually applied in two different sessions, each lasting for about 30-35 minutes, and applied on two consecutive weeks. We calculated mean accuracy for each valence category across the first four lists (without the interference list). Finally, an index of *efficiency of response* (time taken to recall the words on the four lists, divided by the number of words recalled) was also computed. After the immediate memory trials, children were engaged in other cognitive tasks (picture naming, block construction) for about 30 minutes; then the Delayed condition of the List Learning task was applied.

Delayed recognition of emotional facial expressions.

At the beginning of the second session, the children were presented with the 9 pictures from our modified version of the Memory for Faces Delayed task. The pictures were displayed on a computerized format for 5 s each, with 2 s pause in between. The instruction the children received was to look at each picture and say if the person in it was a male or a female. Similar to the scoring used for the Delayed List Learning task, a total index of accuracy and an accuracy index for each valence were calculated.

4.3. Results

Performance accuracy on the *verbal recall task was analyzed* by looking at the main effects and interactions between anxiety, age, memory condition and stimulus valence. We conducted a repeated measures ANCOVA with memory condition (Immediate vs. Delayed) and stimulus valence (positive, negative or neutral) as within-subject factors. Anxiety group (HA vs. LA) represented the between-subjects measure, while Age was the covariate.

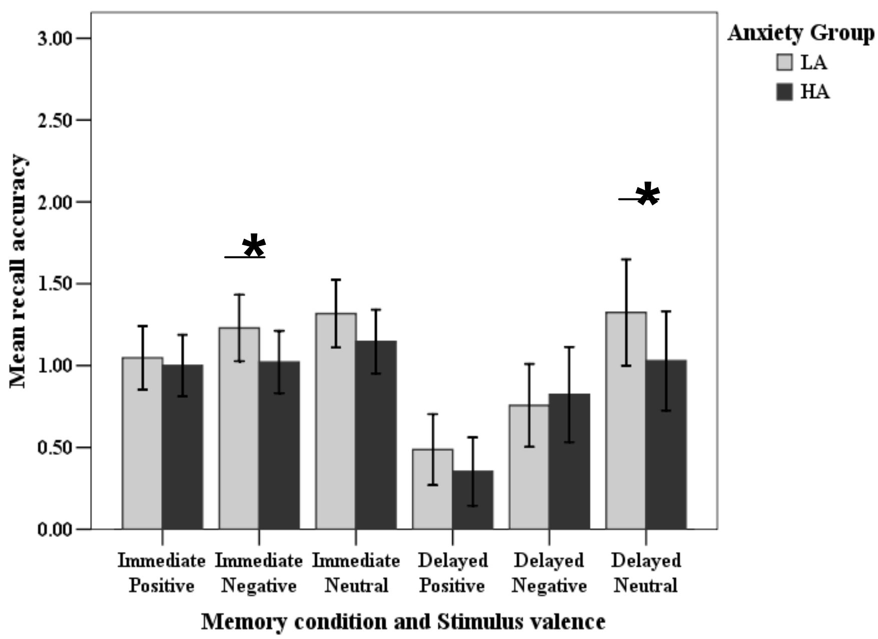


Figure 4.2. Immediate and Delayed verbal recall according to stimulus valence and anxiety group (LA – low anxious, and HA – high anxious).

Results pointed to a marginal effect of Anxiety group, $F(1, 68) = 3.79$, $p < .06$, $\eta_p^2 = .05$, revealing a tendency for LA children to present overall better memory scores than their HA counterparts. There was also a significant interaction between Memory condition, Valence, and Age, $F(2, 136) = 13.44$, $p < .01$, $\eta_p^2 = .17$. Performance on Immediate recall of emotional words increased with age, $B = .03$, $SE = .01$, $p < .01$, $\eta_p^2 = .24$ for positive words, $B = .02$, $SE = .01$, $p < .01$, $\eta_p^2 = .11$ for negative words. No such significant improvement was found on neutral words ($B = .01$, *n.s.*). In the case of Delayed recall however, the situation was reversed, performances on recalling neutral words increasing with age, $B = .04$, $SE = .01$, $p < .01$, $\eta_p^2 = .20$, and no such significant advantage being found for recalling emotional items. Finally, there was a significant interaction between Memory condition, Valence and Anxiety group, $F(2, 136) = 3.04$, $p = .05$, $\eta_p^2 = .04$. Separate ANCOVAs controlling for participant age revealed that negative words were remembered less well by the HA group compared to the LA.

In order to investigate effects of anxiety and age on performance efficiency (response times) for the Immediate verbal recall, we also conducted a univariate ANCOVA, with Anxiety group as between-group variable and Age as covariate. As expected, we found a significant effect of Age, $F(1, 68) = 12.86$, $p < .01$, $\eta_p^2 = .16$, response times decreasing with age, $B = -.30$, $SE = .08$. $p < .01$, $\eta_p^2 = .16$. No effect of Anxiety group on performance efficiency was found.

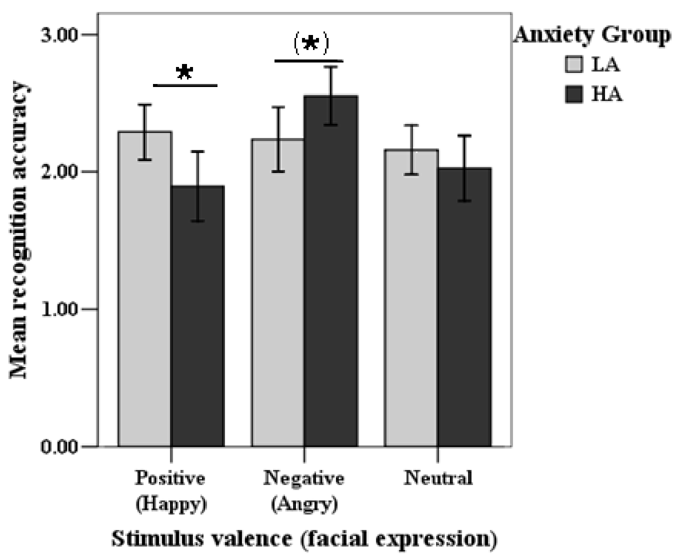


Figure 4.3. Delayed visual recognition according to stimulus valence and anxiety group (LA – low anxious, and HA – high anxious). *$p < .05$; (*) $p = .07$

A repeated-measures ANCOVA was carried out for the *visual recognition task*, with stimulus Valence as a within-group measure, Anxiety group as a between-subject measure, and Age as covariate. Figure 3 displays mean accuracy according to stimulus valence and Anxiety group. Results of the ANCOVA analysis revealed no main effects of valence, $F(2, 146) = .52$, *n.s.*, or Anxiety group, $F(1, 73) = .83$, *n.s*. However, there was a significant Anxiety group X Valence interaction, $F(2, 146) = 7.83$, $p < .01$, $\eta_p^2 = .10$. Identities displaying happy expressions were significantly better recognized by LA than by HA children, $t(74) = -2.60$, $p < .05$, $\eta_p^2 = .09$, while HA children had a marginally better performance than their LA counterparts in remembering identities displaying angry expressions $t(74) = 1.83$, $p = .07$.

4.4. General Discussion

The present study investigated memory for emotional information in high-trait-anxious, versus low-trait-anxious preschoolers. There were several areas of interest regarding the effects of performance measure (accuracy and efficiency) stimulus valence (positive, negative, and neutral) and retention interval (immediate and delayed) across stimulus modalities (verbal and pictorial). First, we will review the main findings for the study's issues of interest. Our results showed that HA children, compared to LA children, had: (1) similar levels of performance efficiency and effectiveness on immediate verbal recall, with a tendency for poorer verbal recall; (2) poorer recall of negative words in the immediate condition; (3) poorer recall of neutral words in the delayed condition; (4) (marginally) better delayed recognition of identities expressing anger; and (5) poorer delayed recognition of identities displaying happy expressions. While some of these findings confirm our hypotheses and generate insights on anxiety's effects on memory functioning in young children (1, 4, 5), others are more intriguing (2, 3) and warrant a detailed analysis searching for potential explanations.

Finding poorer short-term recall for negative words in HA, compared to LA children is at odds with our initial hypothesis, anticipating enhanced recall of negative information as a result of preferential attentional allocation / difficulty in attentional disengagement from this type of information in HA children (Derryberry & Reed, 1996). However, there is only one study (Daleiden, 1998) which found enhanced memory for negative information in HA older children, using a cued-recall format, and not a free-recall format such as the one in the present study. On the other hand, there is some preliminary proof of short-term impairments in memory for negative information in HA participants. Mogg, Mathews, and Weinman (1987) found poorer memory for threatening than nonthreatening material, despite the attentional bias towards threat in anxious individuals. The authors suggest that while in the initial stage of information processing, anxious subjects exhibit vigilance for threat, at strategic level they show the tendency to avoid it (an inhibitory mechanism).

