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Article

The Reflective Mind of the Anxious in Action: Metacognitive Beliefs and Maladaptive Emotional Regulation Strategies Constrain Working Memory Efficacy.

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Abstract: The Attentional Control Theory (ACT) suggests that trait anxiety does not directly affect performance but may alter processing efficiency through the generation of compensatory strategies. However, the ACT does not describe the nature of these strategies, which could be reflective in nature. One hundred ten students ($M = 20.12$; $SD = 2.10$) completed questionnaires on trait anxiety, metacognitive beliefs, and emotion regulation strategies (ERS). They performed two working memory tasks: the digit span task from the WAIS-IV and an emotional n-back task. Anxiety, metacognitive beliefs, and maladaptive ERS were not linked to performance but were associated with longer response times. Additionally, participants using maladaptive ERS, such as catastrophizing and rumination, made fewer negative commission errors and employed more strategies during the digit span. These findings support the role of the reflective level in influencing trait anxiety's impact on performance and emphasize considering metacognitive beliefs and maladaptive ERS for a comprehensive understanding of the ACT. Identifying these variables provides insights to optimize cognitive abilities and promote academic success.

Keywords: anxiety; metacognitive belief; executive function; emotion regulation; working memory; attentional control theory

1. Introduction

When faced with a stressful situation, such as an exam, we do not react in the same way in an attempt to manage our anxiety and optimize our abilities for success. Our experiences are specific to the situation but also to our predisposition to experiencing anxiety [1,2]. These anxious traits are characterized by worry, intrusive thoughts, physiological manifestations, and difficulty detaching from negative stimuli [2]. They would hinder the mobilization of a cognitive function that is particularly essential for learning and academic achievement: Working Memory (WM) [3]. Indeed, one of the most comprehensive definitions of WM is as follows: "The ensemble of components of the mind that hold a limited amount of information temporarily in a heightened state of availability for use in ongoing information processing" [4]. The primary focus of this article will be to examine how trait anxiety impacts working memory and explore the key factors that contribute to its maintenance and enhancement.

1.1. Trait Anxiety and Working Memory

The relationship between trait anxiety and working memory (WM) is not straightforward, as early studies on the subject have yielded conflicting results. Eysenck [1] noted that trait anxiety had no effect on digit span (a measure of WM, discussed later) in 9 studies. Among those studies that did

show significant effects, some demonstrated a positive relationship between trait anxiety and WM, while others showed a negative relationship or no relation at all. In order to explain these differences, the Processing Efficiency Theory (PET) posits that trait anxiety does not necessarily affect performance efficiency in a task, but rather the efficiency of processing. In other words, the cost of a task may be greater for individuals predisposed to experiencing anxiety [10]. The theory proposes that anxious individuals allocate additional processing resources to implement compensatory strategies designed to improve performance. According to Owens et al. [6], this advantage is possible for individuals with cognitive resources - such as high working memory in their study - to compensate for or cope with the negative effects of anxiety. This is why the Attentional Control Theory (ACT), an extension of PET, predicts that the repercussions would be more likely to manifest when cognitive functions requiring attentional control are engaged [7,8]. The primary functions concerned by ACT are executive functions (EF). They allow for guiding, controlling, and regulating actions and behaviors essential to learning and daily tasks [9]. The anxiety has an effect on these three components [10,11]. Conversely, the central executive, a attentional-limited component in Baddeley's WM model [12], has consistently shown sensitivity to anxiety [8,13,14]. The more specific components of this model, the phonological loop (used for repeating verbal material and temporarily storing it) and the visuospatial sketchpad (used for processing and temporarily storing visual and spatial information), seem to be equally affected by anxiety [15]. Rather than showing a more significant impairment in one of these components, as many studies have sought to demonstrate - see [16,17], Moran's meta-analysis [15] indicated that anxiety appeared to affect the shared variance of the two components more. This shared variance would rely on a single general factor known as the central executive. Kane et al. [18] found that complex span tasks, such as remembering both a series of numbers while solving math problems, were based on a general factor of WM, while simple tasks, like recalling a list of unrelated words, relied on specific factors correlated with the WM factor. Therefore, it is necessary for the tasks used to involve attentional control in order for anxiety to have a significant and detrimental effect. In this regard, Moran [15] highlights a more pronounced effect on measures of complex span tasks in which simultaneous processing of the items to be remembered is preceded or followed by concurrent activity [19]. Simpler tasks, such as digit span, which do not involve simultaneous processing, would only rely on storage and repetition of the elements to be remembered, making them less sensitive to anxiety.

1.2. Attentional Control Theory and measurement

At first glance, simple tasks may seem less relevant for research protocols focusing on the evaluation of ACT. However, ACT has primarily been studied at an algorithmic level rather than a reflexive level. Toplak et al. [20] sought to understand and explain the existing differences in measures of executive functions (EF). Drawing on Stanovich's framework [21,22], they propose that questionnaire-based assessment of EF may reflect an individual's goals, beliefs related to those goals, and the choice of rational action based on goals and beliefs (the reflexive level). Tasks assessing EF performance allow for the observation of information processing mechanisms (such as information coding, perceptual encoding, long-term memory, etc.) (the algorithmic level). Both levels of thinking are likely to be engaged by the compensatory strategies of ACT when a specific goal is given.

A study by Cécillon et al. [23] has shown some initial interesting findings. They suggest an impact of the reflexive level on the amplification of trait anxiety, which would explain the consequences on problematic behaviors related to EF and academic outcomes in adolescents. Although they did not measure EF performance, the authors concluded that overreliance on the reflexive level to compensate for performance in anxious individuals could lead to cognitive resource depletion, thus increasing the manifestation of these problematic behaviors as reported by parents in daily life. In this regard, Stanovich [25] emphasizes that Type 2 processes (reflexive and algorithmic) are slow, require a great deal of attention, and interfere with our thoughts and actions compared to Type 1 processes (referring to automatic and less costly processes). Compensatory strategies can manifest from both an algorithmic perspective - through a reorientation of information processing - and a reflexive perspective - through changes in goals or beliefs related to one's performance. In other

words, ACT states that effects of anxiety on performance can be observed in certain tasks, such as demanding complex span tasks. Conversely, simple span tasks that require minimal attentional resources should not be affected by trait anxiety. However, the contribution of Stanovich's theory suggests that the repercussions of anxiety could also be visible at a reflexive level, which may not be directly observable in performance itself. Currently, ACT theorists propose that if no performance differences are observed between anxious and non-anxious individuals, other indicators are available to account for the additional processing cost, such as increased response time, heightened conflict monitoring after errors (detected by a high amplitude of the Error-Related Negativity signal), higher error rates, etc. [24]. Here again, ACT considers behavioral indicators as if compensatory strategies only pertained to the algorithmic level.

