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REVIEW ARTICLE

Components of hot and cold executive functions and their relations to different forms of stress resilience: A systematic review

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Abstract

Increasing evidence points out that Executive Functions (i.e., EFs) may be core mechanisms for the generation of resilient responses to adversity. A systematic review testing the relations between either affective (hot) and/or non-affective (cold) EFs (i.e., inhibition, flexibility and working memory updating) and resilience was conducted. A total of 449 articles were initially identified. After two steps of title-and-abstract ($k = 449$), and full-text reading filtering ($k = 67$), 11 studies were reviewed. Three studies included cold measures of working memory and supported significant positive relations between higher working memory functioning and higher trait resilience levels. One study included cold measures of inhibition and another one both hot and cold measures, with only the first one supporting a positive relation between more efficient inhibition and higher trait resilience levels. Finally, 7 studies measured flexibility in its cold and/or hot dimensions and overall supported significant relations between higher flexibility and higher levels of trait, process and outcome resilience measures. These results support the role of EFs performance to promote different forms of resilience. This review allows to identify different issues that need to be addressed in future research and highlight the need to integrate the analysis of all hot and cold EFs components to understand their role in the generation of resilience.

KEYWORDS
executive functions, flexibility, inhibition, resilience, working memory

1 | INTRODUCTION

1.1 | Cognitive mechanisms of risk versus resilience for stress-related disorders

Stress has become a common experience in people's everyday life. Stress is considered a normal response to situational pressures or demands, whose physical (e.g., increased heart rate, accelerated breathing) and psychological consequences (e.g., feelings of fear or anxiety, behaviours of active coping with or avoidance away from the stressor) may vary depending on the individual interpretation of such stressful situation as more threatening or dangerous (e.g., Biggs et al., 2017). Such reactions to transient stressors are considered natural responses to such adverse events, with an evolutionary value, as they allow individuals to respond and adjust to the environmental demands they find in their daily lives (Park & Fenster, 2004). Thus,

such adaptive reactions to stress are normally considered as resilient responses (Bonanno & Burton, 2013). However, a continuous exposure to stress-inducing situations, resulting in maintained stress reactions, can have deleterious effects for people's physical and psychological homoeostasis (Baum et al., 1983; Hapke et al., 2013). A sustained exposure to stressful events that surpasses one's abilities to cope with them may facilitate the development of stress-related mental disorders such as depression and anxiety, among others (Schmidt et al., 2008). These stress-related disorders, together with other typical stress-related psychopathologies such as Post-Traumatic Stress Disorder (PTSD) and burnout, are highly prevalent and represent some of the main current causes of impairment for people's health worldwide (WHO, 2021).

Given the increasing incidence of these problems and the urge for new effective interventions to treat them, researchers have oriented their interest in understanding the mechanisms that underlie the onset and maintenance of stress-related disorders (see, for instance, Goodwin et al., 2018; Pacheco et al., 2022; Sanislow et al., 2020). In this line, a considerable amount of research has been conducted during the past decades to identify dysfunctional patterns of cognitive processing contributing to the risk to develop stress-related disorders such as depression and anxiety (Ingram & Price, 2001). Among those cognitive processes, there is already a large body of research that supports the negative effects of cognitive control dysfunctions in the generation of biased affective processing and increased risk to develop stress-related psychopathology (Quigley et al., 2020). Thus, Executive Functions (EFs), have been proposed as key cognitive control mechanisms that, when altered, may contribute to the onset and maintenance of depression, anxiety and other stress-related psychopathologies in the face of sustained stress.

EFs can be understood as high-level processes that enable goal-oriented behaviour, involving organisation, sequencing, anticipation, decision-making and flexible adaptation of our cognitions, emotions and behaviours towards different novel and challenging situations (Ardila, 2008; Diamond, 2006). The study of EFs has been extensively done through the conceptualisation of the unity/diversity model proposed by Miyake et al. (2000), that differentiate among three main components of EF: **updating working memory (WM)**, defined as the capacity of replacing mental representations of information that are no longer useful for new information that is more relevant to respond to current internal or external personal demands; **inhibition**, referred to the capacity to block out information that is hampering the cognitive system and is irrelevant to respond to the current situation and/or needs of the individual; and **flexibility,** defined as the ability of adapting one's cognitive processing resources to changes in internal or external demands and thus being able to shift such cognitive resources to process the current demands more relevant to fulfil one's personal goals.

An increasing number of studies have been conducted during the last years supporting that hindered performance in tasks recruiting these three EFs, is related to the onset and maintenance of anxiety and/or depressive disorders in response to stress (e.g., Deveney & Deldin, 2006; Koster et al., 2005; Murphy et al., 2012; Snyder et al., 2014; Visu-Petra et al., 2013; Warren et al., 2021; Wen & Yoon, 2019; Yu et al., 2020). Following Miyake et al. (2000), deficits in each of the three EF components have been described in relation to the occurrence of stress-related disorders. First, it has been consistently demonstrated that WM updating is impaired in depressed individuals (Joorman & Tanovic, 2015; Levens & Gotlib, 2010; Nikolin et al., 2021; Villalobos et al. al., 2021), and that such deficits in WM capacity are also related to core anxiety symptoms, such as worry, which has been found to interfere with the processes required for maintaining recent incoming information in WM (Moran, 2016). Furthermore, inhibition deficits have been demonstrated to be common in stress-related problems of both depression and anxiety. Empirical studies have shown that both higher depression and anxiety levels are associated with higher interference in the ability to ignore irrelevant information that is no longer useful for a goal-oriented performance (e.g., Joormann & Gotlib, 2010; Warren et al., 2021). Additionally, research also highlights that these inhibition deficits present in stress-related disorders are more pronounced in relation to the inhibition of emotional information with a negative valence than for the inhibition of neutral information with non-emotional valence (De Lissnyder et al., 2010; Falquez et al., 2016; Joorman et al., 2015), and that may take the form of difficulties in disengaging attention from negative information (see, for instance, Koster et al., 2005; Sanchez et al., 2013). Further, it has been observed that the habitual use of rumination and worry, which are common predictors of increased risk to develop depression and anxiety, respectively (Feng et al., 2022; Ho et al., 2018; Sanchez-Lopez et al., 2019a), are also associated with these deficits in inhibitory control of both internal and external negative information (Beckwé et al., 2014; De Lissnyder et al., 2010). Finally, there is consistent evidence demonstrating that deficits in flexibility are also related to the onset and maintenance of depression and anxiety disorders. Specifically, it has been shown that individuals with both high depression and anxiety levels are characterised by consistent difficulties in regulating and adjusting their behaviour according to the demands of the context, as well as higher costs for adequately switching their attention towards new relevant information when situational demands change (De Lissnyder, et al., 2010; Deveney & Deldin, 2006; Murphy et al., 2012; Stange et al., 2017; Wen &Yoon, 2019; Yu et al., 2020).

In sum, abundant evidence has demonstrated that the three components of EFs proposed by Miyake et al. (2000) can be affected in individuals with depression and/or anxiety and that impaired functioning of those EFs can increase the risk to develop such psychological problematics in the face of stress (e.g., Feng et al., 2022; Sanchez-Lopez et al., 2019b). Importantly, most of the previous studies have analysed those EFs components individually, with some exceptions providing important initial integrative conceptualizations for the analyses of EFs in relation to psychopathology (see Snyder et al., 2015). Some recent efforts have also been made to provide an integrated analysis of existing evidence on the contribution to EFs to vulnerability to stress-related disorders. For instance, a recent

systematic review and meta-analysis has gathered existing evidence from studies that have considered components of EFs individually, integrated in Miyake's et al. (2000) unity/diversity model in relation to depression (Quigley et al., 2022). In this systematic review and meta-analysis, Quigley et al. (2022) demonstrated that disturbances in EFs, particularly those ones occurring in the processing of negatively valenced stimuli, are present in both currently and remitted depressed patients. This suggests that different forms of EF, in relation to the type of information that must be processed, either affective or non-affective, could play differential roles in the risk to develop stress-related disorders, such as depression. Such distinction between the processing of affective versus non affective information has been addressed previously and is also important to advance knowledge on the different role of different forms of EFs to contribute to the risk of stress-related psychopathologies. In this sense, EFs have been distinguished as either 'Cold', referring to those cognitive abilities or capacities that are associated with EFs, such as inhibitory control, WM updating or cognitive flexibility, when used under conditions of processing of neutral information, or 'Hot', referring to those abilities when used in the context of processing of emotional information (e.g., Tsermentseli & Poland, 2016).