To our knowledge, this is the first study to investigate and reveal immediate memory avoidance of negative information in young HA children. It is a finding is of high relevance for understanding the learning mechanisms which generate threat-related biases in trait-anxious participants. Lavy and van der Hout (1994) suggest that the avoidance of negative information might actually play an active role in the reinforcement of the attentional bias towards threat, similar to a counterintentional effect. Our results show that in delayed recall, HA children no longer display poorer recall of negative stimuli, so the avoidance effect noticeable in immediate recall is only temporary.

The final two findings, regarding the tendency to better recognize identities with (task-irrelevant) emotional expressions in HA participants, and better identity recognition for happy expressions in LA participants confirm previous studies with adults (Moser et al., 2008; Silvia et al., 2006) and young children (Visu-Petra et al., 2010). Moser et al (2008) explain this anxiety-modulated dual outcome by relating to the prediction of the Attentional Control Theory (Eysenck et al., 2007) that in anxious individuals, the anterior attentional control system is overriden by the posterior ‘‘stimulus-driven’’ system, responsive to threatening stimuli. There is evidence for an early adult-like enhanced posterior negativity at occipital sites in response to angry faces as compared to happy ones, already documented by the end of the first year (Grossmann, Striano, & Friederici, 2006), while a later frontal slow wave was more positive for happy and neutral faces across several age groups, from as early as 4 years of age (Batty & Taylor, 2006).

Irrespective of anxiety group, we found that age had significant effects on memory performance. Verbal memory performance (in both immediate and delayed conditions) increased with age, while response times on immediate recall decreased with age. Looking at performance as a function of stimulus valence, and retention interval, memory performance on Immediate recall of emotional words increased with age; but the direction was not maintained on the Delayed recall condition, where memory for words with a neutral valence increased with age. The first age-related findings were to be expected, considering the previously documented memory capacity improvement during the preschool years (e.g. Alloway, Gathercole, & Pickering, 2006). Lower performances for younger children in the Immediate recall of words with emotional valences could be explained by the concrete versus abstract nature of the words.

4.5. Concluding remarks

The identification of connections between individual differences in cognitive functioning and personality traits early during development brings us closer to understanding the etiology of personality disorders (Unsworth et al., 2009), and reveals mechanisms which can be targeted by prevention/intervention therapeutic programs (Ingram & Price, 2010). For instance, if the potential memory bias was conditioned by a primary attention bias, specific attention training programs such as the attention bias modification (ABM, see Bar-Haim, 2010, for a recent review) could be implemented early during development. However, if we are (also) dealing with a primary memory impairment, modulated by stimulus emotional valence, HA children could benefit from a “memory bias modification” program, designed to enhance recall of pleasant stimuli. Visu-Petra, Cheie, and Benga (in preparation) are currently developing an attentional control & working memory training program sensitive to the emotional valence of the stimuli, and adaptable to individual differences in internalizing symptoms by modifying recall demands to preferentially target positive stimuli. The question remains whether such intervention protocols might also influence what anxious children encode and remember from their ongoing experiences, thereby disrupting the formation of vulnerable pathways to anxiety disorders.

CHAPTER 5

STUDY 4. RELATING INDIVIDUAL DIFFERENCES IN TRAIT-ANXIETY TO CHILDREN’S MEMORY FOR EMOTIONAL INFORMATION: AN INVESTIGATION USING ILLUSTRATED EMOTIONAL STORIES

5.1. Introduction

Following results emerging from Study 3, indicating a potential emotional memory bias in children with higher levels of TA, Study 4 attempted to complement these findings by investigating such potential biases for more complex information. This would be (to our knowledge) the first study to investigate both verbal and visual recall of emotional information, as well as visual recognition of emotional scenes, in children with high levels of TA. The study is particularly important as evidence of early memory biases towards negative information would support the prior mentioned information-processing perspectives (e.g. Pine, 2007), highlighting the potential cognitive vulnerability markers in the development and maintenance of anxiety.

Trait anxiety and memory for verbal emotional information in children

As prior reviewed, the developmental research regarding HA children's memory for emotional information is scarce (see Cheie & Visu-Petra, 2012; Visu-Petra et al., in press.), and there is an inconsistency of results that could be partially accounted by research methods. Regarding memory for emotional verbal information related to nonclinical anxiety, developmental research has focused on tasks involving lists of emotional words that children required to recall (Cheie & Visu-Petra, 2012; Daleiden, 1998; Reid et al., 2006) and the results did not converge into a consistent pattern. There could be two procedural explanations that could account for these data (1) tasks involving only recall of distinct emotional stimuli might only elicit subtle effects that could be evident in clinical samples and less in children with nonclinical TA (see Bishop, Dagleish, & Yule, 2004, for a similar proposal in developmental nonclinical depression); (2) the task material could be not engaging enough for children, especially the younger ones. Hence, with regards to verbal emotional recall in HA children, the present study aimed to meet these methodological disadvantages and investigate potential recall biases of emotional stories (accompanied by plot-correspondent images).

Trait anxiety and memory for visual emotional information in children

Although the empirical evidence documenting a memory bias in the case of adult anxiety is inconsistent, especially for clinical samples (Coles & Heimberg, 2002; Mathews & Mackintosh, 1998), a more recent comprehensive meta-analysis (Mitte, 2008) targeting both recognition and recall processes in HA individuals found evidence for: a within-group trend toward preferred recognition of threat-related pictorial (but not verbal) material; a between-group difference indicating better recall of verbal threatening material and poorer recall of positive material compared to LA individuals. Regarding developmental research investigating memory for emotional visual information related to anxiety, the few existent studies (Cheie & Visu-Petra, 2012 (Study 3); Visu-Petra et al., 2010) have mainly confirmed the above mentioned bias-trend in visual information recognition. However, as previously mentioned in the case of verbal emotional memory research in children, the type of tasks used (implying encoding of separate, unrelated stimuli) might not be powerful enough to elicit subtle emotional-induced effects. Moreover, although using emotional facial expressions as salient stimuli is considered to be ecologically valid even for young children (McClure, 2000), questions are raised of whether affective pictures are capable of eliciting discrete emotions (Thibodeau et al., 2008). Hence, a second aim of this study was to investigate whether bias (recall and recognition) for emotional visual information is better elicited in complex-scene tasks.

Trait anxiety and emotion induced memory trade-offs in children

Furthermore, given that HA children seem to better process and remember the visual negative stimuli, but also to have worse performances in remembering positive visual information (Cheie & Visu-Petra, 2012; Visu-Petra et al., 2010), a question arises of whether or not the diminished memory for positive information comes as a direct cost of preferentially processing negative information. Studies with anxious individuals show that they are more likely to remember emotional elements as the emotionally arousing element is acting like an attentional control magnet (see Mathews and

Mackintosh, 2004). Moreover, it seems that this stimulus-driven attention is greater when the stimulus is mood congruent (Calvo & Avero, 2005). Importantly, this process is also found to employ a cost on memory for the unrelated elements accompanying the negative stimuli (Wessel & Merckelbach, 1997). Hence, a new research question arises regarding the potential emotion-induced memory trade-offs in HA children. The third aim of the present study was to investigate the relationship between individual differences in children's TA and emotion induced memory trade-offs.

According to Kensinger, Garoff-Eaton and Schacter (2007), the *emotion induced memory trade-off* consists in the advantage of memory for emotional information in a scene, at the expense of memory for background, peripheral elements. Typical individuals seem to display poorer recognition for peripheral information when this information accompanies an emotional item included in the scene, as opposed to when it accompanies a nonemotional item (e.g. Brown, 2003; Christianson & Loftus, 1991; Kensinger et al., 2007). With respect to the relationship between individual differences in anxiety and the emotion induced memory trade-off, Waring, Payne, Schacter and Kensinger (2010), found that the magnitude of such a trade-off correlated positively with adult anxiety in a task using complex emotional scenes.

Current Study

The major aim was to investigate the relationship between individual differences in children's TA and memory for verbal and visual information, in a task using emotional stories accompanied by complex emotional visual scenes.

(1) The first aim was to determine whether children's *recall* of the *emotional story* information varied as a function of TA levels and information valence. Given the inconsistency of literature findings regarding HA children's memory for emotional verbal information, our investigation in this domain is rather exploratory.

(2) Second, we aimed to investigate whether children's (free and cued) *recall* of the *emotional complex scenes* information varied as a function of TA and stimulus valence. Based on the ACT's prediction (Eysenck et al, 2007) supported by previous data regarding HA children's memory for emotional visual stimuli (Cheie & Visu-Petra, 2012; Visu-Petra et al., 2010), we expected HA schoolchildren to recall greater amounts of negative scenes information and/or relatively lower amounts of positive scenes information.