1.3. Executive function and emotion regulation

Previously, we discussed the involvement of anxiety in executive functions (EF). In their literature review on EF, Baggetta and Alexander [9] note that EF are cognitive processes that also involve the socio-emotional domain. The most influential model that considers this domain is the one proposed by Zelazo and Cunningham [25]. They postulate the existence of distinct pathways that work together depending on the presence or absence of emotions in information processing. "Cool" executive functions are used when individuals face abstract and decontextualized problems. "Hot" executive functions are engaged in tasks requiring emotion regulation to achieve a goal or when the individual is actively involved and motivated in the task. ACT predicts that if the task is non-demanding or lacks clear objectives, anxious individuals will have little motivation to use attentional control mechanisms. However, for demanding tasks with specific objectives, the level of motivation would be high [2,6]. It is in these cases that anxious individuals would extensively employ compensatory strategies. According to this hypothesis, tasks that are most sensitive to anxiety are, by extension, those that engage "hot" executive functions and emotion regulation. Compensatory strategies may be represented, in part, at a reflexive level, by conscious attempts to reduce unpleasant emotions experienced during the task to improve performance. This field was extensively investigated on the basis of conscious emotion regulation strategies (ERS) by developing the Cognitive Emotion Regulation Questionnaire (CERQ) [26]. In this questionnaire, certain strategies are considered adaptive, such as refocus on planning or acceptance, and other maladaptive, such self-blame or catastrophizing. While this binary distinction has been criticized and updated by Ford et al., it remains useful for highlighting thought patterns that may influence the maintenance of anxiety or performance in tasks involving executive functions [27]. ERS have consistently been associated with psychopathology, specifically anxiety. The meta-analysis by Aldao et al. revealed that maladaptive ERS (rumination, avoidance, and suppression) were associated with greater psychopathology, while adaptive ERS (acceptance, reappraisal, and problem-solving) were associated with lower psychopathology across various psychological disorders [28]. Maladaptive ERS showed a stronger association with psychopathology compared to adaptive ERS, with the exception of problem-solving. Different associations were observed between mood disorders such as anxiety and depression, and externalizing disorders (substance use and eating disorders), suggesting that the use of ERS may have different effects on behaviors or emotions. Significant associations between adaptive and maladaptive ERS and symptoms of anxiety and depression were also described in another meta-analysis conducted with adolescents [29]. A Japanese meta-analysis examining the CERQ and its relation to anxiety (8 studies) and depression (16 studies) confirmed previous findings [30]. Some strategies yielded unexpected results, such as blaming others and acceptance, which were positively associated with anxiety and depression. Although the direction of the relationship was as expected, blaming others had the smallest absolute value. Regarding acceptance, Wilson suggests that it can be actively applied as a form of self-assertion or passively as a form of resignation [31]. Consequently, the questionnaire is sensitive, particularly regarding this strategy, to how each individual conceptualizes acceptance. Despite the limitations of this tool and the binary conceptualization of ERS, they are likely to be involved in the relationship between anxiety and EF. McLaughlin et al. demonstrated that emotional dysregulation could be the cause of anxiety

rather than the reverse [32]. ERS may act upstream of anxiety. However, these conclusions should not be overgeneralized. While their study has robust internal validity, the questionnaires used limit the generalizability of their findings [23], especially in relation to our study. We suggest continuing to conduct correlations rather than regressions until further studies have been conducted incorporating additional tools. Regarding the link between ERS and Executive Functions (EF), several studies have shown significant correlations between ERS and EF as assessed by parents [23,33]. These studies found that adolescents reporting the use of maladaptive ERS (except for blaming others) were more likely to exhibit problematic behaviors related to EF, as evaluated by the Behavior Rating of Executive Function (BRIEF) [34,35]. Conversely, adaptive ERS were correlated with less problematic behaviors, except for positive refocusing and reappraisal. Most studies have focused on the influence of cognitive abilities on emotion regulation [36]. Studies on WM suggest that individuals with low updating capacity may have depleted most of their executive resources, making it difficult for them to regulate their emotional experiences effectively [37,38]. In this regard, Barkus's recent literature review [39] reveals that the increased rejection of maladaptive ERS could be explained by a greater WM capacity. However, the results were more mixed regarding the influence of WM on the choice of adaptive ERS [39]. In fact, the development of adaptive ERS is not necessarily linked to greater EF capabilities [40,41]. For example, Veloso and Ty showed that training in emotional WM was associated with a decrease in trait anxiety, but it did not improve ERS [42]. The authors argue that training individuals to divert their attention from emotionally salient stimuli and focus on task-relevant information may indeed impact some ERS processes, but not the ones examined in their study (reappraisal and suppression). These findings complement those of Pe et al. [37], who suggested that effective updating abilities can preserve cognitive resources for emotion regulation. Some researchers have also attempted to characterize the direction of the relationship between EF and ERS. One of the few studies that investigated the influence of emotion regulation on EF provided evidence that inhibition, but not switching, was more strongly engaged during emotion regulation, leading to interference with the task [43]. Considering ACT, this suggests that emotion regulation should be considered when studying the relationship between anxiety and EF performance. However, from a reflective perspective, it would be interesting to determine the thought processes that drive individuals to choose maladaptive ERS rather than adaptive ones when attempting to regulate emotions.

1.4. Metacognitive beliefs

Wells [44] proposed a theory and therapy aimed at addressing thoughts that may exacerbate or maintain mood disorders, including anxiety. According to Wells, there is a metacognitive thinking mode that leads individuals to view mental events, perceptions, or emotions as separate from themselves. In contrast, the object mode encourages individuals to see these elements as integral to themselves [44]. These specific thinking styles influence individuals to use strategies to regulate their thoughts and feelings. In the object mode, individuals adhere to certain metacognitive beliefs that perpetuate and exacerbate biased threat evaluation. For example, positive belief in worry, such as "I need to worry in order to work well," encourages vigilance toward threatening stimuli, while beliefs about thought control, such as "If I did not control a worrying thought, and then it happened, it would be my fault," prevent individuals from changing their perspective. It is worth noting that the latter example can significantly contribute to the use of maladaptive ERS, such as self-blame in the CERQ. Other negative beliefs, such as "My worrying could make me go mad," are likely to increase feelings of danger significantly and persistently. The Metacognitive Knowledge Questionnaire (e.g., MCQ-65) [45] was developed to assess these beliefs, as well as lack of confidence in one's cognitive resources and awareness of one's thoughts. In adults, this scale has been highly effective in explaining the propensity to experience anxiety (explaining 83% of the variance) [50]. Some findings show that the subscale of negative metacognitive beliefs (MCneg) is consistently linked to various symptoms, including anxiety, in both clinical and non-clinical populations [46–48]. Similarly, the global scale and MCneg predict the use of maladaptive ERS or emotional dysregulation in several studies with healthy individuals [23,49–51]. In contrast, positive metacognitive beliefs and the Consciousness scale

have less pronounced effects than the other subscales [23,52–54]. The studies by Mansuetto et al. [55] and Laghi et al. [56] highlight that the Consciousness scale had an inverse relationship with emotional dysregulation. In other words, focusing attention on one's thoughts was associated with better emotional regulation. Cécillon et al. [23] demonstrated in French adolescents that the Consciousness scale predicted the use of both maladaptive and adaptive ERS. The authors concluded that being aware of one's thoughts prompts individuals to choose ways to regulate their emotions that may not necessarily be maladaptive. Like Sica et al. [57], they propose revising this subscale to emphasize the negative aspects of excessive and rigid consciousness to better represent the object mode advocated by Wells [44].