Overall, there is already a large body of knowledge that has shed light in the understanding of EFs deficits that can contribute to the onset of stress-related disorders. However, less is known regarding the understanding of processes in this cold and hot EFs that might help individuals to prevent the occurrence of these forms of psychopathologies in the face of stress. Also, there are current claims (e.g., Miret et al., 2015; Schönfeld et al., 2017) that point out a necessity to understand the cognitive processes that promote more integrative forms of resistance to stress, including not only reduced symptomatology, but also preserved wellbeing and life-satisfaction in the face of adverse events (i.e., any life event that involves a significant demand or threat to an individual and require a significant change in the individual's life pattern and adaptive or coping behaviour; Schönfeld et al., 2017). For instance, in the context of resilience against the development of depression in face of adverse events, some authors argue that a marker of lower risk for these problematics would include not only an adequate ability to down-regulate associated negative moods, but also a capacity to sustain positive moods that facilitate adaptive functioning (e.g., Waugh & Koster, 2015). Thus, a new relevant and promising research venue comprises understanding how different EFs in its different cold and hot dimensions may facilitate adaptive responses and stress resilience.

1.2 | Resilience: A unique phenomenon? Different conceptualizations and approaches for its study in relation to EF mechanisms

A central concept of positive adaptation to stress is **resilience**. Resilience has been conceptualised in different forms, such as the ability to flexibly adapt to one's contextual demands (Bonanno & Burton, 2013), as the capacity to resist to psychopathology in the face of stress (Ingram & Price, 2001) and as the process to enable positive adaptation despite the experience of adversity or trauma (Luthar, 2006). Thus, the study of EFs promoting resilience to stress may be an additional strategy to identify protective targets of mental health in the face of stress and adversities, rather than solely focussing on the specific EFs forms that confer risk for psychopathology (Kalisch et al., 2015, 2017). To fulfil that purpose, in the present work we consider the study of the different forms of EFs (i.e., WM updating, inhibition, flexibility; either referring to cold and hot EF dimensions) in relation to variables of resilience, which have been conceptualised through different types of frameworks and definitions, as discussed below.

The conceptualisation of resilience has been conceptually changing across the last decades. Resilience was first conceptualised as a series of **trait** stable characteristics of some individuals. This approximation states that resilience is mainly determined by certain personal characteristics that would predispose some individuals to have a faster and/or more effective adaptation to stress, thus assuming a stable and innate nature of resilience (Block & Block, 1980; Connor & Davidson, 2003; Ong, et al., 2006; Southwick et al., 2014). Among other resilience factors, previous research has identified individual personal factors such as the ability to reappraise situations, experience positive emotions, seek meaningful social support or approach situations through active coping as important markers of trait resilience (Gloria & Steindhart, 2016; Gooding et al., 2012; Mecha et al., 2023; Riepenhausen et al., 2022). These trait-oriented resilience factors are measured through self-reported questionnaires such as the Connor-Davidson Resilience Scale (CD-RISC) (Connor & Davidson, 2003), or the Resilience Scale (Wagnild & Young, 1993). Although there is evidence that individual differences in these measures of personal resilience factors are related to positive indicators of mental health (e.g., Färber & Rosendahl, 2020; Hu, et al., 2015), this trait-oriented perspective has several limitations. First, research has shown that personal factors are only one of many risk or resilience factors involved in maintaining or regaining mental health in the face of adverse events (e.g., Bonanno & Diminich, 2013; Luthar et al., 2000). Furthermore, researchers have argued that this trait-oriented perspective is a too static view of resilience and that there is a need to shift towards conceptual and methodological approaches that understand resilience as a more inter- and intra-individual dynamic process (Chmitorz et al., 2018; Kuldas & Foody, 2022). This dynamic perspective refers to the study of processes and outcomes underlying resilience functioning, which can vary for different individuals in the face of different types of stressor or adversities (Kalisch et al., 2017, 2019). Consequently, this view gave rise to understanding resilience as an outcome and/or as a process of positive responses to adverse events.

The **outcome-oriented approach** understands resilience as the maintenance of mental health and/or positive outcomes despite the current or recent exposure to stressful or adverse events (Fergus & Zimmerman, 2005; Kalisch et al., 2015, 2017). For this conceptualisation of resilience, the existence of exposure to a stressful

or potentially adverse event (e.g., job-loss, examination periods, health issues, etc.) that can surpass one's cognitive and emotional resources is key. Higher resilience outcomes would be reflected by the fact that, despite the occurrence of such stressful or adverse experiences, the individual reports high levels of mental health (i.e., low depression/anxiety symptom levels and/or high well-being levels; Chmitorz et al., 2018). Additionally, to provide operative measures of outcome-resilience, Kalisch et al. (2015) proposed a framework of assessment of stressor load, referred to the quantification of stressors in a cumulative manner. Concretely, these authors proposed that in order to achieve quantitative indices of outcome resilience, cumulative stressor load between two temporal moments (T1 and T2) should be addressed as a sum score of stressors (ΣS) accumulated between T1 and T2. A similar quantification should be then done of the difference in mental health levels from T1 to T2. In that way, it would be possible to quantify how an individual is more resilient at T2, the less that the person develops mental problems or reduced well-being between T1 and T2, in proportion to the accumulated stressor load from T1 to T2. This approach allows to control for heterogeneous time differences between individuals' experiences in mental health outcomes, despite differential ΣS levels (Kalisch et al., 2015), making possible to analyse how hypothetical resilience mechanisms preceding that temporal period (e.g., better executive performance at T1) might ameliorate effects of ΣS on the change in mental health outcomes.

Finally, a **process-oriented approach** of resilience, refers to the dynamic capacity of adapting successfully in the face of adversity, trauma, or significant threat across time (Kalisch et al., 2019). From this view, resilience can be better understood on a time continuum and as potentially changeable across life periods (Bonnano et al., 2015; Horn & Feder, 2018; Kalisch et al., 2019). This perspective conceptualises resilience as a dynamic process of regaining, relatively early, high mental health (i.e., low depression/anxiety symptom levels and/or high well-being) levels after the onset of a stressful or adverse experience (Chmitorz et al., 2018). This process approach of resilience is based on the use of longitudinal designs to obtain multiple self-reported measures of mental health in at least two or more different temporal times (i.e., depression, anxiety and/or PTSD scales administered in T1, T2, T3…) following the occurrence of a stressor or adversity. Such longitudinal designs inform on the trajectories of mental health adjustment following a potentially adverse situation (Galatzer-Levy et al., 2018) and performance in EFs at T1 can be considered as potential predictors of differences in mental health trajectories (e.g., maintained mental health and/or faster return to mental health levels existing before the occurrence of the stressor).