(3) Finally, we aimed to determine whether high TA influenced performance *recognition* of the *emotional complex scenes*. Specifically, we were interested to investigate whether high levels of TA enhanced the magnitude of the negative emotion induced memory trade-off. Given the documented recognition impairment for backgrounds associated with negative stimuli in HA individuals (Waring et al. 2010) as well as the documented memory bias in HA children (Cheie & Visu-Petra, 2012; Visu-Petra et al., 2010), we expected HA children to display an enhanced negative emotion memory trade-off.

5.2. Methodology

5.2.1. Participants

For this study, we used the evaluation of 99 children (54 girls) with an age range of 8.9 years to 11.8 years (mean age = 125.8 months, *SD* = 7.64), recruited from three schools. The children were selected after their parents gave their written consent and completed the RCADS-P (Chorpita et al., 2000). From the total of 99 children, 98 completed the verbal story recall task, 99 the image recall task, and 92 the recognition task.

5.2.2. Measures

Trait anxiety

The total anxiety score derived from RCADS-P (Chorpita et al., 2000) was used as a measure of each child's trait anxiety level. For this sample, the trait anxiety scale had a good internal consistency, Crombach's α of .85.

Memory for emotional information task: The emotional stories and slides presentation

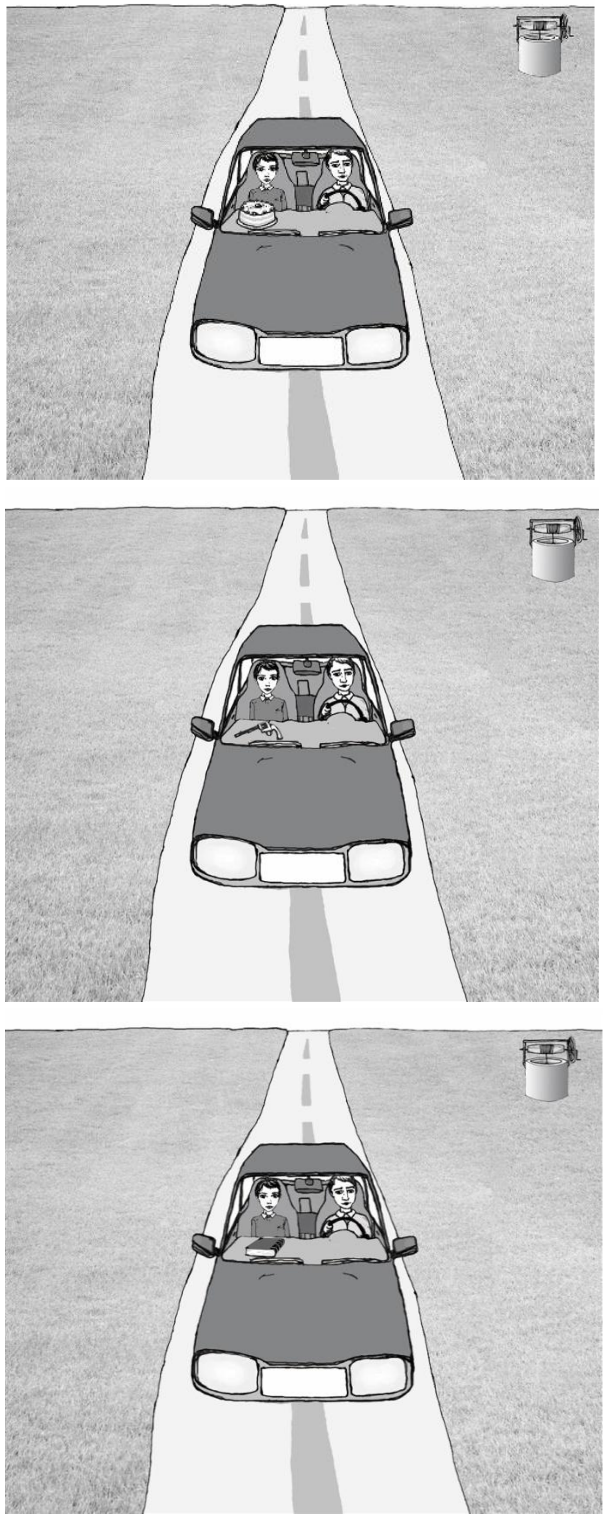
Based on the three core stories developed by Bishop, Dalgleish, and Yule (2004), in order to investigate emotional stories recall in children with depression, we designed a task that would allow us to measure both recall performance of the stories, as well as recall and recognition performances for visual information (presented in complex scenes accompanying each story). Each story had three different valence versions (positive, negative, neutral) and consisted of a constant section (Section 1) that is not altered across valence versions, and a second section (two-thirds of the story) that varies as a function of valence (Section 2). Hence, the Emotional Stories Recall task comprised three core stories (in three different valence versions) developed after the original stories created by Bishop et al. (2004):

(1) the "Park" story (positive, negative, neutral versions);
(2) the "Beach" story (positive, negative, neutral versions);
(3) the "Going home" story (positive, negative, neutral versions);

These narrated valence versions were created by alteration of a number of key-words within Section 2. In a similar manner, the first images were identical across valence versions; but the last two images accompanying Section 2 of the story varied as a function of valence. These variations were created by changing a target object. For instance, in the "Going home" story, the main character sees a cake (positive valence) a pistol (negative) a book (neutral) in the 6th image (see Figure 5.1). Hence, the only element that varied across valences was the target item.

Figure 5.2. illustrates the three valence alternative ending images for each story. Each story had a positive, negative, or neutral ending. The main character was reunited with a family member (uncle or mother) who was either upset and carrying a bat ("Park" and "Going home" stories) or a first aid kit ("Beach" story; negative valence), happy and carrying a basket of toys (all stories; positive valence), bored and carrying a shopping bag ("Park" and "Going home" stories) or a beach bag ("Beach" story; neutral valence). These "endings" were visually represented in the 7th image of each slide accompanying the narration. The only element that varied across valences was the object the family member carried.

Slides were presented synchronized with the plot, for 10 seconds each, and 5 seconds interpause (with the exception of the introduction slide which was presented for 25 seconds and was not used in the testing phase). Each image comprised a minimum three and a maximum four elements that formed the conceptually linked *central* placed in the center of the image and the unrelated *peripheral* element, placed in one of the top corners.

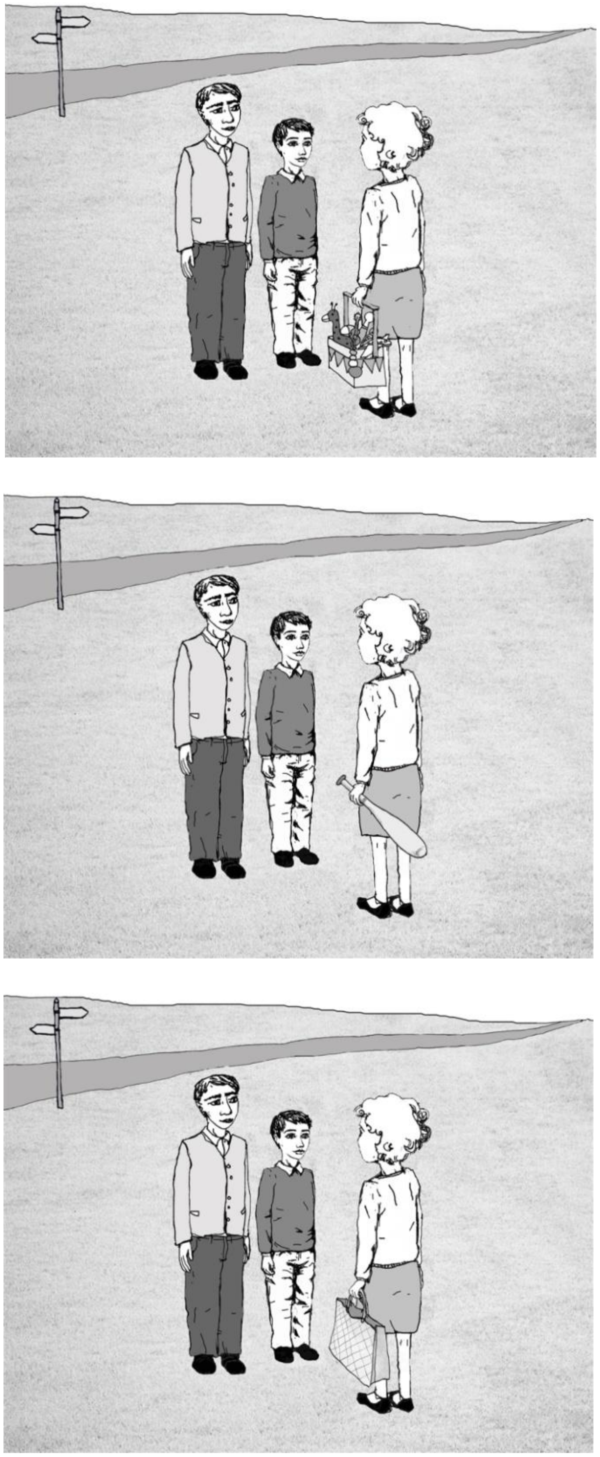


A.