1.5. *Present study*

Given these different reflective variables - metacognitive beliefs and ERS - we believe that all tasks are likely to reflect the impact of anxiety on information processing efficiency. However, measurement does not necessarily occur at the behavioral level as proposed in ACT. Eysenck et al. [2] describe compensatory strategies at an algorithmic level, which is not independent of the reflective level [58]. The reflective level partly involves conscious thoughts and strategies that individuals may have during the task. Our study aims (1) to extend the findings of Cécillon et al. [23] to another population and (2) to observe the influence of the reflective level on the algorithmic level in ACT theory. Therefore, we selected a task that minimally or does not require attentional control. The digit span task seemed to be a good candidate since it is frequently used in neuropsychological and speech therapy test batteries. It has been extensively studied but gradually overshadowed by tasks deemed more complex and better suited for assessing EF. Comprising multiple subtests, some researchers or clinicians may consider forward digit recall as assessing short-term memory, while backward recall may require more attention, making it a complex span task reflecting both the phonological loop and the central executive of WM [59,60]. Schmeichel [61] reported that backward span was sensitive to reduced executive capacity following previous executive control efforts. He concluded that inhibition, used to test executive control, relied on an underlying capacity shared with information updating. However, St Clair-Thompson and Allen [62] conducted a comparative study of these two tasks and concluded that backward recall behaved more like a simple span task, with relatively minimal additional processing required only during the recall stage. This is consistent with similar findings [63]: forward and backward span reflect the same cognitive capacity. As suggested by Schmeichel's study [61], adding a sequencing task to the digit span (e.g., ascending order sequencing) could make the total score more representative of complex WM, but evidence does not support this [64]. Ultimately, clinicians have limited indications of WM with the use of digit span as a reference measure. As suggested by Grégoire [60], scores obtained on Wechsler tasks need to be carefully interpreted by the clinician to draw valid conclusions about the individual's cognitive functioning (p.11). The score itself, on the tasks administered in clinical settings, only reflects a partial reality that is far more complex. Thus, the Wechsler scales, including the digit span task, possess a richness that is currently difficult to quantify. Aware of this challenge, we attempted to measure the subject's conscious processes during the task through their spontaneous verbalizations and by questioning them at the end of the task. We hoped to establish correlations between the questionnaires and the decisions made during the tasks to understand the influence of reflective processes on algorithmic processes. We tried to assess the subject's awareness of their efficiency, changes in strategies employed during the task, and the number of strategies used. Unfortunately, the first two could not be fully evaluated as participants had difficulty quantifying their sense of efficacy and the changes for each subtest. Prior notification to participants to focus on these internal processes would have compromised the administration of the task. However, we wanted to be able to extrapolate the implications of the measured variables on this task to the context of psychological or speech therapy assessments. We do not anticipate any impact on digit span performance, but it is highly likely that we may observe repercussions at the reflective level: the strategies used during the task.

To compare the results obtained on the digit span task and considering that ACT predicts larger effects on demanding tasks or tasks with high emotional load, we adapted a computerized emotional

N-back task described as very difficult by the authors [37]. They were hesitant to use response time (RT) in the N-back task as a measure of subject capacity. They explained that studies using RTs have average accuracy scores above 80% [38,65], while their accuracy rate was .59 (SD = .13) for Study 1 and .67 (SD = .14) for Study 2. Besides processing verbal and emotional stimuli, it was highly likely that participants would experience unpleasant emotions that needed regulation due to the difficulty of the task. The task itself provides a true measure of hot EFs because (1) emotion regulation is necessary to achieve a specific goal and/or (2) the emotional information to be processed requires the activation of neural circuits involved in emotion processing. Moreover, N-back tasks can provide a wealth of information about how a person makes decisions and mobilizes their capacities. Meule [66] argues that accuracy score and RT are not interchangeable and provide non-redundant information. Additionally, he expresses dissatisfaction about the fact that omissions (not pressing a button) and commissions (making an error by clicking the wrong button) are not consistently utilized. According to him, the correlates vary between these two pieces of information, and each of them provides complementary data. Consistent with ACT, we expect that trait anxiety may explain longer response times in the N-back task with repercussions on performance. We will also explore its impact on commissions and omissions. Making an error can be due to multiple reasons such as interference. In this case, preceding words with different emotional valences can create proactive interference and lead to commission errors due to a lack of inhibition or impulsivity. Conversely, the subject may have difficulties in retrieving information, resulting in omission errors due to retroactive interference. An additional error could be an emotional salience bias. Words with positive or negative emotional valence may have different emotional salience, meaning that they can attract the subject's attention more. Numerous studies on trait anxiety have shown the presence of attentional bias towards negative information [71]. Errors can also be caused by WM overload, which can result in confusion (commission) or forgetting (omission). Given the limited information we have on digit span sequencing and this emotional N-back task, we will take advantage of the concurrent use of these two WM tasks to examine correlations between different variables, detailing the scores obtained for forward, backward, and ascending order series.

2. Materials and Methods

2.1. Sample

The study initially included 126 students, but after excluding 9 for incomplete tests, 4 non-native French speakers, 1 due to a neurological operation, and 2 for misunderstanding task instructions, the final sample comprised 110 students aged 18-28 ($M = 20.127$, $SD = 2.103$), with 67.27% female. Most were from Lyon 2 University (68.18%) and Catholic University of Lyon (25.45%), including psychology students. Predominantly undergraduates (90%), 10% were in master's programs. Eleven reported cognitive or affective characteristics. The University Grenoble Alpes ethics committee approved the study, and all participants gave informed consent (CERGA-2022-25).

2.2. Procedure

The entire experiment took place over a period of 6 months, from November 2022 to April 2023. Participants were recruited directly on campus. They were all volunteers and did not receive any rewards or course credits for their participation. Participants performed the digit span task, derived from the Wechsler Adult Intelligence Scale - 4th Edition (WAIS-IV) [68], which was administered by an experimenter, and the computerized emotional n-back task, adapted from Pe, Raes, and Kuppens [37]. The average duration of the session was 25 minutes. Subsequently, participants were invited to complete the questionnaires online at home. All questionnaires were completed within a maximum interval of one month after the task session. To avoid order effects, the tasks alternated between participants. The digit span task was administered 55 times initially, and the n-back task was administered 57 times.

2.3. Measures

2.3.1. Emotional n-back.

Participants completed the emotional n-back task, which measures emotional information updating. This task was adapted from Pe, Raes, and Kuppens [37], who themselves adapted it from Levens and Gotlib [65]. Pe et al. [37] used words instead of faces as stimuli. The material provided by the authors was translated from Dutch to French using a back-translation verification process. When there were doubts about the translation, we relied on the Affective Norms of English Words list [69] originally used. Like Pe et al. [37], we listed the 47 positive words and the 49 negative words in a table, describing their valence, number of letters, and number of syllables, see supplementary materials. One term was updated: "Malaria" was changed to "Covid". The task consisted of 24 training trials and 96 actual trials, divided into 4 blocks of 24 trials. The first two trials of each block were not scored, leaving 88 trials for our analysis. Specifically, each trial involved the presentation of an emotional word in the center of the screen for 500 ms, followed by an inter-trial interval of 2500 ms. Participants were instructed to press the "1" or "2" key if, respectively, the valence of the current word matched the valence of the word two trials ago (match) or if the valence did not match (non-match). There were 44 match trials, equally divided between negative and positive valence stimuli (22 trials each), and 44 non-match trials (21 trials were positive valence stimuli, meaning that the current stimulus was positive but the stimulus two trials later was negative). Pe et al. [37] used average accuracy scores for all trials as the main measure rather than response time due to the difficulty of the task. To improve precision, we also calculated commission errors (pressing the incorrect key) and omission errors (not pressing any key).