As it can be seen, resilience can be conceptualised in multiple ways for which different EF processes might act as mechanisms with different contributions. However, most of the extant research has to date only considered the study of EF impairments that make some individuals more vulnerable to suffering stress-related psychopathologies like depression and/or anxiety following adversities (vulnerability paradigm). Although relevant, this perspective is limited to the study of cognitive deficits (e.g., impaired EF functioning) and does not include the study of non-impaired or 'adaptive' cognitive functions, thus, leaving an area of knowledge underexplored (i.e., to understand how different EFs may contribute to different forms of resilience). Despite this, complementary to the traditional vulnerability paradigm, there is a current increasing interest in advancing the study of hot and cold EFs that may contribute to resilience, in its different forms. For instance, there are already some studies that have proven associations of better cold executive functioning and higher resilience in older adults as well as in individuals suffering from disorders such as cancer (Gordon et al., 2022; Kaufman et al., 2021). As for research on the relations between EFs and resilience in adults, considering the different mental-health indicators of resilience, initial research has been conducted, yet no review of the state-of-the-art on this issue has been conducted. This is important, as a systematic review and integration of existing evidence on these associations can provide a clear understanding of how different EFs (e.g., hot and cold EFs) may facilitate resilient functioning and protect against stress-related psychopathologies and inform new interventions to promote them (Koster et al., 2017; Sanchez-Lopez et al., 2019a). Given this, the present systematic review aimed to provide an integrative analysis and discussion of the extant evidence on the relations between the performance of the abovementioned three EFs components in its cold and hot dimensions and the three defined forms of resilience (i.e., trait, process, outcome).

1.3 | The current study

Given the necessity to advance an integration of current evidence on the influence of EFs in resilience the face of stress and the practical implications that this might have for the development of new interventions and trainings of EFs to promote resilience, the present study provides a systematic review and integrative analysis of the extant empirical evidence on the role of EFs as predictors of resilience variables. Specifically, we analysed current empirical evidence on the relations between the components of EFs proposed by Miyake et al. (2000) (i.e., inhibition, updating WM and flexibility), both in their cold and hot forms, and individual differences in measures of trait resilience, as well as their potential role as predictors of forms of resilience after the exposure to adverse events (i.e., outcome and process resilience).

Accordingly, several hypotheses were formulated. Overall, we expected to find significant positive relations between a better performance in the measures of EFs and resilience levels in one or more of the three forms considered in this review. That is, it was expected that better executive functioning would positively predict higher levels in each of the three forms of resilience included in the review. To date, there is consistent evidence showing that poor EF functioning in its different forms is related to worse mental health levels (see, for instance, Everaert et al., 2017a; Koster et al., 2005, 2017). On the contrary, we expected better performance in EF tasks would

relate to higher resilience levels in their different forms. Besides, we intended to expand the knowledge of these relationships by distinguishing evidence from studies where EFs were assessed comprising the processing of affective versus non-affective stimuli (i.e., differentiating relations for hot and cold EFs, respectively). In general, EFs have been described and studied as purely cognitive non-affective aspects, leaving aside the consideration of how emotions or motivation might affect individual's cognitive performance (Salehinejad et al., 2021). That is, EFs have normally been assessed through tests that decontextualise EFs under non-affective conditions (Tsermentseli & Poland, 2016). Yet, current proposals point to the necessity of differentiating the 'Cold' and 'Hot' dimensions of EFs (e.g., Salehinejad et al., 2021; Zelazo & Carlson, 2012). In the context of research in resilience, there is a specific interest in investigating responses of individuals to emotionally demanding adverse situations and the underlying cognitive processes that enable or hinder a successful recuperation. Thus, it is necessary to consider measures of EFs that involve the processing of affective stimuli. In consequence, in the present review we integrated evidence on the relations between EF performance and resilience levels, differentiating studies that measured cold and/or hot EFs, in order to identify any differences in this relations as a function of the nature of EF assessments, in case that they were found. Based on previous research that has demonstrated differences in the processing of emotional versus non-emotional stimuli in tasks assessing EF components (see Everaert et al., 2017b; Levens & Gotlib, 2010; Quigley et al., 2020; Sanchez et al., 2013; Wen &Yoon, 2019), we expected that differential results would emerge when the studies assessed hot aspects (tasks that included emotional stimuli) compared to cold aspects of EFs (tasks that included neutral non-emotional stimuli). Specifically, higher relations between EFs performance and resilience were expected for tasks comprising the processing of emotional stimuli (hot aspects of EFs), compared to tasks comprising the processing of neutral non-emotional stimuli (cold aspects of EFs).

2 | METHOD

2.1 | Literature search strategy

A systematic review and qualitative analysis of the current empirical evidence on the relation between the three components of EFs (inhibition, flexibility and working memory updating) and trait, process and/or outcome resilience levels was conducted, considering differences in these relations depending on the performance due to the emotional valence of EFs tasks (hot vs. cold EFs). Our systematic review model was based on the rigorous guidelines of the Evidence-Based Practice in Psychology (EBPP), which guarantees the objectivity, systematicity, and replicability of the review process. Furthermore, this systematic review followed PRISMA guidelines (Page et al. 2021). We searched for empirical investigations that had been conducted to study the role of EFs as possible modulators of resilience levels, in their different forms. Accordingly, a search protocol was established and pre-registered in PROSPERO (ID: CRD42022369971), after conducting a preliminary search on studies analysing relations between EFs and resilience, where we pre-established all the specific characteristics and conceptual definitions of the variables under study, and the existing operative measures of each of the variables. This served to define the objectives and hypotheses of the study, as well as to pre-establish the operational search strategy and selection criteria of the systematic review, as presented below.

The search of the systematic review was carried out using PubMed and PsycINFO databases and was completed in June 2023. Based on the information extracted in the previous preliminary review, the key terms used to carry out the main systematic search were organised into two categories: (1) Concept of Resilience, AND (2) Concept of EFs and their components. Therefore, the main search string used was: (resilience OR resilient OR "bounce back" OR "adaptive respon*" OR "adaptive coping") AND ("executive control*" OR "executive function*" OR "executive process*" OR "executive flexib*" OR "cognitive control*" OR "cognitive flexib*" OR "attention* control*" OR "attention* flexib*" OR "cognitive inhibition" OR "response inhibition" OR "working memory" OR shift* OR switch). The selection process was independently conducted by the first and second authors (PM, MM). The full PRISMA flow diagram of this review can be consulted in Figure 1.

2.2 | Inclusion and exclusion criteria

In order to conduct a rigorous selection process, several inclusion/exclusion criteria were established beforehand based on (1) the characteristics of the sample (i.e., participants) and (2) the type of studies that would be considered to be included in the systematic review.

2.2.1 | Participants

- Samples must comprise adults with age ranges between 18 and 65 years. Studies in which mean ages were between 18 and 65 years were discarded, as our aim was analysing normative relations between EF performance and resilience in adulthood, since EF have specific developmental characteristics in infant and older adulthood stages that deserve further specific considerations.

- Studies must include participants that were psychologically healthy (i.e., they did not report any current or past history of mental disorders or were below cut-off scores of the mental health measures used in the studies), since we aimed to analyse EFs