B.

C.

Figure 5.1. Representation of the 6th presentation image for the "Going home" story, in all three valence versions: positive (cake, A), negative (pistol, B), and neutral (book, C).



A.

B.

C.

Figure 5.2. Representation of the 7th presentation image for the “Going home” story, in all three valence versions: positive (toy basket, A), negative (bat, B), and neutral (grocery bag, C).

Procedure and scoring

The children were specifically instructed to pay attention to both “what happens at the center of the image” and to “what appears on one of the corners” as they would be asked several questions at the end of the presentation. After each story presentation, both emotional story recall and memory for emotional visual-scenes were evaluated in a counterbalanced order. Children also completed a vocabulary test prior the presentation of stories. The whole testing session lasted for approximately 45-55 minutes.

The emotional stories recall task

Children were required to recall the story “word for word”, at their own pace, in as much detail as possible. Following Bishop and colleagues’ coding procedure (2004; after Omanson, 1982; Van de Broek, Lorch, & Thurlow, 1996), the text of each story comprised several idea units; each idea representing a separate event or state. Each story comprised 67 to 74 units, with the number of units not varying across valence versions (the “park” story – 74 units; the “beach” story = 67 units; the “Going home” story = 73 units). Using Bishop et al.’s scoring procedure, participants received a 1 point score/ idea unit when all the elements or their exact meaning was recalled and a 0.5 score when any of the elements were recalled. Two raters practiced the coding system and independently coded all protocols.

Images Free Recall Task

In this task, children were required to recall all the elements they had seen in the images accompanying the narrated story. Scores were attributed beginning with the second image, the first image being introductory and used to exemplify the task. A score of 1 was attributed for each item/ image remembered correctly.

Images Cued Recall Task

For this task, the requirements were identical to the Free Recall task, only this time children were aided by being presented with each image’s background. By “background”, we mean any element that was either central or peripheral element (grass, road, rock on the beach etc.). Children were required to say the elements and press the Spacebar key whenever they had finished recalling. Again, a score of 1 was attributed for each item/ image remembered correctly.

Memory Recognition Task

In order to investigate the potential emotion-induced recognition trade-offs, children reviewed the central (from each image) and peripheral elements separately. Additionally, children saw centrals and peripheral elements that have not been shown during story presentation. For each central or peripheral element, were asked to decide whether it is identical (“*same*”), shares the same verbal label and is not identical (“*similar*”), or is it’s something that has not been viewed during story presentation (“*new*”). Each previously seen central had two correspondent “similar” centrals, and two “new” ones. The total five items were presented in a counterbalanced order. In a similar manner, each peripheral element had two “similar” correspondents, and two “new” ones. Children were required to hit “Same”,”Similar”, or “New” on the designated keyboard buttons. These keys were covered in colored tape (that changed order every 30 participants) and had “Same”, “Similar”, “New” written on them. The *central* versus *peripheral* recognition task order was counterbalanced across participants. *Figure*

5.3. and *Figure 5.4.* illustrate the Memory Recognition Task for the central and peripheral elements, respectively.

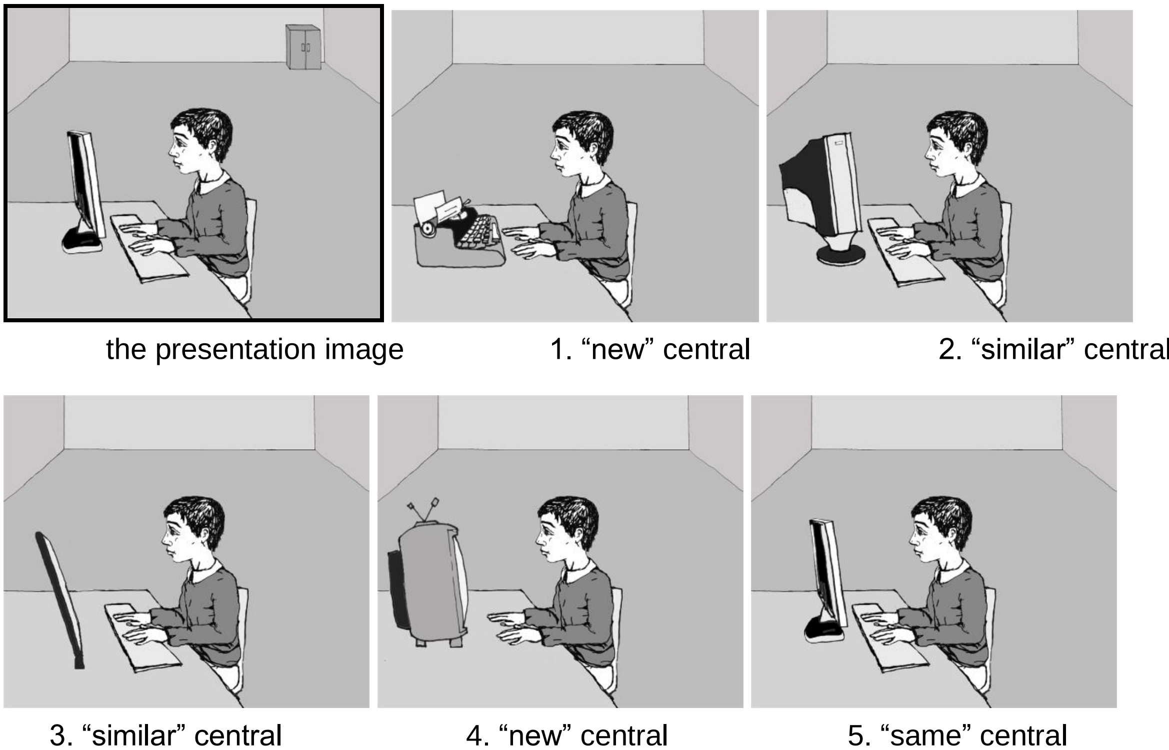


Figure 5.3. Illustration of the Memory Recognition Task; Example of recognition task for the central in the second image of the “Going Home” story.

Two types of scores were computed:

(1) a specific recognition score: children received a 1 point score for each exact recognition correspondence;

(2) a general recognition score: children received a 1 point score for each exact recognition correspondence, but also a 0.5 score if the item’s general features were recognized (e.g. when the previously seen cake was the test item, the child was only attributed a 1 point score if he had hit the “same” key, and 0.5 if he had hit “similar”).

Prior the recognition task, children were presented with “similar”-“same”-“new” training, during which they were familiarized with the concepts and correspondent keys. The training consisted in showing the children three target images that were successively followed by similar, same, new correspondents (in a random order).

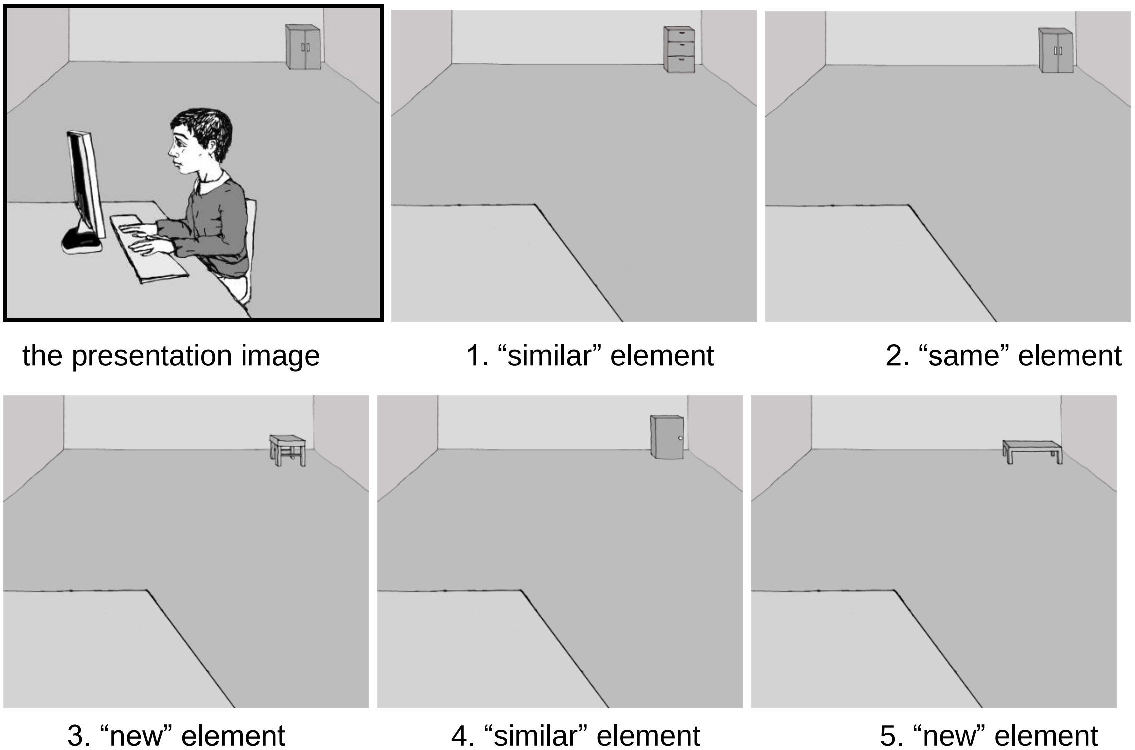


Figure 5.4. Illustration of the Memory Recognition Task; Example of recognition task for the peripheral element in the second image of the “Going Home” story.