2.3.2. Digit Span Task.

Participants completed three subtests of the digit span task: recalling number series in the same order (forward), in reverse order (backward), and in ascending order (sequencing). Numbers were presented at one per second, and participants repeated them, following procedures in the administration manual [68]. Raw scores, maximum digits recalled, and age-relative standard scores were recorded. Participants' strategies (e.g., subvocal repetition, visualization) were noted and scored, with a total strategy score calculated for each. Intuitive recall without a specific strategy was scored as 0.

2.3.3. Online questionnaires

The questionnaire included consent forms, questions about age, sex, and education level. The last 4 digits of their mobile phone number were also requested to link the responses to the results from the laboratory tasks. We then administered three self-reported questionnaires.

2.3.3.1. Trait anxiety

Trait anxiety were assessed using the State Trait Anxiety Inventory version Y (STAI) [70] in its French version adapted by Gauthier and Bouchard [71]. This scale measures trait and state anxiety. We specifically used the assessment of trait anxiety. It consists of 20 items rated on a 4-point Likert scale with the following choices: 1 = Almost never, 2 = Sometimes, 3 = Often, 4 = Almost always. The scale includes reversed items. In the French version, Cronbach's alphas range from .90.

2.3.3.2. Emotion regulation strategies

Emotion regulation strategies were assessed using the Cognitive Emotion Regulation Questionnaire (CERQ) [26] which was used in its validated French version [72]. The CERQ is a self-report questionnaire that assesses 9 cognitive strategies used to regulate emotions in response to negative or unpleasant events [26]. A total of 36 items are rated on a Likert scale ranging from "almost never" (1) to "almost always" (5) and are divided among these 9 strategies: Acceptance (A; "I think I should accept that it happened"), Positive Refocusing (PR; "I think about more pleasant things than

what I have experienced"), Planning (P; "I think of a plan regarding the best way to handle it"), Positive Reappraisal (PR; "I think I can become a stronger person because of what happened"), Putting into Perspective (PP), Self-blame (SB; "I feel that I am to blame for what happened"), Rumination (R; "I keep thinking about how awful the situation was"), Catastrophizing (C; "I often think that what I experienced is the worst thing that can happen to someone"), and Blaming Others (BA; "I feel that ultimately others are to blame for what happened"). This questionnaire has been validated in a population aged 13 to 19 years. Participants are instructed to reflect on their thoughts when experiencing negative or unpleasant events. In the French version, Cronbach's alphas range from .68 to .87 for all factors.

2.3.3.3. Metacognitive beliefs

Metacognitive beliefs were assessed using the Short MetaCognition Questionnaire (MCQ-30) [73] which was used in its validated French version [74]. This questionnaire consists of 30 items evenly distributed across 5 factors: Positive metacognitive beliefs (MCpos factor), Beliefs about uncontrollability and danger (MCneg factor), Beliefs about cognitive competence (Lack of Confidence factor), Negative beliefs about thoughts related to superstitions, punishment, and responsibility (Control factor), and Cognitive self-consciousness (Consciousness factor). In this questionnaire, participants are asked to rate the statements on a 4-point Likert scale ranging from "Not at all agree" to "Completely agree". For each factor, the score can range from 6 to 24, and the minimum total score ranges from 30 to a maximum of 120. In the French version, Cronbach's alphas range from .72 to .93 for all factors.

3. Results

3.1. Data analyses

We conducted numerous additional analyses to replicate the findings of Cécillon et al. [23]. To maintain the primary focus of this article, we opted to include these analyses along with the discussion of their results in the supplementary material. It is made available at [location]. These results demonstrate differences in the expression of anxiety, the use of emotion regulation strategies, metacognitive beliefs, and working memory utilization between boys and girls. Hence, we controlled for sex in all our analyses. The complete dataset is available on the Mendeley Data website at [10.17632/z4fdg43ynn.2], reference number [75].

3.2. Trait anxiety

3.2.1. ERS and trait anxiety

A correlation matrix was conducted between trait anxiety and emotion regulation strategies (Table 2). Sex was controlled for these correlations. Maladaptive ERS showed a strong correlation with trait anxiety, as did the sub-scales, except for Blaming Others. On the other hand, adaptive ERS showed weaker and non-significant correlations with anxiety. Only the sub-scales Positive Refocusing and Positive Reappraisal were significantly, but weakly, associated with trait anxiety compared to Self-blame and rumination.

Table 2. Pearson correlations between emotion regulation strategies and trait anxiety.

Variables	ERSm	ERSa	A	PRef	RP	PRea	PP	SB	R	C	BO
STAI	.569**	-.169	.037	-.231*	-.037	-.241*	-.079	.594**	.459**	.290**	-.072

Conditioned on variables: sex. ERSm = Emotion Regulation maladaptive Strategies; ERSa = Emotion Regulation adaptive Strategies; A = Acceptance; PRef = Positive Refocusing; RP = Refocus on planning; PRea = Positive Reappraisal; PP = Putting into Perspective; SB = Self-Blame; R = Rumination; C = Catastrophizing; BO = Blaming others. * $p \leq .016$ ** $p \leq .002$.

3.2.2. Metacognitive beliefs and trait anxiety

This linear regression analysis allowed us to examine the influence of metacognitions on participants' anxiety while controlling for participants' sex (Table 3). It revealed that a high metacognition score predicted 21.34% of the variance in anxiety.

Table 3. Multiple regression analysis of metacognitions predicting anxiety.

Variables	β (SE)	t(ddl)
Metacognition Score	.462 (.061)*	7.589 (107)
Positive Metacognitive Beliefs	-.235 (.153)	-1.539 (104)
Negative Metacognitive Beliefs	1.431 (.173)*	8.251 (104)
Lack of Confidence	.209 (.140)	1.487 (104)
Control	.486 (.169)*	2.868 (104)
Consciousness	.198 (.167)	1.188 (104)

Conditioned on variables: sex. * $p \leq .005$.

As done previously, we conducted a supplementary regression analysis to determine the most influential subscales (Table 3). The "negative metacognition" scale was the strongest predictor of anxiety, followed distantly by the "control" scale. On the other hand, the influence of positive metacognitions, the "awareness" factor, and the "lack of confidence" factors were not significant. Although not significant, positive beliefs negatively predicted participants' anxiety.

3.3. Correlations between metacognitive beliefs and emotion regulation strategies

A Pearson correlation matrix was conducted to determine the strength of the associations between metacognitions and ERS (Table 4). Maladaptive ERS positively correlated with all subscales of the MCQ. However, the significance threshold was not reached for positive metacognitive beliefs. The strongest correlations were found between negative beliefs, the control factor, and the consciousness factor. Adaptive ERS showed weak and non-significant negative correlations with negative metacognitions, the lack of confidence factor, and the control factor. Positive metacognitions were positively correlated, but the correlation was not significant. However, the consciousness factor showed a significant positive correlation with adaptive ERS.

Table 4. Pearson correlations between metacognitions and SRE.

Variables	Maladaptive ERS	Adaptive ERS
Positive beliefs	.118	.121
Negative beliefs	.458**	-.026
Lack of Confidence	.218*	-.062
Control	.410**	-.121
Consciousness	.342**	.215*

Conditioned on variables: sex. * $p < .05$ ** $p < .001$.