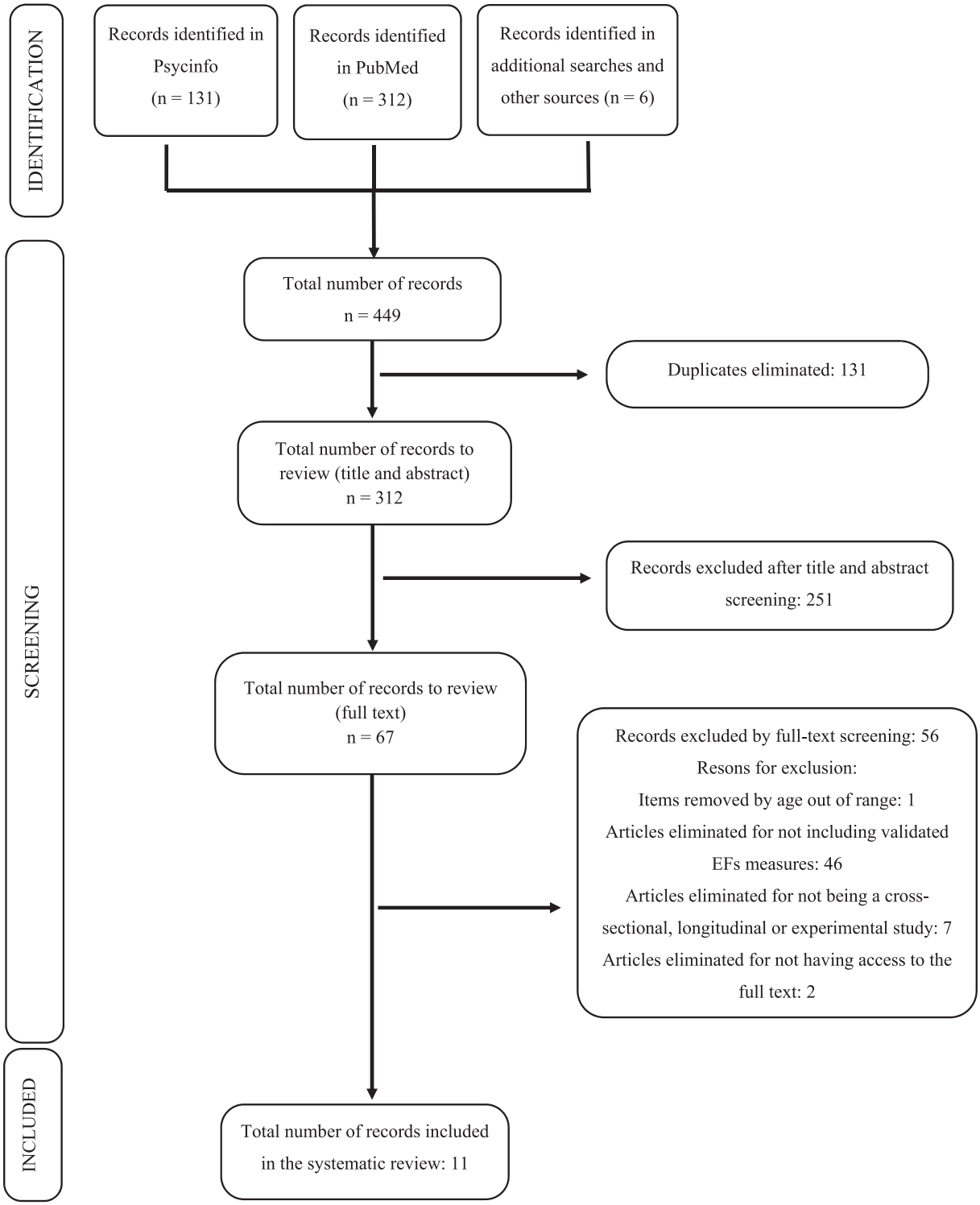

FIGURE 1 PRISMA flowchart depicting the literature search strategy followed.

predictors of resilience in healthy samples (i.e., not having developing mental disorders as result of the experience of stressors or suffering from previous disorders that might affect the interpretations of the results on the hypothesised relations).

- Studies with participants who showed any kind of altered cognitive process (i.e., after traumatic brain injury, neurodegenerative disorders, neurodevelopmental disorders, genetic disorders, severe mental disorders, etc.) were also excluded.

2.2.2 | Type of studies

- Studies in which participants completed any form of currently validated tasks to assess at least one of the three defined components of EFs (i.e., WM Updating, Inhibition, Flexibility), either in versions of cold and/or hot EFs forms.

- Studies must include an assessment of at least one of the three types of defined forms of resilience. For trait-resilience, participants must have completed at least one validated trait-resilience scale (i.e., CD-RISC, RS, etc.). For outcome-resilience, participants must have completed at least one form of validated surrogate mental health measure during or immediately after exposure to an adverse event, allowing to establish indicators of mental health despite the exposure to stressor load (i.e., outcome resilience; Kalisch et al., 2015). For process-resilience, participants must have completed at least one form of validated surrogate mental health measure multiple times following an adverse event and the study had to provide analyses of its trajectory over time. By surrogate measures, we considered those scales that are not validated resilience scales themselves but scales of mental health reflecting the ability to maintain or regain mental health despite the exposure to specific adverse events (i.e., measures of depression, anxiety, negative/positive affect, wellbeing), following the operative definitions of these measures of Chmitorz et al. (2018).

- Cross-sectional studies were included in two cases. First, when EFs-resilience relations were tested considering the relations between individual differences in trait-resilience questionnaires (i.e., Trait Resilience) and performance in one or more EFs assessed at the same time. Second, cross-sectional studies were also considered when they included measures of one or more EFs components and one or more surrogate measures of outcome-resilience referred to mental health measures taken during or after exposure to one or more predefined adverse event/s (study of Resilience Outcomes) at the same time.

- Longitudinal studies were included when one or more assessments of EFs were collected at Time 1 (i.e., T1) followed by at least two temporal measures (i.e., at least T1 and T2) of resilience and/or surrogate measures of resilience referred to mental health measures taken during and/or after exposure to a predefined adverse event (study of Resilience Processes).

- Studies in which participants attended to one or more clinical interventions previous or during the assessment of EFs were excluded. In case that intervention studies reported relations between EFs and resilience measures, only the relations that were not part of the intervention (e.g., naturalistic executive functioning in daily stressful situations) that were collected before the start of the intervention were considered.

- Papers written in a language that was not English were also excluded.

- Finally, protocol or study designs, qualitative studies, case studies, meta-analyses, and review articles, not providing empirical data on EF-resilience relations, were also excluded.

2.3 | Screening and study selection process

A total of 449 articles were initially identified through the databases (see Figure 1). Additionally, 6 articles were identified by other sources (review of bibliographic references of the selected studies, searches of other works made by the authors identified in the main search, and further review of literature in other databases - Google Scholar, Web of Science - using the keywords and established connectors for the main systematic search).

Two independent reviewers (PM and MRM) conducted all the phases screening. The inter-rater agreement was calculated computing Cohen's kappa coefficient. The results showed that inter-rater agreement was good according to Landis and Koch's guidelines (Kappa = 0.73; Landis & Koch, 1977). When there was a mismatch between the two independent reviewers on the eligibility of some of the studies, the third author was consulted (ASL).

To maximise the coverage of all possible results, the aforementioned search string with the main terms was entered into both databases (see Literature Search Strategy). In addition, in both searches the criteria of 'link to the full text' and 'academic publications' were applied. Subsequently, 131 articles were eliminated due to identification of duplicates between both databases, so that 312 records remained to be reviewed. Then, title and abstract screening was carried out resulting in 251 studies being excluded because they did not meet the total of the inclusion criteria (see Inclusion and Exclusion criteria). In this way, 67 records passed the first screening filtering, and considered in the second phase of full-text reading screening. Two articles did not meet the type of sample and age criteria, so they were excluded. Moreover, it was found that 50 of the articles either comprised an intervention study, or not included validated measures of EFs and/or resilience, so they were excluded. It was also observed that 6 of the articles did not use cross-sectional or longitudinal designs to test EF-resilience relations (e.g., studies that included some type of EFs tasks manipulation or intervention), so they were also excluded. In addition, 2 articles also had to be excluded because they did not have access to the full text and could not be accessed after contacting the authors of that work. After the second screening phase, a total of 7 articles were included in the review.

To complement this source of evidence, 6 additional articles were identified to be reviewed by other sources, as mentioned above, and after reviewing them analytically, and following a process similar to that previously described, finally 4 additional articles that met all the inclusion criteria were also selected. Thus, finally, after performing both systematic searches and after including articles from

additional sources, a total of 11 articles testing relations between EF performance and resilience were included in the review.

2.4 | Analysis of potential biases in the review process

In order to maximise the scientific rigour of this systematic review, we aimed to minimise any potential bias that may affect this type of work.

First, regarding the accessibility bias, only 2 articles were eliminated because they lacked accessibility to the full text and could not be accessed through requests to the authors. Furthermore, only 1 article was excluded due to the language barrier, since it was not written in English. Therefore, it can be considered that the limitations that these exclusions entailed were minimal, considering the total number of records identified.