5.3. Results

5.3.1. Emotional Stories Recall

In order to investigate factors affecting children’s recall performance of emotional stories, we conducted a repeated measures ANCOVA with story section (1,2; emotional, nonemotional) and valence (positive, negative, neutral) as within subject measures, and TA as covariate. As the number of idea units within Story Section 1 was not identical to number of idea units in Section 2, we used z scores for the direct comparison. The results revealed a significant effect of Story Section X Valence interaction, $F(2,186) = 4.50$, $p = .012$, $\eta_p^2 = .05$. Breaking down this interaction, results indicated that children displayed better recall performances for negative information in the Emotional Story Section. Post hoc paired sample t-tests revealed better recall performances for negative information as opposed to positive, $t\ (95) = 6.08$, $p < .001$, and to neutral information, $t\ (96) = 4.19$, $p < .001$.

No main effect of TA was found, $F(1,86) = .42$, $p = .52$, $\eta_p^2 = .00$, *ns.*, and no significant interaction effects between TA and other variables were found ($\eta_p^2 < .02$).

5.3.2. Free and Cued Image Recall

Free Recall Performance

The hypothesized factors influencing recall performances were investigated by conducting a repeated measures ANCOVA, with TA as covariate, and three within-subject measures: Story Section

(1, 2; without emotional visual elements, with emotional elements), Scene component (central, peripheral), and valence (positive, negative, neutral). For the direct comparisons between central and peripheral elements recall performances, we used z scores. The results revealed a Story Section X Scene Component X Valence X TA interaction marginally significant effect, $F(2,194) = 2.88$, $p = .06$, $\eta_p^2 = .03$, suggesting that TA's might have influenced children's recall performance in interaction with valence only in a particular story section and scene component. It is possible that this interaction was not straightforward, as a result of the first story section being already contaminated with emotional information from the narrated story.

Hence, two additional repeated measures ANCOVAs were conducted for each story section, with Scene component and Valence as within measures, and TA as covariate. As expected, no significant effects of TA, or TA interaction with other variables effects were found ($p > .52$; $\eta_p^2 < .02$) regarding performance for the non-emotional section. However, the analysis for the emotional section revealed several significant factors that influenced children's recall performance. First, a marginally significant effect of Scene component, $F(1,97) = 3.55$, $p = .06$, $\eta_p^2 = .04$, was found, reflecting children's tendency to better recall central elements than peripheral information. However, this effect was better qualified by an interaction between Scene component and TA, $F(1,97) = 4.30$, $p = .041$, $\eta_p^2 = .04$. Moreover, there was a significant Scene component X TA X Valence interaction, $F(2,194) = 4.09$, $p = .018$, $\eta_p^2 = .04$, suggesting that children with higher TA scores had varying recall performances as a function of item's valence and its role in the image (central or peripheral). Results revealed that while children with higher TA levels better recalled negative central items, their recall performance for peripheral elements accompanying the negative central information was significantly disrupted, $B = -.02$, $SE = 00$, $t = -3.13$, $p = .002$, $\eta_p^2 = .09$. No other significant differences were found ($\eta_p^2 < .02$). There was no significant TA X Valence interaction, $F(2,194) = .80$, $p = .45$, $\eta_p^2 = .01$, *ns.*, or a significant effect of Valence, $F(1,97) = .50$, $p = .61$, $\eta_p^2 = .00$, *ns.*, or TA, $F(1,97) = .92$, $p = .45$, $\eta_p^2 = .01$, *ns.*

Cued Recall Performance

A repeated measures ANCOVA with Story Section (1, 2; without emotional visual elements, with emotional elements), Scene component (central, peripheral), and valence (positive, negative, neutral) as within-measures, and TA as covariate was conducted for analyzing children's cued recall performance. The results pointed out that their cued recall performance was influenced by factors like TA and scene component. First, results suggested a tendency for children to have worse memory for peripheral elements, $F(1,97) = 3.29$, $p = .07$, $\eta_p^2 = .03$, but, similar to the free recall performance, this effect was better qualified by a Scene Component X TA interaction, $F(2,194) = 4.42$, $p = .038$, $\eta_p^2 = .04$. No other significant within subject effects were found ($\eta_p^2 < .02$).

These results suggest that children with higher TA scores have significantly worse cued recall performances on peripheral items, irrespective of the item's valence. Parameter estimates indicate differences in performance on the peripheral items recall, children showing significantly worse recall performances on recalling peripheral negative elements, $B = -.02$, $SE = 00$, $t = -3.13$, $p = .002$, $\eta_p^2 = .09$, but, as opposed to their performance on the Free Recall task, also (marginally) on recalling peripheral positive elements, $B = -.01$, $SE = 00$, $t = -1.90$, $p = .06$, $\eta_p^2 = .04$. Moreover, a main effect of TA was found, $F(1,97) = 4.55$, $p = .036$, $\eta_p^2 = .05$, suggesting the children's cued recall performance was impaired by higher levels of TA.

5.3.3. Specific and General Recognition

Specific Recognition

A repeated measure ANCOVA was conducted for investigating children's specific recognition performance, with Story Section (1, 2; without emotional visual elements, with emotional elements), Scene component (central, peripheral), and valence (positive, negative, neutral) as within-measures, and TA as covariate. The results revealed a main effect of Scene component, $F(1,90) = 50.68$, $p < .001$, $\eta_p^2 = 36$, suggesting that images were recognized on dependence of whether the item was peripheral or central. There was also a main effect of valence, $F(2,180) = 4.38$, $p = .014$, $\eta_p^2 = .05$, and these results were qualified by a significant Scene component X Valence interaction, $F(2,180) = 4.38$, $p = .014$, $\eta_p^2 = .05$, suggesting that emotional information was recognized differently, in accordance to whether it was central information or peripheral. First, all items, irrespective of valence, were worse recognized if they were peripheral elements ($p < .001$). Second, children seemed to have better performances in recognizing the neutral elements as opposed to the negative ones (mean difference = .19, $p = .003$), and this difference was better accounted for remembering the peripheral elements accompanying negative and neutral central elements.

Moreover, there were no significant interaction effects between these factors and TA ($\eta_p^2 < .02$). However, tests of between-subjects revealed a main effect of TA, $F(1,90) = 5.52$, $p = .021$, $\eta_p^2 = .06$, suggesting that TA significantly influences children's specific image recognition performance, irrespective of the items' valence or role in the image (scene component). Results revealed that this influence was disruptive, and it significantly affected almost all measures of image recognition. All peripheral items were significantly less well recognized, $B = -.01$, $SE = 00$, $t = -2.26$, $p = .026$, $\eta_p^2 = .05$ for the negative items, $B = -.02$, $SE = 00$, $t = -2.54$, $p = .013$, $\eta_p^2 = .07$ for the positive items, and $B = -.01$, $SE = 00$, $t = -2.21$, $p = .030$, $\eta_p^2 = .05$ for the neutral ones. For the central images the same effect direction was maintained (η_p^2 between .01 and .06).

General Recognition

A similar ANCOVA was conducted to investigate the potential factors influencing children's general image recognition performance. Results indicated a pattern of effects similar to the one found for performance in specific recognition. Hence, following the same directions, there was a main effect of Scene component, $F(1,90) = 42.87$, $p < .001$, $\eta_p^2 = 32$, a main effect of Valence, $F(2,180) = 4.53$, $p = .014$, $\eta_p^2 = .05$, and these results were qualified by a significant Scene component X Valence interaction, $F(2,180) = 4.90$, $p = .009$, $\eta_p^2 = .05$. Again, there were no significant interaction effects between these factors and TA ($\eta_p^2 < .02$), and TA impaired overall performance, $F(1,90) = 5.15$, $p = .026$, $\eta_p^2 = .05$.

5.4. Discussions

Summary of findings

(1) Regarding children's *recall performance on the emotional stories*, results indicated there was no emotion induced memory bias related to TA. However, there was an effect of valence manifested on the Emotional Story Section, indicating that all children displayed a significant preferential recall of negative verbal information.