3.4. Relation between Working Memory tasks

Before proceeding with further analyses, we present the descriptive statistics of our variables (Table 5). The accuracy score of the n-back task falls within the range of Pe et al.'s study (Study 1: $M = .59$ and $SD = .13$; Study 2: $M = .67$ and $SD = .14$) [37]. Commission scores were calculated by summing all errors per participant and dividing the total by the number of trials. Omission scores were calculated by summing the trials with no response and dividing by the total number of trials. A Student's paired-samples t-test revealed that commission scores were significantly lower than

omission scores, indicating that participants made more omission errors than commission errors ($t = 7.269$; $df = 109$; $p < .001$).

Table 5. Descriptive statistics of Working Memory tasks.

Working Memory Tasks		n (missing)	Mean	SD	Min	Max
Digit Span	Total score	110	9.518	2.566	4.00	17.00
	Strategies	109 (1)	2.358	.866	1.00	5.00
	Accuracy	110	.65	.119	.375	.966
	RT	110	1423.50	292.52	705.98	1999.32
	Omission	110	5.661	7.755	.00	39.773
	Commission	110	.283	.090	.034	.50
n-back	POE	110	.058	.091	.00	.50
	NOE	110	.048	.083	.00	.417
	PCE	110	.271	.150	.00	.667
	NEC	110	.375	.194	.00	1.00
	ETO	110	.053	.078	.00	.375
	ETC	110	.323	.134	.00	.708

Conditioned on variables: sex. RT = Response Time; Strategies = number of strategies used during the Digit Span Task.

We also separated the commissions and omissions made due to proactive interference on sequences alternating emotional valences (negative word - positive word - negative word or positive word - negative word - positive word). We thus isolated the 24 responses containing this type of sequence from the other 88. For each participant, we calculated an average for the number of commission errors and omission errors, which we named Emotional Total Commission error (ETC) and Emotional Total Omission error (ETO). We also subdivided the 24 sequences by differentiating between positive sequences (positive word - negative word - positive word) and negative sequences (negative word - positive word - negative word) to assess potential emotional salience biases. For each participant, we calculated an average for the number of negative commission errors (NCE), positive commission errors (PCE), negative omission errors (NOE), and positive omission errors (POE).

We conducted paired-samples t -tests to determine if there were differences between ETC and ETO compared to total commission errors and total omission errors. Participants had significantly more ETC than commission errors ($t = 4.936$; $df = 109$; $p < .001$). In other words, sequences that contained alternating emotional valence words resulted in more commission errors than other sequences. Conversely, participants had more omission errors than ETO ($t = -7.647$; $df = 109$; $p < .001$). They were therefore more likely to not respond during sequences where emotions were not alternated.

We conducted a correlation matrix to analyze the relationships between the two tasks. For the n-back task, commission and omission errors were strongly and significantly correlated with task accuracy (Table 6). Each of these errors showed an inverse relationship with response time (RT). Omissions significantly increased RT, while commissions tended to decrease RT ($p = .081$). For the digit span tasks, correlations were very strong and significant with the total score. However, correlations between the two tasks were weak but significant. The number of strategies employed during the tasks (Strategies) was not correlated with the total score or the digit span tasks. In terms of correlations between the tasks, commission errors were correlated with all indicators of the digit span tasks. The weakest correlations were observed with the forward task and Strategies. Although to a lesser extent, task accuracy was also correlated with all tasks and the total score, except for

Strategies. Lastly, RT was correlated with the total score and the backward task. The correlation with the Sequencing task did not reach the threshold of significance ($p = .90$).

Table 6. Pearson correlations between working memory tasks.

Variables	n-Back			Digit Span				
	Accuracy	RT	Omission	Com	Total score	Strategies	forward	backward
RT	-.074	—						
n-Back								
Omission	-.614**	.295**	—					
Commission	-.736**	-.159	-.067	—				
Total score	.358**	.156	-.036	-.445**	—			
Strategies	.127	.033	.084	-.224*	.109	—		
Digit span								
Forward	.215*	.028	-.094	-.213*	.706**	.109	—	
Backward	.261**	.192*	.050	-.389**	.753**	.079	.377**	—
Sequencing	.279**	.124	-.036	-.329**	.705**	.078	.233*	.301**

Conditioned on variables: sex. RT = Response Time; Com = Commission; Strategies = Number of strategies used during the digit span task. * $p < .05$ ** $p \leq .006$.

3.5. Relation between Working Memory tasks and main variables

A Pearson's correlation matrix (Table 7) was conducted to assess the relationships between our main variables while controlling for the effect of sex. Metacognitions were correlated with maladaptive ERS and STAI. Higher levels of metacognitions in students were associated with higher trait anxiety and greater use of maladaptive ERS. Metacognitive beliefs were also correlated with RT and omission scores in the n-back task. Participants with stronger metacognitive beliefs had longer RTs and higher rates of omissions. Maladaptive ERS were correlated with trait anxiety, RT, and the number of strategies employed during the digit span task. In other words, individuals using maladaptive ERS were more likely to have higher trait anxiety, longer RTs, and employ more strategies during the digit span task. More precisely, rumination and catastrophizing were positively and significantly correlated with the number of strategies employed (respectively, $r = .255$; $p = .008$ and $r = .227$; $p = .018$). Self-blame and blaming others showed no correlation. A significant negative correlation was found between maladaptive ERS and commission scores. Trait anxiety was positively correlated with RT in the n-back task but was not correlated with other indicators of working memory performance. However, trait anxiety was close to a significant correlation with adaptive ERS ($p = .079$), omission scores ($p = .052$), and emotional omission scores ($p = .064$). Omission scores were also close to a significant correlation with maladaptive ERS ($p = .060$) and adaptive ERS ($p = .052$).

Table 7. Pearson correlations between main variables.

Variables	MCQ	ERS		STAI
		Maladaptive	Adaptive	
ERS				
Maladaptive	.519**	—		
Adaptive	.038	-.066	—	
STAI	.592**	.569**	-.169	—
Accuracy	-.103	.050	.064	-.096
RT	.195*	.308**	-.120	.205*
n-Back				
Commission	-.040	-.214*	.058	-.017
ETC	-.068	-.151	.004	-.005
Omission	.200*	.181	-.187	.187
ETO	.296**	.191*	-.138	.178
Digit span				
Total score	-.103	.040	.004	-.034
Strategies	-.000	.263**	.012	.014

Conditioned on variables: sex. ERS = Emotion Regulation Strategies; ETC = Emotional Total Commission error; ETO = Emotional Total Omission error; RT = Response Time; Com = Commission; * $p < .05$ ** $p \leq .006$.

We also explored the possibility of the presence of an attentional bias toward threatening stimuli. While controlling for sex, we conducted correlations to determine if our reflective variables

(metacognitive beliefs, trait anxiety, adaptive and maladaptive ERS) were correlated with NEC, PCE, POE and NOE (Table 8).

Table 8. Pearson's correlations between commissions, omission and main variables.

Variables	MCQ	ERSm	ERSa	STAI
ETO	.296**	.191*	-.155	.178
POE	.266**	.154	-.126	.127
NOE	.266**	.193*	-.122	.197*
ETC	-.068	-.151	.004	-.005
PCE	-.050	.038	.049	-.035
NCE	-.056	-.238*	-.032	.021

Conditioned on variables: sex. ETC = Emotional Total commission errors; ETO = Emotional Total omission errors; NCE = Negative commission errors; PCE = Positive commission errors; NOE = Negative omission errors; POE = Positive omission errors; MB = Metacognitive beliefs; ERSm = Maladaptive Emotion Regulation Strategies; ERSa = Adaptive Emotion Regulation Strategies * $p < .05$ ** $p \leq .005$.