Second, out of the 11 articles included in the review, the number of times that each author appeared cited in the rest of the articles was also analysed, as it can be observed in Table S1 in the supplement. This allowed to analyse a possible bias of authorship, this is, a tendency for the results obtained to be based on the research of a single author or a small number of authors. Out of the 22 names recorded (first and last author of each reviewed paper), 12 were cited in at least one additional article on the list. The authors who were most cited were Jessica J. Genet and Matthias Siemer (4 times each), followed by Rudi De Raedt (3 times). These data indicate that the results may be relatively influenced by the studies conducted by these authors.

Additionally, we analysed a potential bias emerging from the journals in which the studies included in this review had been published. None of the articles included in the review were published twice or higher in the same scientific journal. Thus, there was an appropriate heterogeneity in the journals, as observed in Table S2 in the Supplement.

Finally, in relation to a potential bias referred to the years of publication of the studies, as observed in Table S3 in the Supplement, the selected articles were all published between 2004 and 2022, being 2020 the year in which more articles were published, with a total of 3 articles published in that year. This last data indicates that the reviewed topic (i.e., the relations between EFs and resilience) is relatively recent, with an increasing interest particularly in the last 3 years, as 6 out of the 11 articles reviewed had been published in such time period.

2.5 | Methodological quality of the reviewed studies

In order to assess the methodological quality of the selected articles, the Downs and Black's Checklist criteria (Downs & Black, 1998) were followed. Such assessment was carried out using an 18-item adaptation from the mentioned list, which has been created in accordance with previous systematic review studies in related areas of work (i.e., role of cognitive processes in affective symptom levels; Everaert et al., 2017a; Quigley et al., 2022). In each of the criteria, a 0 was scored when the article did not meet the established criterion, and a score of 1 was used when it met it. Results can be observed in Table 1.

Overall, the average quality of the studies was 0.81 over 1. As observed in Table 1, the quality of the reviewed studies was good, with the item 'A priori *power analysis to determine the required sample*', being the item with the worst scores, and the items '*Clear description of the hypothesis/objective?*', '*Results described previously*', '*Main outcome measures valid and reliable*', '*Statistical tests appropriate* ", '*Main findings described*', '*Estimates of the random variability in data main outcomes*', '*Probability values reported*', the ones with the highest scores.

3 | RESULTS

3.1 | Characteristics of the studies and the analysed variables

As noted above, a total of 11 studies was included in the review (see Table 2 for an overview of all the studies, all their relevant methodological characteristics and a summary of their main results). These articles were published between 2004 (Twamley et al., 2004) and 2022 (Rademacher et al., 2022).

The average sample size of the studies was 118.1 (SD = 121.13) participants. The study of Samuelson et al. (2020) was the one with a higher sample size (N = 473) and the study of Bemath et al. (2020) the one with a smaller sample size (N = 38). As for gender distribution, 63.81% of the participants in the reviewed studies were women. The mean age of the participants in the reviewed studies was 23.96 years (SD = 10).

In relation to the type of resilience measures used in the selected articles, , 8 studies measured resilience as a trait (Afek et al., 2021; Bemath et al., 2020; Genet & Siemer, 2011; Grol & De Raedt, 2018; Otero et al., 2020; Rademacher et al., 2022; Weiland et al., 2012). Two studies included a longitudinal design that measured resilience as a process (Gordon et al., 2022; Samuelson et al., 2020) and one study (Shields et al., 2017) measured resilience as an outcome. As for the 8 studies that measured trait resilience, four of them used the CD-RISC (Afek et al., 2021; Connor et al., 2003; Genet & Siemer, 2011; Otero et al., 2020; Rademacher et al., 2022), and two of them also used the RS (Grol & De Raedt, 2018; Otero et al., 2020). The other four studies measuring trait resilience included different measures in each study, the Resiliency subscale of the California Child Q-Set (Block & Block, 1980; Weiland et al., 2012), the Resilience Research Centre Adult Resilience Measure (RRC- ARM, Ungar & Liebenberg, 2013; Bemath et al., 2020), the Brief Resilience Scale and Resilience Scale for Adults (Friborg et al., 2005; Rademacher et al., 2022; Smith et al., 2008) and the Ego- Resilience Scale (ER89, Block & Kremen, 1996; Genet & Siemer, 2011). As for the

TABLE 1 Methodological quality ratings of the selected studies based on the adapted 'checklist for measuring quality'.

	Author and year/item	Weiland et al. 2012	Bermath et al. 2020	Afek et al. 2021	Gordon et al. 2021	Otero et al. 2020	Rademacher et al. 2022	Shields et al. 2012	Genet & Siemer 2011	Grol & de Raedt 2018	Samuelson et al. 2020	Twamley et al. 2004	M	SD
1	Clear description of the hypothesis/objective?	1	1	1	1	1	1	1	1	1	1	1	1	0.00
2	Results described previously?	1	1	1	1	1	1	1	1	1	1	1	1	0.00
3	Participant characteristics clearly described?	1	1	1	1	1	1	1	0	1	1	1	0.91	0.28
4	Participants are representative of the population?	0	1	1	1	1	1	1	0	1	1	1	0.81	0.38
5	Representative sample size?	0	1	1	1	1	1	1	1	1	1	1	0.91	0.28
6	Clear description of tasks used?	0	1	1	1	1	1	1	1	1	1	1	0.91	0.28
7	Main outcome measures valid and reliable?	1	1	1	1	1	1	1	1	1	1	1	1	0.00
8	Same participant recruitment population?	1	1	0	0	1	0	1	1	1	1	1	0.72	0.44
9	Same recruitment period?	0	1	0	0	1	0	1	0	0	0	1	0.36	0.48
10	Statistical tests appropriate?	1	1	1	1	1	1	1	1	1	1	1	1	0.00
11	Main findings described?	1	1	1	1	1	1	1	1	1	1	1	1	0.00
12	Estimates of the random variability in data main outcomes?	1	1	1	1	1	1	1	1	1	1	1	1	0.00
13	Probability values reported?	1	1	1	1	1	1	1	1	1	1	1	1	0.00
14	Withdrawals and drop-outs reported?	0	1	1	1	-	-	-	0	0	0	1	0.5	0.5
15	Explanation of retrospective data analysis?	0	1	1	0	1	1	0	0	1	0	1	0.54	0.49
16	Adjustments in final data analyses	1	1	1	0	1	1	1	1	1	1	1	0.91	0.28
17	A priori power analysis to determine the required sample?	0	1	0	0	0	1	1	0	0	0	0	0.27	0.44

Note: Item 14 M and SD were computed only with provided data resulting in a $N = 8$ of items computed as done by Everaert et al. (2017).

TABLE 2 List of studies included in the systematic review: Study characteristics and summary of main findings.

Title of the article	Authors and year of publication	Journal of publication	Design of the study	Sample size	Measure of resilience: Trait, outcome or process	Component/s of EFs measured	Measure of EFs used	Hot or cold EFs	Adverse event	Main results
WM updating										
1 Resiliency in adolescents at high risk for substance abuse: Flexible adaptation via subthalamic nucleus and linkage to drinking and drug use in early adulthood.	Weiland, et al. (2012)	Alcoholism: Clinical and experimental research	Cross-sectional	67 adults (38,82% women) Age range: 18–22 years Mean age (SD): 20.2 (1.2)	Resiliency subscale of the California child Q-sort (Block & Block, 1980)	Working memory	n-back task (Callicot et al., 1999)	Cold	Risk of alcohol and drug use	Higher resiliency was correlated with better performance in WM.
2. Working memory and psychological resilience in South African emerging adults.	Bemath, et al. (2020)	South african journal of Psychology	Cross-sectional	38 adults (55,2% women) Mean age (SD): 24.52 (1.65)	Trait resiliece RRC- ARM (Ungar & Lieben berg, 2013).	Updating working memory	Automated working memory assessment (AWMA, Alloway, 2007).	Cold	Group of young adults from South Africa at risk (with a disadvantaged past)	Pearson's correlations results point to indirect positive relationships between WM as a predictor of resilience promoting behaviours.
Inhibition										
3 Psychological resilience, mental health, and inhibitory control among youth and young adults under stress	Afek, et al. (2021)	Frontiers in Psychiatry	Cross-sectional	138 adults (63% women). Age range: 18–21 years Mean age (SD): 19.05 (0.57)	Trait resilience CD-RISC 25 (Connor & Davidson, 2003).	Inhibition	Go-no go task	Both	Initial combat training in the military	Positive correlation between the resilience measure were found with the non-emotional version. No significant correlation with the affective task.