(2) *Free recall performance of emotional visual information* varied as a function of the interaction between TA, item valence, and its role in the image (central or peripheral). Children with higher levels of TA displayed an emotion induced memory trade-off, as they better remembered

negative central information, at the cost of a poorer recall of the neutral peripheral elements accompanying the negative stimuli.

(3) In the *cued version of the recall* task, performance varied as a function of the interaction between TA and scene component (central or peripheral), results suggesting that TA impaired children's cued recall of peripheral information, irrespective of central stimulus valence.

(4) Scores on the *visual recognition* task (both specific, and general) revealed that children's recognition performance was poorer for the peripheral elements as opposed to recognition performance for the central information. Children also displayed poorer recognition of peripheral elements accompanying negative central information (compared to those accompanying neutral information). Higher TA affected overall recognition performance, irrespective of stimulus valence, or role in the scene.

First, the results regarding children's recall of the emotional stories show no variation of children's performance as a function of TA. This result is in line with our previous findings in children with TA (Cheie & Visu-Petra, 2012), as it shows that there was no significant variation in HA children's delayed verbal recall performance as a function of information valence. Again, our results contradict Daleiden's (1998) findings showing enhanced memory for negative verbal information in HA children. However, there are several procedural limitations of this study, preventing us from drawing the conclusion that there is no emotional memory bias in children with high levels of TA. First, the stories were accompanied by images, which could have redirected many of the attentional resources. Second, the order of the verbal and image recall tests was counterbalanced. Studies suggest that finding an emotional bias can also depend on testing delay (Cheie & Visu-Petra, 2012; see Mitte, 2008). However, all children showed a preferential recall of negative verbal information, hence an emotional induced memory bias. This result is confirming numerous other findings suggesting that information is best remembered when it is emotionally arousing, as opposed to when it is nonemotional (e.g. Cahill et al., 1996; Christianson, 1992; LaBar & Phelps, 1998; Touryan, Marian, & Shimamura, 2007).

Second, children with higher levels of TA, demonstrated an emotion induced trade-off for central versus peripheral scene components in the image free recall task. They displayed a better performance, compared to their counterparts in recalling the central negative scenes, at the cost of a poorer performance in recalling the peripheral elements shown with the specific scenes. This finding is consistent with previous visual memory negative biases found in HA children (e.g. Visu-Petra et al., 2010) and the documented biases found in studies with adults (e.g. Moser et al., 2008; Silvia et al., 2006). The findings are also consistent with the Waring and collaborators' study (2010) that found this memory trade-off in a recognition task to be related to individual differences in anxiety. Moreover, this outcome is also in line with the predictions of ACT (Eysenck et al, 2007) as it suggests that the deleterious effects of anxiety are greater with threat-related than with neutral distracting stimuli because the bottom-up attentional system in HA is more responsive to threat related stimuli (Eysenck et al., 2007).

Nevertheless, when cued, the emotion induced memory trade-off was not significant, findings suggesting that high levels of TA impaired children's cued recall of peripheral information, irrespective of central stimulus valence. This result could be accounted by the fact that a cued recall memory test would require less attentional control resources than a free recall test. As previously shown anxiety's deleterious effects are expected to be less evident in tasks imposing less cognitive demands (see also Derakshan & Eysenck, 2009). Moreover, this outcome is again in line with the ACT, as it suggests that HA children's goal driven attentional control system is overridden by the stimulus driven control system when a salient or a conspicuous stimulus is present (see also Corbetta

& Shulman, 2002). Furthermore, this result could also be corroborated with previous findings in HA children's PM and WM memory functioning (e.g. Cheie et al., submitted; Visu-Petra et al., 2011), as it suggests that when the task stimuli are more salient on the primary task (i.e. encoding the images linked to the story plot), anxiety impairs the secondary task performance (i.e. encoding the peripheral, unrelated images).

Finally, the expected emotion induced memory trade-off was not elicited in the visual information recognition task, results showing the TA impaired children's overall performance, irrespective or both stimulus valence and scene component. The finding contradicts the results found in adults in a complex scene recognition task (Waring et al., 2010), suggesting that this is not held true in children. However, the finding could also be accounted by the fact that as recognition solicits less cognitive processes (e.g. Whiting & Smith, 1997), anxiety's detrimental impact should be less evident (Eysenck et al., 2007). However, there was a detrimental overall impact of anxiety, children's recognition performance being impaired irrespective of valence or scene component. This finding confirms previous developmental research findings suggesting that children's memory and other cognitive processes are impaired by high levels of nonclinical anxiety (e.g. Hadwin et al., 2005; Ng & Lee, 2010; Owens et al., 2008; Visu-Petra et al., 2011).

5.5. Concluding remarks

The findings confirm once again anxiety's deleterious effects on children's memory functioning, as we found that: (1) there was an emotion-induced memory trade-off in children with higher levels of anxiety, as they preferentially recalled negative information, at the cost of poorer recall of the neutral peripheral elements accompanying the negative stimuli (2) there was an overall central-peripheral trade-off for the same group of children; cued recall performance for peripheral information being impaired; and (3) there was an overall recognition impairment for children with higher levels of TA.

Findings of an emotion-induced memory trade-off in children with higher levels of TA is of particular importance, as there is evidence for early adult-like biased responses to emotional stimuli (e.g. Batty & Taylor, 2006; Grossman et al, 2006). In this respect, our corroborated results (see also Cheie & Visu-Petra, 2012, Visu-Petra et al., 2010) are particularly important as they bring evidence towards an anxiety-related neurobehavioural interaction that, most probably, occurs during early development, while processing anxiety-relevant emotional information. The fact that we found a an emotion-induced memory trade-off in children with nonclinical anxiety reveals that such biases are not found at clinical levels of anxiety only, supporting the possibility of a continuum of anxiety symptoms - anxiety disorders documented by previous research with children (Schniering, Hudson, & Rapee, 2000).

CHAPTER 6

ANXIETY AND MEMORY FUNCTIONING IN CHILDREN: CONCLUDING REMARKS

6.1. General findings

The present thesis explored the interplay between trait anxiety and various aspects of memory functioning in children. Research was channeled into two main directions: the first direction line focused on investigating the relationship between trait anxiety and memory for non-emotional information (on both retrospective and prospective memory) and its links to academic achievement; the second direction line focused on exploring the role of trait anxiety in various aspects of memory for emotional information.

Chapter 1 reviewed the scientific literature which left us with a couple of question marks regarding anxiety's effects on children's memory functioning. First, answers were needed to the question of whether anxiety interferes with children's memory processes (WM and PM) even when the to-be-remembered contents do not involve an explicit threat. Although it highly depends on the level of executive demands requested by the task, the answer is yes. Importantly, although the ACT (Eysenck et al., 2007) predicts that deleterious effects of anxiety should be evident on tasks involving the shifting and/or inhibition functions (e.g. on PM tasks) and less on tasks requiring mainly updating (e.g. WM tasks), our corroborated findings show an indiscriminative disruptive impact. Hence, both PM and WM seem to be impaired at similar levels by trait anxiety (see Study 1 and Study 2), which could mean that children's updating, shifting and inhibition functions require similar amounts of attentional control. In this respect, findings show that when shifting/ inhibition/ updating impose great demands on the children's attentional control system, reductions in both effectiveness and efficiency are evident (see also Visu-Petra et al., 2011). Importantly, this conclusion suggests that children with high levels of trait anxiety could be aided by reducing the executive demands of the task (see Study 1 and Study 2 for evidence in this direction), via redirecting their attention to task-relevant stimuli (Study 1) or reducing/ eliminating the additional demands imposed by a concurrent task (Study 2). There are, however, several questions that still need to be answered. For instance, it has been suggested that task-switching costs should be more evident in tasks imposing strong temporal constraints, as a self-paced task would require less need for competition (e.g. Baddeley et al., 2001; Liefooghe et al., 2008). Hence, it would be highly important to see whether HA children's PM and WM are disrupted at similar levels, as temporal constraints are applied.

The other research question regarded children's memory for emotional information. Specifically, whether or not children's memory performance varies as a function of information emotional valence. As reviewed in Chapter 1, the answer needs to be calibrated according to the relevance of task information, and the level of threat being experienced, both influencing how motivation and emotion interact to enhance or impair executive control (Pessoa, 2009). However, evidence suggests that the answer is yes, as emotion-induced memory biases were found in both HA preschoolers (see Study 3) and HA school-children (Study 4). Our findings suggest a preferential memory for negative/threatening information in children with high levels of TA, as they displayed (1) an emotion-induced memory trade-off, preferentially recalling negative information, at the cost of poorer recall of the neutral peripheral elements accompanying the negative stimuli (Study 4); (2) a (marginally) better delayed recognition of identities expressing anger (Study 3); and (3) poorer delayed recognition of identities displaying happy expressions (Study 3). Findings suggest that HA children display a superior "emotional capture" of attention (see Pessoa, 2009 for a theoretical discussion regarding the interaction between emotion and motivation), threat related stimuli benefiting from sensory enhancement, leading to further preferential information processing and retention. These findings (see also Visu-Petra et al., 2010) allow us to speculate that anxiety-related neurobehavioural interactions could already occur during early development, while processing anxiety-relevant emotional information. However, clarifications are still needed regarding how HA children's display of an attentional positive bias affects memory processes. Also, future research should investigate children's memory for high threat value, as studies show that despite benefiting from the same enhanced sensory processing, it actually diverts resources away from the central executive and this is evident to a greater degree in high-anxious individuals than in their low-anxious counterparts (Bishop, 2007).