Table 8 reveals distinct correlations between our three main variables (MB, ERSm, and STAI). MB showed a strong positive and significant correlation with omission scores. ERSm was correlated with the total omission score, specifically with NOE. STAI was also significantly and exclusively correlated with NOE. The correlations of ERSa were all non-significant but showed an inverse relationship with ERSm for omission scores. Finally, only ERSm exhibited a significant negative correlation with NEC. In other words, individuals using ERSm made fewer commission errors on sequences involving alternating emotional valences that required a negative response. As before, to understand the inappropriate strategies that were involved in the correlation with commissions, we conducted a new correlation for each of the strategies. The results show that catastrophizing and rumination were negatively associated with negative commissions (respectively, $r = -.182$; $p = .059$ and $r = -.226$; $p = .018$). Self-blame and blaming others showed no correlation.

4. Discussion

The first objective of the present study was to verify and generalize the findings from Cécillon et al.'s [23] study regarding the reflective dispositions - metacognitive beliefs and ERS - that may influence trait anxiety levels. The second objective was to observe the impact of these dispositions on WM performance, reflecting the algorithmic level. ACT proposes that anxious individuals should use compensatory strategies during tasks to adjust their performance, which would impact processing efficiency. This additional cost has been consistently described at the algorithmic level in terms of behavioral measures [2], but has not been extensively studied to understand the influence of the reflective level on this aspect, in line with Stanovich's theory [21]. This study aimed to shed new light on the ACT in relation to this aspect.

4.1. Trait anxiety, metacognitive beliefs and ERS (reflexive level)

Our data replicate and confirm similar results to those of Cécillon et al. [23]. Metacognitive beliefs, maladaptive ERS, and trait anxiety were strongly interrelated to an equivalent extent. Specifically, trait anxiety was found to be correlated with the subscales of maladaptive ERS, except for blaming others. Additionally, adaptive ERS were weakly correlated with trait anxiety, with only two of the subscales, positive refocusing and reappraisal, showing significant correlations, while the others exhibited no correlation. The absence or weakness of correlations for adaptive ERS and blaming others has been noted in several studies [28–30,76,77]. We do not reiterate all the conclusions and proposed solutions from Cécillon et al. [23] here, as the aim of this study was to extend their findings to a different population. The main difference in results was the presence of correlations between anxiety and the positive refocusing and reappraisal subscales. Aldao and Nolen-Hoeksema

[78] propose that adaptive ERS are more context-dependent than maladaptive ERS. They observe greater inter-situational variability in the implementation of acceptance and problem-solving. This increased variability suggests that the use of adaptive strategies is influenced by a more flexible evaluation of different contextual situations. Instead of a random approach where individuals non-systematically and uniformly try different adaptive strategies, they appear to adopt a more targeted and tailored approach based on specific variations in each context. Therefore, it is entirely normal in our study to not observe correlations between all adaptive ERS, such as acceptance, and anxiety. Conversely, the implementation of maladaptive ERS showed low variability, suggesting their comparable usage across situations. This explains the more consistent results observed in most studies.

Our findings are consistent with those of Cécillon et al. [23] and previous literature on metacognitive beliefs, maladaptive ERS, and trait anxiety. Metacognitive beliefs were found to predict participants' trait anxiety. The MCneg and control subscales were the only ones that significantly predicted anxiety, with a larger effect size for MCneg. The other three factors did not show significant associations. Nordhal et al. [50] also reported a similar correlation between MCneg, control, and anxiety, but they found additional weaker yet significant correlations for the other factors. Given the replicability of our results in adolescents and young adults, these differences could be partly explained by cultural bias and differences in the interpretation of certain beliefs. Interestingly, the MCpos factor negatively predicted anxiety. Like the consciousness factor, MCpos was correlated with both adaptive and maladaptive ERS. However, the correlation with maladaptive ERS, like the consciousness factor, was not significant but proportionate. These results align with Cécillon et al. [23], who found a significant correlation between MCpos and maladaptive ERS. This suggests that considering worry as something that could help predict the future (MCpos) is not necessarily negative or likely to amplify anxiety. Like the consciousness factor, MCpos may be a way to direct behaviors toward adaptive or maladaptive ERS. However, a recent meta-analysis on healthy adults and individuals with psychopathology revealed that the combined effects were reliable for all four scales of the MCQ, but the positive metacognitive beliefs subscale was unstable or even nonsignificant [79]. Benedetto et al. [53] suggested that positive metacognitive beliefs could be considered an effective coping strategy. In our previous study with adolescents, we concluded that they did not seem to be effective since they were positively correlated with maladaptive ERS. The current findings partly support this hypothesis by indicating that positive metacognitive beliefs can play a determining role, albeit less important than the consciousness factor, in individuals' inclination toward the use of adaptive or maladaptive ERS. The changes observed in the MCQ may be due to cultural factors as well as age-related factors. Irak [54] demonstrated a significant age effect on MCpos. Significant differences observed between different school years suggested that the development of MCpos could be influenced by factors related to the cognitive and emotional development of children and adolescents. Similarly, a study on French-speaking adolescents [80] showed that MCneg, MCpos, and consciousness factors significantly increased between the ages of 13 and 17. However, it is important to note that the age effect in Irak's study, although significant, was relatively small, suggesting that other factors may also contribute to the variation in MCpos beyond age alone. Unfortunately, studies specifically examining age and other factors related to the MCQ that may explain such variations are limited. These findings should be considered when interpreting future studies using the MCQ on healthy samples. It is likely that in samples with emotional disorders, the consciousness scale would be correlated with psychopathology, as predominantly maladaptive emotion regulation strategies would be used. As suggested by Sica et al. [57] and Cécillon et al. [23], it may be beneficial to rephrase the items of this scale to highlight a more negative aspect of excessive and rigid consciousness, which would make the questionnaire more discriminant.

4.2. Working memory (algorithmic level)

4.2.1. Emotional n-back.

Regarding the n-back task, our results were reassuring as the average accuracy rate was equivalent to those reported in two studies by Pe et al. [37] that also utilized the task. The low accuracy rate indicates that the task was highly challenging compared to similar tasks [38,65], which achieved accuracy scores above 80%. Meule [66] emphasized the importance of considering multiple aspects of the n-back task, including accuracy, omission and commission rates, and response times, as they can provide different insights. Our findings support this perspective, revealing significant associations between omission/commission scores and accuracy, although no significant relationship was found between omission and commission scores themselves. Additionally, the relationships between omission and commission scores and response times (RT) were different. Commission errors showed a negative correlation, although not significant ($p = .081$), suggesting that these errors are not necessarily associated with inhibition deficits or impulsivity. In contrast, omissions were positively and significantly correlated with RT, indicating that participants took longer to respond when they omitted a response. These results highlight that the commission score is minimally associated with response time compared to omission errors in our study. Commission and omission errors provide different and non-redundant information. We also hypothesized that proactive interference might lead to impulsive responses in participants. However, our results showed that response time (RT) was minimally correlated with commission errors, challenging this hypothesis. This suggests that commission errors are not necessarily related to inhibition deficits or impulsivity but may be influenced by other factors. Furthermore, when specifically examining sequences where positive and negative emotional valences alternate, we found that the alternation of emotional valences was associated with more frequent and regular commission errors. This observation suggests the presence of emotional interference in the decision-making process, where emotional stimuli can disrupt performance and increase commission errors. It is possible that this emotional interference captures participants' attention more strongly and leads them to make more errors when processing contrasting emotional stimuli. This interpretation may explain the higher frequency of total omission errors compared to emotional omission errors. Emotional alternation of responses may increase cognitive load and engage participants' attentional resources more, thereby facilitating the production of responses. In contrast, in sequences without emotional alternation, where emotional valences remain constant, the cognitive load and attention may be lower, increasing the risk of total omission errors. These findings highlight the complexity of interactions among emotions, attention, and decision-making. Commission errors may be influenced by emotional interference, while omission errors may be influenced by the emotional salience of stimuli. Further research is needed to ensure the validity of these conclusions.