TABLE 2 (Continued)

	Title of the article	Authors and year of publication	Journal of publication	Design of the study	Sample size	Measure of resilience: Trait, outcome or process	Component/s of EFs measured	Measure of EFs used	Hot or cold EFs	Adverse event	Main results
4	An experimental study to identify key psychological mechanisms that promote and predict resilience in the aftermath of treatment for breast cancer.	Gordon, et al. (2021)	Psycho-Oncology	Longitudinal	70 wome. Mean age (SD): 53.53 (11.38)	Process and outcome resilience CD-RISC (Connor & Davidson, 2003)	Inhibition	Attention network task (Fan et al., 2002).	Cold	Going through breast cancer (1 year later)	No significant relationships were found between executive functioning and resilience in either T1 or T2. Negative correlations were found between resilience and cancer- related interpretation bias.
Flexibility											
5	Cardiac defence reactivity and cognitive flexibility in high- and low-resilience women	Otero, et al. (2020)	Psychophysiology Psychological research	Cross-sectional	54 women (27 women with high resilience and 27 women with low resilience) average age (SD): 19.98 (2.83)	Trait resilience CD-RISC 25 (Connor & Davidson, 2003) RS (Wagnild & Young, 1993)	Flexibility	CAMBIOS Test (Seisdedos, 2004).	Cold	-	Higher scores on trait resilience (as well as better scores on measures of mental health) correlate with better scores on cognitive flexibility.
6	Individual differences in resilience to stress are associated with affective flexibility	Rademacher, et al. (2022)		Cross-sectional	100 adults (50% women). Age range: 18–35 Average age (SD): 23.7 (3.8)	Trait resilience CD-RISC (Connor & Davidson, 2003), BRS (Smith et al., 2008), RSA (Friborg et al., 2005).	Flexibility	TST (Armbruster et al., 2012) and AT (Dierolf et al., 2016)	Both	-	Significant positive correlation between resilience measures and ATST, but no significant correlation between non-affective TST.

(Continues)

TABLE 2 (Continued)

	Title of the article	Authors and year of publication	Journal of publication	Design of the study	Sample size	Measure of resilience: Trait, outcome or process	Component/s of EFs measured	Measure of EFs used	Hot or cold EFs	Adverse event	Main results
7	Better executive function under stress mitigates the effects of recent life stress exposure on health in young adults	Shields, et al. (2017)	Stress	Experimental	110 adults (72% women) Age range: 18–33 years Average age (SD): 19.91 (2)	Outcome resilience K-6 (Kessler et al., 2002) and PHQ-10, (Schat et al., 2005).	Flexibility	BCST (Piper et al., 2012)	Cold	Adult Strain-TTC (Slavich & Shields, 2018) and TSST	The association between recent exposure to stress and health complaints is moderated by executive functioning in the acute stress induction condition (but not in the control condition). No significant differences were found between perseverative errors in any of the groups. Also, better executive functioning in the stressful situation was associated with lower emotional reactivity to stress.
8	The effect of positive mood on flexible processing of affective information.	Grol & De Raedt (2018)	Emotion	Cross-sectional	80 adults (80% women) Age range: 17–46 years Average age (SD): 21.64 (3.7).	Trait resilience Resilience scale (RS, Portzky, 2008)	Flexibility	ATST (Genet et al., 2011)	Hot	-	Better levels of resilience were associated with a lower cost in the change task, as well as with a facilitation in performance with affective information. Positive information and the induction of a positive mood facilitate performance in this task, thus facilitating flexible behaviour.

TABLE 2 (Continued)

Title of the article	Authors and year of publication	Journal of publication	Design of the study	Sample size	Measure of resilience: Trait, outcome or process	Component/s of EFs measured	Measure of EFs used	Hot or cold EFs	Adverse event	Main results
9 Predeployment neurocognitive functioning predicts postdeployment posttraumatic stress in army personnel.	Samuelson, et al. (2020)	Neuropsychology	Longitudinal	473 adults (5.92% women) Average age (SD): 25.8 (5.94)	Process resilience PCL-5 (Weathers et al., 2013)	Flexibility	Switching of cold attention test (Reitan, 1992).	Cold	Deployment in Afghanistan	The resilient group (90.9% of the participants) showed better performance in neurocognitive tests. Inhibitory control was a key component to surviving in war zones.
10 Neuropsychological function in college students with and without posttraumatic stress disorder	Twamley, et al. (2004)	Psychiatry research	Cross-sectisuonal	105 young adults (73% women. Mean age (SD): 19.2 (2.2))	Outcome resilience Posttraumatic diagnostic scale (Foa, 1995) State-trait anxiety inventory (STAIT, Spielberger, 1983) Beck depression inventory (BDI, Beck et al., 1988)	WM and flexibility	WM: Digit span and letter-number sequencing subtests of WAIS-III Wechsler, 1997). Flexibility: TMT-B (Reitan & Wolfson, 1993) WCST (Kongs et al., 2000)	Cold	CTQ (Bernstein et al., 1994, 1997)	Some significant positive correlations were found between mentally healthy participants, despite exposition to trauma, and neuropsychological performance in the tasks.
11 Flexible control in processing affective and non-affective material predicts individual differences in trait resilience	Genet, et al. (2011)	Cognition & emotion	Cross-sectional	64 adults (64% women) Average age: 19	Trait resilience ER89 (Block & Kremen, 1996) CD-RISC (Connor & Davidson, 2003).	WM and flexibility	TST (Schneider & Logan, 2005) AST (Genet & Siemer, 2011) Automated reading span task (Unsworth et al., 2005)		-	Resilience was positively associated with lower change task cost in both the general change task and the affective change task, thus supporting the idea that resilient people have more effective flexible affective processing. Trait resilience was not associated with WM ability.

studies that evaluated resilience as an outcome and/or process, resilience was measured through surrogate measures of maintained mental health after an adverse event. Specifically, two out of the three studies used the PCL-5 checklist (Samuelson et al., 2020; Weathers et al., 2013) and K-6 and PHQ-10 (Kessler et al., 2002; Schat et al., 2005; Shields et al., 2017). The study conducted by Gordon et al. (2022) measured resilience through temporal repeated measures of the CD-RISC scale. Finally, the study by Twamley et al. (2004) used the PTSD checklist.

Regarding the EF component measured in the selected articles, 7 studies used measures of cognitive flexibility (Genet & Siemer, 2011; Grol & De Raedt, 2018; Otero et al., 2020; Rademacher et al., 2022; Samuelson et al., 2020; Shields et al., 2017; Twamley et al., 2004), 3 included a WM updating measure (Bemath et al., 2020; Twamley et al., 2004; Weiland et al., 2012) and 2 used inhibition measures (Afek et al., 2021; Gordon et al., 2022). It should be noted that only the studies conducted by Twamley et al. (2004) and Genet & Siemer (2011) included more than one measure of EFs, being WM and flexibility the measures that were included in both studies. In sum, most of studies solely tested one EF component and the most evaluated EF component in the reviewed studies was flexibility.