In conclusion, the present series of studies bring their contribution to the literature, by revealing anxiety's deleterious impact upon children's retrospective and prospective memory, as well as its links to children's preferential memory for emotionally negative information.

As they were previously discussed within each chapter, we will now present a summary of the main *findings* and conclusions (presented in Table 6.1.), emphasize each study's core *empirical contributions* (see Section 6.2.1.), as well as the thesis' main *theoretical contributions* (see Section 6.2.2.) to the research domain. After reviewing the established adverse effects of anxiety upon various aspects of children's memory functioning, Section 6.4. attempts to provide a general guideline of the findings' practical implications.

Study	Type of memory (EF involved)	Population Age (N)	Method / Instrument	Variation of resource demands / emotional valence	Main Conclusions
Chapter 2 Study 1	*Prospective memory* (inhibition and shifting)	4 – 7 years old (N = 73)	Task-switching procedure Ecologically-valid task	With / without external memory aid	1. Trait anxiety impaired overall PM in preschoolers; anxiety's deleterious effects were significantly diminished in the presence of a salient PM cue; 2. The findings suggest that preschoolers with high levels of trait anxiety were less impaired when the task required minimum attentional resources to be allocated in response to task goals. 3. Findings confirm ACT's predictions regarding anxiety's deleterious effects on the shifting function; and that its' adverse effects are evident when the primary task contains less salient stimuli.
Chapter 3 Study 2 (N = 214) **Study 2a**	*Working memory* (updating) *+ _academic performance_	9 – 11 years old (N = 69)	Modified Operational Span task	Three Arithmetic conditions increasing in processing demands	1. Arithmetic processing performance was negatively associated with trait anxiety; 2. Overall working memory recall was negatively associated to trait anxiety, but the effects became evident on the more demanding processing conditions. Findings suggest anxiety impairs the updating function in children; 3. Trait anxiety was negatively associated with academic performance in mathematics. However, the anxiety – academic performance relationship was mediated by WM.

Chapter 3 Study 2 (N = 214)	**Study 2b**	*Prospective memory* (inhibition and shifting)	9 – 11 years old (*N* = 74)	Modified Operational Span task (without WM demand) in a task-switching procedure	Three Arithmetic conditions increasing in processing demands	1. Trait anxiety was negatively associated to prospective remembering, but the effects were only significant on the high processing demanding conditions; 2. Arithmetic processing performance was negatively associated with Trait anxiety on the highest demanding processing condition; 3. Findings confirm ACT's predictions regarding anxiety's deleterious effects on the shifting or/and inhibition function(s).
Chapter 3 Study 2 (N = 214)	**Study 2c**	*Working memory* and *prospective memory* (updating, inhibition, and shifting)	9 – 11 years old (*N* =71)	Modified Operational Span task (WM+PM demands)	Three Arithmetic conditions increasing in processing demands + Presence of the concurrent task	1. Both trait anxiety and WM demands were found to be negatively related to children's prospective remembering; 2. Trait anxiety and the presence of the concurrent prospective memory demands seemed to impair children's WM; 3. Findings suggest that the adverse effects of anxiety on memory performance become greater in the presence of concurrent inhibition, shifting or updating demands.

Chapter 4 Study 3	*Emotional verbal memory recall* *Emotional visual recognition*	4 – 7 years old (N = 76)	Word recall Identities recognition	Affective words (positive, negative, neutral) Variation of emotional expression (happy, angry, nreutal)	1. High anxious preschoolers were found to show immediate memory avoidance of negative verbal information, as well as poorer recognition of identities expressing happiness, and a tendency to better recognize of identities when they were expressing anger; 2. Findings suggest an anxiety-related emotion-induced memory bias in preschoolers.
Chapter 5 Study 4	*Emotional verbal and visual recall* *Emotional visual recognition*	9 – 11 years old (N = 99)	Illustrated Emotional Story recall Complex scene free and cued recall Central & peripheral element recognition	3 emotional verbal stories (positive, negative, neutral) Complementary emotional scenes: (positive, negative, neutral)	1. High anxious children had better recall performances of negative central elements; children's trait anxiety was associated with impaired performance regarding memory for peripheral neutral visual stimuli when presented concurrently with central negative visual stimuli; 3. Findings suggest the existence of an emotional induced memory "trade-off" in high anxious children; 4. Children with higher levels of trait anxiety had overall impaired recognition performances, irrespective of emotional valence, or scene content (peripheral versus central).

Note. ACT = Attentional Control Theory (Eysenck et al., 2007); PM = prospective memory; WM = working memory

6.2. Empirical and theoretical contributions

6.2.1. Empirical contributions

***Chapter 2, Study 1.* Event-based prospective memory in young children: effects of age, trait anxiety, and memory aids**

- ✓ For the first time, to our knowledge, the relationship between anxiety and prospective remembering was investigated in children;
- ✓ For the first time, to our knowledge, the relationship between anxiety and PM was investigated by directly testing the ACT's predictions regarding anxiety's deleterious effects on shifting (in a prospective memory task-switching procedure);
- ✓ The trait anxiety – prospective memory relationship was investigated by developing a prospective memory task-switching procedure that would:
  - ***a)*** be more suitable for young children;
  - ***b)*** engage preschoolers in the ongoing task and preserve the secondary nature of the prospective demand;
  - ***c)*** allow manipulating allocation of attentional control demands (in absence/presence of a salient prospective memory cue).
- ✓ Trait Anxiety was found to significantly impair overall prospective remembering in preschoolers; however, importantly, its deleterious effects were significantly diminished in the presence of a salient prospective memory cue;
- ✓ The findings suggest that preschoolers with high levels of trait anxiety were less impaired when the task required minimum attentional resources to be allocated in response to task goals.

***Chapter 3, Study 2.* Adverse effects of trait-anxiety upon children's working memory and prospective remembering: implications of processing load and secondary executive demands manipulation**

- ✓ For the first time, to our knowledge, effects of increasing processing demands on high-anxious children's working memory (*Study 2a*), and prospective memory (*Study 2b*) were investigated;
- ✓ For the first time, to our knowledge, the conjoint impact of trait anxiety and working memory demands on prospective remembering was studied (*Study 2c*);
- ✓ For the first time, to our knowledge, the conjoint impact of trait anxiety and prospective memory demands on working memory performance was studied (*Study 2c*);
- ✓ An innovative Operational span task was developed so that:
  - ***e)*** it would involve sentence reading in order not to allow verbal rehearsal and grouping of items, and thus provide a purer measure of the updating function for *Study 2a* and *Study 2c*;
  - ***f)*** it would allow generating different levels of processing demands on the same structure of item lists;
  - ***g)*** it would be more suitable for school age children; making it more appealing than the classic Operation Span (that only requires operating with numbers) and preventing boredom and fatigue;
  - ***h)*** its primary operational task could be used as the invariant processing procedure concurrently performed with working memory span demands (*Study 2a*), prospective memory demands (*Study2b*), and both working memory and prospective memory demands conjointly (*Study 2c*).

- ✓ Trait anxiety was found to impair performance on both working memory (*Study 2a*) and prospective memory (*Study 2b*);
- ✓ Both trait anxiety and working memory demands were found to be negatively related to children's prospective remembering (*Study 2c*);
- ✓ Trait anxiety and the presence of the concurrent prospective memory seemed to impair children's working memory (*Study 2c*);
- ✓ Trait anxiety was also found to be negatively associated with academic performance in mathematics. However, this association was better explained by working memory performance, as the anxiety – academic performance relationship was mediated by working memory (*Study2a*).

Chapter 4, Study 3. **Relating individual differences in trait-anxiety to memory functioning in young children an investigation with task-irrelevant emotional stimuli**

- ✓ To our knowledge, this is the first study to explore both immediate and delayed verbal recall for affective words in high-anxious preschoolers;
- ✓ To our knowledge, this is the first study to explore delayed visual recognition of identities varying in emotional facial expressions in high-anxious preschoolers;
- ✓ Two standard memory tests were modified in order to contain affective stimuli: NEPSY's List Learning task for the immediate and delayed verbal recall, and NEPSY's Memory for Faces task – for the delayed recognition of identities varying in emotional facial expressions;
- ✓ High anxious preschoolers displayed an emotion induced memory bias, as they were found to show immediate memory avoidance of negative verbal information, as well as poorer recognition of identities expressing happiness, and a tendency to better recognize of identities when they were expressing anger.