4.2.2. Digits span

It is important to note that the total standard score of the Digit Span task was close to the average, but some values could be considered as deficient or exceptionally high. We chose to keep all the data, considering it representative of the student population in our sample. The correlation matrix (Table 5) revealed strong positive correlations between the three tasks of the Digit Span from the WAIS and the total score. This indicates that high performance in each individual task of the Digit Span is generally associated with a higher total score. However, it is important to note that the three tasks of the Digit Span showed weak correlations with each other. This suggests that the specific skills required to succeed in each task may differ, despite all of them sharing a component of digit memory. The specific correlations reveal that the backward task is strongly correlated with the forward task, confirming the findings of Jaeggi et al. [81]. This suggests a close relationship between these two tasks, likely limited to the recall phase [62]. However, the correlations remain weak, indicating the presence of distinct processes beyond this phase. Additionally, the backward task also shows relatively high correlations with the sequencing task. However, the sequencing task and the forward task have the weakest correlation among the three tasks, implying that they may be more influenced by specific and distinct factors. Some researchers consider the digit manipulation tasks (backward task) as an active component of WM, while the forward task is seen as more passive [59,60]. Other researchers consider the two tasks as similar with minimal differences [62,63]. At this stage, our data

on the Digit Span alone do not allow us to conclude about the involvement of these three tasks in WM. Nevertheless, they suggest differences in the processes involved in each task. For example, Wisdom et al. [82] showed that the digit repetition sequence was inherently unique, as its age-related dispersion pattern behaved differently from the forward and backward tasks. It seems to provide distinct information that has not yet been fully understood. Additionally, Lumpkin and Sheerin [83] demonstrated that the digit span sequencing task was as relevant as the backward task in predicting neurocognitive impairments [84,85]. The specific factors responsible for these differences are not yet fully understood, and further research is needed to explore and identify them. One possible explanation that we propose is that the digit span sequencing task may more strongly engage and rely on the "mental number line" [86]. This mental representation of numbers is organized linearly in our minds. When performing the sequencing task, we not only have to remember the presented sequence of numbers but also order them in a certain sequence based on their respective positions. This requires a linear mental representation of numbers, that is, the ability to mentally place the digits in a sequential order. In contrast, the other two tasks may not rely as much on this cognitive representation as they do not require the same level of linear organization of numbers in WM. Thus, the use of the mental number line in the digit span sequencing task could be a key factor contributing to the observed variations between the tasks. This is a speculative hypothesis that warrants further investigation to substantiate and validate this idea. To partially address the question of the specificity of the mechanisms involved in each task, a comparison with the emotional n-back task could provide further insights. Furthermore, our study focused on the reflective level (conscious processes leading to decision-making based on beliefs and goals) and its impact on WM tasks. This perspective adds additional elements to understand the underlying processes involved in performing these tasks as will be discussed below.

4.2.3. Digit span and emotional n-back.

Regarding the links with the Digit Span task, the accuracy score was correlated with all variables of the Digit Span, except for the number of strategies employed during the task. The strongest correlation was with the total score of the Digit Span, followed by the Sequencing task, Backward task, and then the Forward task. A previous study found correlations between the Digit Span and accuracy on various n-back tasks using auditory, visuospatial, and mixed (simultaneous auditory and visuospatial) materials [81]. The correlations they reported were like ours (.21 to .30), which aligns with the results of the meta-analysis by Redick and Lindsey [87] on this topic. Interestingly, these correlations were only significant for 3-back tasks, indicating a high cognitive load. This confirms that the n-back task used in our study had a high cognitive load. Redick and Lindsey [87] propose that both the backward digit span task and the n-back task require temporal reorganization of information. In the backward task, participants need to update the position of elements in memory, while in the n-back task, they need to modify the position of previously encoded elements. According to them, this similarity in the reorganization process may explain the stronger correlation between the n-back task and backward digit span compared to other complex verbal span tasks or forward digit span.

We propose that the sequencing task shares more similarity with the n-back task in terms of the sequential aspect of information processing. Regular updating occurs as information is presented to the participants [88]. It is interesting to note that only the backward task was specifically associated with a significant increase in response time in the n-back task. In other words, individuals who were more efficient in the backward task took more time to make a decision in the n-back task. They also made significantly fewer commission errors. This correlation could explain the longer response time. Having higher abilities in the backward task may lead to increased precision in the provided responses. These individuals may be less prone to proactive interference caused by the different words and emotions encountered in the n-back task. They may achieve greater precision by taking more time to resolve conflicts present in memory and make more accurate decisions. In contrast, the overall weak correlation between the two tasks can be explained by the content and different processes involved. On one hand, the Digit Span task is performed with auditory, neutral, and

numerical materials with a verbal response, while the n-back task uses visual, emotional, and textual materials with a motor response. On the other hand, the n-back task may rely on processes of emotional recognition or interference resolution, while the Digit Span task requires retrieving specific information or manipulating the memorized digits during recall [62,89].

Our study provides new information on the correlations between the Digit Span tasks, including the rarely studied sequencing task, as well as omission and commission errors in the emotional n-back task. Omission errors did not show any significant correlation with the Digit Span tasks. However, the commission score exhibited a stronger, significant, negative correlation with all variables of the Digit Span compared to accuracy. The strongest correlation was with the total score of the Digit Span, followed by the Backward task, Sequencing task, and weakly with the Forward task and Strategies. We believe that commission scores provide new insights into information processing (the algorithmic level) and decision-making processes (the reflective level). For example, participants who made fewer commission errors were those who employed more strategies during the tasks. At a minimum, this suggests that individuals seeking optimization of their performance in the Digit Span task were the ones making fewer commissions in the n-back task. These individuals may be particularly motivated to succeed in the task and pay more attention to what they need to do. This could lead them to respond less systematically and more accurately. However, neither the accuracy score nor the omission score showed a significant correlation with Strategies. Another possible explanation is that the use of strategies may also occur during the n-back task in a search for greater efficiency. This emphasizes the importance of considering the reflective level to understand what these tasks can measure. Although we received qualitative feedback on the implementation of strategies during the n-back task, we did not quantify these observations. Future studies should focus on developing means to verify the observed link. Importantly, while the influence of strategies on the Digit Span tasks was minimal, the opposite was observed for the n-back task. It is possible that the use of verbal material with meaning may depend more specifically on the reflective level than other types of material. The interference of the reflective level may be more significant in this case. This hypothesis has long guided anxiety theorists in differentiating visual and verbal content, seeking to demonstrate the greater impact of anxiety on verbal material [16]. Furthermore, Redick and Lindsey [87] found higher correlations when complex span and n-back tasks both used visuospatial content and weaker correlations when the content was verbal. We believe that visuospatial tasks are more likely to reflect algorithmic information processing processes, while verbal tasks may be more involved in both levels, especially if emotional content is related to the material.