As for the measures used in the studies to assess the different components of EFs, regarding flexibility, one study used the CAMBIOS test (Otero et al., 2020; Seisdedos, 2004), one study used the Berg Card Sorting Test (BSCT, Piper et al., 2012; Shields et al., 2017), three studies used the Task Switching Task (TST, Schneider & Logan: Genet & Siemer, 2011; Grol & De Raedt, 2018; Rademacher et al., 2022), three used the emotional variant of the TST, that is, the Affective Switching Task (AST, Genet & Siemer, 2011; Grol & De Raedt, 2018; Rademacher et al., 2022), and one study used the Switching of Cold Attention Test (SCAT, Reitan, 1992; Samuelson et al., 2020). Regarding inhibition, one study used the Go-no go task (Afek et al., 2021) and the remaining one the Attention Network Task (ANT, Fan et al., 2002; Gordon et al., 2022). Finally, regarding WM updating measures, Twamley et al. (2004) included the Digit Span and Letter-Number Sequencing Subtests of the WAIS-III as a WM updating measure (Wechsler, 1997), Weiland et al. (2012) used the N-Back Task (Callicot et al., 1999) and Bemath et al. (2020) used the Automated Working Memory Assessment (AWMA, Alloway, 2007). In this case, it can be seen that the most used measure of EFs across the reviewed studies was the TST, however significant variability of measures used to assess each EF component can be observed.

Finally, in relation to the differentiation between hot or cold component of EFs, the selected articles mostly measured 'cold' components of EFs (Afek et al., 2021; Bemath et al., 2020; Genet & Siemer, 2011; Gordon et al., 2022; Otero et al., 2020; Rademacher et al., 2022; Samuelson et al., 2020; Shields et al., 2017; Weiland et al., 2012). Further, 4 articles included a measure of hot EFs additional to the cold measures (Afek et al., 2021; Genet & Siemer, 2011; Rademacher et al., 2022), and one further study specifically measured the hot component of EFs only (Grol & De Raedt, 2018). The paradigms used to assess hot EF components, as seen above, were the Afective Switching Task paradigm (AST, Genet & Siemer, 2011; Grol & De Raedt, 2018; Rademacher et al., 2022) and an emotional variant of the go-no-go paradigm (Afek et al., 2021). The AST comprised the use of emotional words as stimuli in the study by Genet & Siemer (2011), emotional images in the study of Grol & De Raedt (2018) and emotional faces in the study by Rademacher et al. (2022). Finally, the emotional go-no-go task also included emotional faces as stimuli in the study of Afek et al. (2021).

3.2 | Main results

3.2.1 | Relations between working memory updating and resilience measures

Four studies tested relations between performance in WM updating tasks and resilience. Bemath et al. (2020) conducted a cross-sectional study in a sample of 38 South African young adults who had lived in disadvantaged environments (i.e., history of socioeconomic and family problems; *M age* = 24.52, *SD* = 1.65, 55.2% women), analysing the relations between their performance in WM and personal and academic development under that context. They measured WM using the AWMA task, which comprises recalling both verbal and spatial stimuli (Alloway, 2007), and controlled for trait resilience levels using RRC- ARM questionnaire (Ungar & Liebenberg, 2013). In this study, researchers found positive significant correlations between performance in the AWMA and the self-informed measure of trait resilience (i.e., RRC-ARM). Furthermore, they found that WM acted as a significant predictor of resilience outcomes (Bemath et al., 2020).

Relatedly, Weiland et al. (2012) measured WM performance using the n-back task (i.e, 0-, 1-, 2-, and 3-back conditions, Kirchner, 1958) and analysed their relations with levels of self-reported resilience in a sample of 67 young adults (*M age* = 20.2, *SD* = 1.2, 38.82% women), using the Resiliency subscale of the California Child Q-Set (Block & Block, 1980). They found that individuals with a higher score of self-reported resilience (i.e., higher trait resilience) showed lower reaction times (RTs), in both, 0-back and 2-back conditions of the n-back task, compared to individuals with lower scores of trait resilience (i.e., better WM updating performance). That is, faster response across n-back phases were positively related with higher levels of resilience, thus supporting a connection between better WM performance and higher trait resilience. Finally, Twamley et al. (2004) were interested in testing whether there were differences in WM updating performance between individuals who were exposed to traumatic events and showed PTSD symptoms compared to individuals who had been similarly exposed to traumatic events but did not manifest PTSD symptoms (i.e., resilient group; *n* = 105 young adults, *M age* = 19.2, *SD* = 2.2, 73% women). They used the Digit Span and the Letter-Number Sequencing subtests of the WAIS-III as WM updating measures (Wechsler, 1997). The Digit Span subtest assesses the ability of the participant to recall an increasing sequence of digits directly, in an inverse manner or recalling the digits from smaller to bigger, whereas the Letter-Number Sequencing subtest assesses the ability of the participant of reorganising a

sequence of number and letters told by the examiner and reporting the letters in alphabetical order and digits in ascending order. They found moderate correlations across the sample between performance in both, the Digit Span and the Letter-Number Sequencing subtests of the WAIS-II, and a positive outcome of recuperation from the experience of one or more adverse events (e.g., higher outcome resilience, as measured through the CTQ).

Contrary to this set of findings, Genet & Siemer (2011), did not find significant correlations between WM updating, assessed using the automated reading span task (which consist of choosing if sentences are true or false, after which a letter is presented and the participant has to recall the letter sequence of the previously presented set; Unsworth et al., 2005), and trait resilience levels assessed with the ER-89 and the CD-RISC.

Overall, although the latter study did not support significant associations between WM updating performance and trait resilience, the three other studies consistently support such associations using other types of WM assessment, all referred to cold measures of WM updating, with some studies also supporting a link between such performance and outcomes levels of resilience following adversities.

3.2.2 | Relations between inhibition and resilience measures

The literature search identified only 2 studies that included an assessment of inhibition in relation to resilience levels. Firstly, the cross-sectional study of Afek et al. (2021) included affective and non-affective versions of the go-no-go task as measures of hot and cold inhibition. In this tasks, participants had to press a button whenever they saw a frequent image (appeared 80% of the time) and withhold their response to rare, infrequent target images (appeared 20% of the time). In the non-affective condition, the target image was a river and in the affective condition the target image was an emotional face (i.e., happy, sad or angry face). Moreover, they measured trait resilience through the Connor-Davidson Resilience Scale (CD-RISC; Connor & Davidson, 2003). They conducted their study in a sample of 138 military men and women who had to go through initial combat training (*M age* = 19.05, *SD* = 0.57, 63% women). Researchers found that performance in the non-affective version of the inhibition task (cold measure of inhibition) was positively correlated with higher trait resilience levels. On the contrary, when the go-no-go task was completed using affective stimuli (hot measure of inhibition), no significant relations were found with trait resilience levels (Afek et al., 2021). These results contrast with the findings of the longitudinal study conducted by Gordon et al. (2022). In this study, the researchers conducted a longitudinal study in a sample of 70 women who had survived breast cancer (*M age* = 53.53, *SD* = 11.38). They analysed how performance in an inhibition task, comprising the ANT (Fan et al., 2002) predicted outcome resilience levels in two different temporal moments (T1, at the time of EF assessment and T2, 6 months later) using repeated measures of the CD-RISC at each time. In the ANT task, participants are asked to press a key whenever the participant detects changes in the direction of a string of arrows that is sequentially presented in a screen. These authors did not found relations between individual performance in the ANT and resilience levels neither in T1 or T2.

In sum, studies analysing the connection between inhibition capacities and resilience are very scarce and the overall results, both for cold and hot modalities of inhibition are inconclusive and mixed.

3.2.3 | Relations between flexibility and resilience measures

A total of 7 of the reviewed studies included a measure of flexibility. Five of them were cross-sectional studies testing relationships between flexibility performance and self-reported trait resilience (Genet & Siemer, 2011; Grol & De Raedt, 2018; Otero et al., 2020; Rademacher et al., 2022; Twamley et al., 2004). One study was experimental and assessed relations between flexibility performance and outcome resilience after exposure to naturalistic stressful situations and experimentally induced stress in a sample of healthy adults (Shields et al., 2017). Finally, only one study was longitudinal, and provided an analysis of the predictive role of flexibility on process resilience in a sample of pre-deployed military men and women (Samuelson et al., 2020).