Chapter 5, Study 4. **Relating individual differences in trait-anxiety to memory for emotional information in children: an investigation using illustrated emotional stories**

✓ To our knowledge, this is the first study to investigate both verbal and visual recall of emotional information embedded within emotional stories (presented both verbally and visually) in relation to children's trait anxiety;

✓ To our knowledge, this is the first study to investigate high-anxious children's visual recognition of emotional scenes and non-emotional peripheral elements;

✓ For this study, we developed an emotional memory task consisting in three emotional stories accompanied by visual complex scenes (depicting the storyline). This innovative method of exploring children's emotional memory was created so that it would:

- ***a)*** be more engaging and age suitable for exploring children's emotional memory;
- ***b)*** contain both verbal and visual emotional information presented less artificially (i.e. within verbal stories accompanied by complex scenes depicting the storyline);
- ***c)*** allow measurement of both free and visually-cued *recall* of the complex scenes;
- ***d)*** allow us to investigate verbal information recall performance;
- ***e)*** allow measurement of the magnitude of memory trade-offs (between central and peripheral elements within a complex scene);
- ***f)*** allow us to investigate specific and general visual *recognition* of both central and peripheral elements within the scenes.

✓ To our knowledge, this is the first study to investigate and demonstrate the existence of an emotional induced memory “trade-off” in high anxious children; High anxious children were found to have better recall performances of negative central elements at the expense of poorer recall of the neutral peripheral elements concurrently presented within a scene.

6.2.2. Theoretical contributions

The general aim of these series of studies was to explore the interplay between trait anxiety and various aspects of (non-emotional an emotional) memory functioning in children. By offering the most complete account of the detrimental impact of anxiety upon cognitive performance, the Attentional Control Theory (ACT; Eysenck et al., 2007) provided an ideal conceptual framework within which to explore the relationship between children’s individual differences in anxiety and memory performance. In this section, we will make a summary of the main ACT predictions directly tested in our studies, with regard to high trait anxious children’s attentional control and its effects on memory performance.

I. Predictions regarding anxiety’s deleterious effects on the executive functions (specifically shifting and inhibition) confirmed by findings in our children samples

(1) Anxiety impairs performance (efficiency and / or effectiveness) on tasks involving the shifting and / or inhibition function(s).

Empirical developmental evidence:

1. Trait Anxiety impaired prospective remembering in preschoolers on a task switching procedure (tapping shifting and inhibition; *Chapter 2, Study 1*);
2. Trait Anxiety was negatively associated to prospective remembering in school children on an innovative complex task-switching probe (tapping shifting and inhibition; *Chapter 3, Study 2b).*

(2) Adverse effects of anxiety on performance become greater as overall task demands on inhibition and / or shifting increase (when processing demands are increased or in the presence of a concurrent task loading on the executive functions).

Empirical developmental evidence:

1. Trait Anxiety impaired overall prospective remembering in preschoolers, but its deleterious effects were significantly diminished in the presence of a salient prospective memory cue, thus when task processing resource demands were reduced (*Chapter 2; Study 1*);
2. Ongoing arithmetic processing performance (associated to prospective memory) was impaired as a function of Trait Anxiety X processing demand condition; children displaying higher levels of Trait Anxiety performed significantly worse on the most demanding condition (*Chapter 3, Study 2b*);
3. Overall school children’s prospective remembering was negatively associated to Trait Anxiety, but the effects were only significant on the high processing demanding conditions (*Chapter 3, Study 2b*).
4. Ongoing working memory performance was impaired as a function of Trait Anxiety and the presence of the concurrent prospective memory task (*Chapter 3, Study 2c*).

II. Extended predictions regarding anxiety's deleterious effects on the executive functions derived from findings in our children samples

(1) Anxiety impairs performance (efficiency and / or effectiveness) on tasks involving shifting, inhibition, or ***updading****.*

Empirical developmental evidence:

1. Trait Anxiety was negatively associated to working memory performance in school children on an innovative complex task-switching probe (tapping the updating function; *Chapter 3, Study 2a*);

(2) Adverse effects of anxiety on performance become greater as overall task demands on inhibition, shifting, or ***updating*** *increase (when processing demands are increased or in the presence of a concurrent task loading on the executive functions).*

Empirical developmental evidence:

1. Arithmetic processing performance was negatively associated with Trait Anxiety in the working memory task (*Chapter 3, Study 2a*);
2. Overall school children's working memory recall was negatively associated to Trait Anxiety, but the effects became evident on the more demanding processing conditions (*Chapter 3, Study 2a*).
3. Prospective memory performance was impaired as a function of Trait Anxiety and the presence of the concurrent working memory task (*Chapter 3, Study 3c*).

III. Predictions regarding anxiety's adverse effects on attentional control when the influence of the stimulus-driven attentional system is increased, confirmed by findings in our children samples

(1) Dual-task performance: anxiety impairments are more evident on the secondary task performance when the primary task is cognitively demanding and contains stimuli that are more salient.

Empirical developmental evidence:

1. Preschoolers' ongoing image naming (primary task) performance was not impaired by trait anxiety, at the expense of having worse prospective memory performances (secondary task; *Chapter 2, Study 1*).

(2) Anxiety enhances performance when the task involves responding to threat-related stimuli.

Empirical developmental evidence:

1. High-anxious preschoolers displayed poorer recognition of identities expressing happiness, and a tendency to better recognize of identities when they were expressing anger (*Chapter 4, Study 3*);
2. Children's trait anxiety was associated with enhanced performance regarding memory for central negative visual stimuli, at the cost of impaired recall of peripheral neutral stimuli concurrently presented (*Chapter 5, Study 4*).

6.3. Practical Implications

Memory is of central importance for every aspect of human mental life, from attention (Huang & Pashler, 2007), to language comprehension (Lewis, Vasisth, & VanDyke, 2006), cognitive style (Alloway, Banner, & Smith, 2010), or long-term memory formation (Ranganath, Cohen, & Brozinsky, 2005). Hence, the study of its interplay with personality characteristics such as trait anxiety becomes highly relevant for research and interventions for optimization of cognitive performance and individual well-being. After establishing trait anxiety's deleterious effects on various aspects of children's memory functioning, we will attempt to delineate the practical implications for these findings.

Trait anxiety and prospective remembering in children

From an applied perspective, our studies regarding the trait anxiety – prospective memory relationship, provide data suggesting ways to improve prospective memory performance in high anxious children. As suggested, high anxious children's prospective remembering seems to be less impaired when attentional demands are diminished and they can rely on the stimulus-driven attentional system (see Eysenck et al., 2007). Hence, detecting an explicit cue in a related ongoing activity, would (more or less automatically) redirect their attention and trigger the previously planned action. Thus, these children can be aided to achieve prospective memory success just by using external cues that would help them remember carrying out their intentions (e.g. putting a card /sticker depicting an apple on their school bag so they could remember getting one before heading for school).

Trait anxiety, working memory, and academic performance.

Although the neurocognitive underpinnings of the anxiety - academic performance relationship have been largely overlooked, evidence presented in Chapter 3, as well as other developmental studies (Owens et al., 2008; Yousefi et al., 2009), show there are reasons to believe that WM functioning represents a specific mechanism that accounts for anxiety's detrimental effect on academic achievement. The implications of targeting working memory as a mediator in the relation between anxiety and school performance are great, as WM could represent an important factor to be considered in developing educational interventions for underachieving children with higher levels of anxiety. Several interventions targeting various aspects of WM functioning have already been validated (Alloway, in press; Holmes, Gathercole, & Dunning, 2009; Loosli, Buschkuehl, Perrig, & Jaeggi, 2011). Aside from improving cognition and school performance, such interventions could provide high-anxious children with a more efficient buffer against anxiety's detrimental effects on academic achievement.

Implications for clinical prevention and intervention.

Cognitive Behavioral Therapy (CBT) has been found to significantly reduce information processing biases, especially attentional (see Tobon, Ouimet, & Dozois, 2011, for a recent review). However, there is little intervention research targeting memory functioning in high-anxious or clinically anxious individuals. One of the few proposals of memory modification as an outcome variable in clinical anxiety treatments is provided by Tryon and McKay (2009), suggesting that therapeutic outcome should also be measured via memory change, tapping changes in long term memory retention and learning processes. Bomyea and Amir (2011) trained non-clinical participants with an inhibition task and showed that participants in the training group presented an enhanced working memory capacity and experienced fewer intrusions during a thought suppression task, suggesting a potential common underlying mechanism responsible for these changes. Given that working memory processes play an essential role in self-regulation and cognitive control over affect (Hoffman, Schmeichel, Friese, & Baddeley, in press), the development of interventions targeting memory for neutral and threat-related information in high-anxious or clinically anxious participants is to be considered.

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