4.3. Attentional control theory: reflexive and algorithmic levels

Our results confirmed our hypotheses that trait anxiety would influence RT in the n-back task. Although the correlation was weak, it was still significant, suggesting that anxious individuals tend to have longer response times. In other words, the cost of processing associated with the use of compensatory strategies is manifested in the additional time required to achieve optimal performance. Given the emotional nature and difficulty of the task, we had anticipated that anxiety might impact performance. According to ACT, it is expected that anxiety may have more negative effects on the demand and emotional load of a task, due to higher processing costs. Accuracy was not correlated with anxiety levels, but omission scores approached the threshold of significance ($p = .052$). Participants reporting high anxiety tended to have more omissions. These omissions may explain the longer response times of anxious individuals. Several interpretations are possible for the omissions. ACT proposes that compensatory strategies employed by anxious individuals may incur an additional processing cost, which is reflected in behavioral measures such as longer response times [24].

Our results also indicate that interference is not due to the processing of emotional valence, as correlations are nearly identical between total omission score and emotional omission score. It is therefore conceivable that interference stems from an overload of WM and the inability to retrieve relevant information, resulting in prolonged response times and more omission errors [90]. Similar findings were observed for metacognitive beliefs. However, correlations were stronger for omission

scores, particularly emotional omissions. These results may explain some of the findings related to anxiety. Metacognitive beliefs emphasize the role of worrisome, repetitive, and negative thoughts that may amplify or maintain anxiety. Thoughts such as "I must not worry" could complicate the process of information retrieval in WM and decision-making. This may be especially true when emotional sequences alternate, creating greater confusion. There was no difference between alternating sequences requiring a negative or positive response. However, omissions were more pronounced for anxiety, as well as maladaptive ERS, on negative response sequences, indicating increased sensitivity to those sequences. One possible explanation for this observation is related to the nature of negative stimuli. Negative emotional stimuli, such as threatening or anxiety-inducing stimuli, may have a stronger impact on individuals' emotional and cognitive state. In this regard, a study revealed that anxious individuals exhibited delays in disengaging from threatening cues, resulting in slower responses to non-targets. These delays in disengagement were interpreted as difficulties in shifting attention away from the cues rather than an initial bias towards the cues themselves [91]. This is a common characteristic among our three variables.

In contrast, it is interesting to note that only maladaptive ERS were negatively correlated with negative commission errors. This may result from increased focus on negative stimuli and reduced accuracy in detecting positive or neutral stimuli. In other words, individuals may be more sensitive, precise, and demanding regarding negative stimuli, resulting in fewer commission errors and more omissions. This interpretation is supported by the observed links between maladaptive ERS and the number of strategies employed in the digit span task. The more individuals use maladaptive ERS, the more strategies they employ. We proposed that increased use of strategies could reflect a significant investment by individuals in the task, with a desire to succeed and effectively mobilize their abilities. These individuals may also be more prone to having negative or worrisome thoughts during the digit span task. Interestingly, the correlations found between maladaptive ERS, negative commission errors, and the number of strategies were specifically related to dramatization and rumination. These maladaptive ERS tend to increase the salience of negative stimuli, one through amplification and the other through repetition. This dynamic may explain the negative correlation observed with negative commission errors and the positive correlation with an increased number of strategies. Indeed, these maladaptive ERS are associated with the unpleasant situation, which may trigger the need to enhance performance by generating more strategies. Conversely, self-blame or blaming others is associated with the cause of the unpleasant situation. These strategies would not encourage a proactive approach in seeking solutions. Dramatization and rumination could be considered mechanisms that elicit the use of costly compensatory strategies in ACT.

4.4. Limitations

The study's stability, aligned with Cécillon et al. [23] and broader literature, supports its internal validity. Observations across diverse groups (adolescents, young adults) suggest good external validity. However, the focus on French-speaking, highly educated populations may limit broader applicability, especially considering cultural sensitivity in certain processes like ERS [92].

The study utilized n-back and digit span tasks, differing significantly yet sharing underlying processes, as evidenced by reflective variables such as ERS_m. While only two of many methods to assess working memory (WM), the study's aim wasn't to evaluate these tasks' representation of WM but to show trait anxiety's impact on them, irrespective of their executive function loading. The n-back task focuses on emotional recognition, and the digit span on simpler memory span tasks.

We can also question the relevance of the tools used. Despite criticisms of assessing unclear concepts [93] and potential overlap with depression [94], STAI is supported by its proven reliability, ability to differentiate anxiety types, and numerous validations [71,95]. Our results are reassuring as they show convergences consistent with the literature. For example, the MCneg subscale of the MCQ has been consistently linked to trait anxiety in many studies [45,73,74], specifically to pathological worry [96], a central component of anxiety. Our results largely support these findings and allow us to consider the STAI as a reliable tool for assessing vulnerability to anxiety.

Improvements might involve revised questionnaires following our suggestions and additional tasks for enhanced robustness and broader insights. This preliminary study, examining numerous variables, warrants cautious interpretation. Additionally, we did not clearly distinguish between hot and cold executive functions, as the tasks were significantly different in content and administration modalities. Lastly, no causal links were established to determine the primacy of reflective variables (ERS and metacognitive beliefs) on anxiety. However, we consider these variables to be part of the predispositions to experience trait anxiety and believe they should be evaluated alongside the current restricted form of trait anxiety. The interplay between these variables is so intertwined that it seems impossible to evaluate one without considering the presence of the other.

5. Conclusions

This study aimed to (1) understand the mechanisms of trait anxiety and its correlates and (2) assess the influence of the reflective level on working memory (WM) within the theoretical framework of ACT. Our results highlight the complexity of interactions between trait anxiety, attention, WM, and decision-making processes related to metacognitive beliefs and Maladaptive Emotion Regulation Strategies (ERSm). Firstly, the overall variables and their correlations share strong similarities with the study by Cécillon et al. [23] conducted on an adolescent population. Some subscales showed particularly strong correlations with trait anxiety, such as ERSm, while others reliably predicted anxiety, such as MCneg. The relevance of subscales like "blaming others" (CERQ) and "conscience" (MCQ) has been discussed in the context of evaluating anxiety. Secondly, this study highlights the importance of considering both the reflective level (beliefs and strategies) and the algorithmic level (task performance) to understand the underlying mechanisms of cognitive performance in the context of ACT. A decrease in commission errors or an increase in omission errors (algorithmic level) were associated with anxiety, but more prominently with metacognitive beliefs and SREs (reflective level). SREs, such as catastrophizing and rumination, were also linked to strategy use in digit span and a reduction in negative commission errors, indicating heightened sensitivity to negative stimuli and an attempt to succeed in the task at all costs. This study also underscores the need for further research to deepen our understanding of these processes and their interactions within the framework of ACT.

Supplementary Materials: The following supporting information can be downloaded at: CECILLON, François-Xavier (2023), "Study 2023", Mendeley Data, V2, doi: 10.17632/z4fdg43ynn.2

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