Overall, results of all studies supported significant positive relations between better performance in the flexibility tasks used in each study and higher resilience levels (Genet & Siemer, 2011; Grol & De Raedt, 2018; Otero et al., 2020; Rademacher et al., 2022; Samuelson et al., 2020; Shields et al., 2017; Twamley et al., 2004). More specifically all the five cross-sectional studies found significant positive correlations between higher flexibility and higher trait resilience. For instance, in the study made by Otero et al. (2020), with a sample of 54 women (*M age* = 19.98, *SD* = 2.83), positive correlations between performance in the CAMBIOS test and the CD-RISC (i.e, measure of trait resilience) were supported. The CAMBIOS test is a measure of the cold component of flexibility, in which participants have to detect changes in a set of figures according to a number of interchangeable rules (Seisdedos, 2004). These results, according to the authors, would support the hypothesis that better cognitive flexibility facilitate the ability to adapt human behaviour to changes in the environment, which would ultimately confer resilience.

Further, in the study conducted by Rademacher et al. (2022), the authors studied the relationship between cognitive flexibility (i.e., cold EF), affective flexibility (i.e, hot EF) and trait resilience in a sample of 100 adults (*M age* = 23.7, *SD* = 3.8, 50% women). Researchers included both cold and hot measures of flexibility, using the TST and the AST, respectively (Dierolf et al., 2016; Genet & Siemer, 2011). In the TST, participants need to detect changes in digits' position rules presented in the screen by pressing two different keys. In the AST, participants need to sort out faces either by gender or emotional valence, by pressing two different keys. As trait-resilience measures, they used the CD-RISC, RSA and BRS (Connor et al., 2003; Friborg et al., 2005; Smith et al., 2008). Overall,

Rademacher et al. (2022) found that better performance in the hot measure of flexibility (i.e., AST) predicted higher levels of resilience, as assessed with all the three resilience measures. Contrarily, only one of the three self-reported resilience measures, the CD-RISC scale, was significantly related with better performance in the cold measure of flexibility (i.e., TST).

Similar results were found in the study conducted by Genet & Siemer (2011). In this study, the authors examined whether individual differences in both affective and non-affective flexibility (using the AST and the TST, respectively) were related to individual differences in trait resilience levels (i.e, scores in the ER-89 and the CD-RISC) in a sample of 64 adults (*M age* = 19, 64% women). As hypothesised, lower task switching cost in the non-affective cognitive flexibility task (i.e., reflecting higher flexibility) was significantly associated with higher levels of trait resilience. Further, results supported that the better performance in hot measure of affective flexibility was also positively correlated with higher self-reported levels of trait resilience (Genet & Siemer, 2011). Such results were also replicated in the study by Grol & De Raedt (2018) in a sample of 80 adults (*M age* = 21.64, *SD* = 3.7, 80% women). These researchers used the AST as a measure of affective flexibility and they correlated it with trait resilience, as assessed with the RS (Genet & Siemer, 2011; Portzky, 2008). Similar to the former reviewed studies, they also found that lower switching costs in the AST (i.e., reflecting higher flexibility), and specifically a higher facilitation to switch to positive affective information processing compared to negative and neutral information, were related to higher trait resilience levels.

As for Shields et al. (2017), these authors included an outcome measure of resilience, defined as the result of exposure to stressful situations (i.e., measured through Adult Strain-TTC, Block & Block, 1980) in mental health maintenance levels (assessed with the K-6, Kessler et al., 2002; and the PHQ-10, Schat et al., 2005) in a sample of 110 adults (M age = 19.91, SD = 2, 72% women). Authors divided the participants into two groups, an experimental group that was exposed to the Trier Social Stress Test (TSST; Kirschbaum et al., 1993), and a control group that was not exposed to experimental stressor. The TSST comprises a stress induction in which participants are asked to give a 3-min speech explaining why they would have a good fit for a job position of that person's choice. In this study, researchers wanted to examine whether better performance in cognitive flexibility was related to better recovery of such stressful situation (i.e., outcome resilience). The authors found that better performance in cognitive flexibility, as assessed with the BCST (i.e., an open format of the Wechsler Card Sorting Test; WCST), was positively correlated both to a higher recovery of the experimental stressors as well as to higher scores in the mental health questionnaires despite the exposures to stress.

Finally, Samuelson et al. (2020) studied process resilience through a longitudinal design completed by a sample of 473 military men and women who were deployed to Afghanistan for 10 months (*M age* = 25.8, *SD* = 5.94, 4.73%women). Participants completed two temporal measures of mental health maintenance (T1, pre-deployment and T2, post-deployment), based on measures of absence of traumatic symptoms, using the PCL-5 questionnaire (Weathers et al., 2013), at baseline (i.e., pre-deployment, T1) and 8 months after (i.e., post-deployment, T2). Their measure of flexibility was the SCAT, and results supported significant positive relations between better performance in the flexibility task under adversity (i.e, post-deployment) and higher levels of process resilience (i.e., temporal maintenance of higher levels of mental health across time following deployment). Although this last study was conducted with a specific sample of pre-deployed military men and women and specific stressors might be particularly relevant in this sample, the same results of positive associations between flexibility and resilience were found as in the rest of reviewed studies. Thus, it seems that flexibility is a key EF for stress regulation as well as for the promotion of resilience despite the type of sample of stressor. However, more research is needed to extend this evidence and confirm the last conclusion.

In sum, extant research in the relation between flexibility and resilience is larger than for the other two EFs, and studies mostly support relations between higher flexibility and higher trait resilience, as well as a potential role of this EF, both in cold and hot formats, to facilitate outcomes and processes of resilience in the face of adversities. Yet, an integrative analysis of studies differentiating cold versus hot EFs in relation to resilience must also be considered (see following subsection).

3.2.4 | Differentiation of hot and cold components of EFs in their relations to resilience variables

The reviewed literature included 7 studies that measured one of the three cold EFs components (Bemath et al., 2020; Gordon et al., 2022; Otero et al., 2020; Samuelson et al., 2020; Shields et al., 2017; Twamley et al., 2004; Weiland et al., 2012), whereas one study only included a hot measure of one EFs (Grol & De Raedt, 2018), and three included both, hot and cold measures of EFs (Afek et al., 2021; Genet & Siemer, 2011; Rademacher et al., 2022). As for the studies that included both, hot and cold measures of EFs components, two of them coincided in the cold measure used, the TST (Genet & Siemer, 2011; Rademacher et al., 2022), but they differed in the hot measure used. Genet & Siemer (2011) used the Affective Switching Task (AST, Genet & Siemer, 2011), whereas Rademacher et al. (2022) adapted the task switching paradigm developed originally by Armbruster et al., 2012., switching from non-affective stimuli (e.g., digits) used in the original task, to affective faces in their adaptation based on the paradigm proposed by Dierolf et al., 2016 (e.g. positive and negative facial expressions). These two tasks, although differ in the stimuli used (e.g., affective

and non-affective words vs. only affective faces, respectively), are similar in their experimental design. The remaining study used an affective and non-affective version of the same task, in this case the go-no-go task (Afek et al., 2021) with neutral, non-affective images of nature and neutral and emotional faces as affective stimuli. As for the study that measured EFs in only its hot aspect (Grol & De Raedt, 2018), the AST, comprising both emotional and non-emotional images, was used.

Results in the studies that included both hot and cold EFs measure differ in their results. For instance, Genet & Siemer (2011) found that both hot and cold variants of their TST using emotional and non-emotional words both predicted higher levels of trait-resilience. Similarly, Rademacher et al. (2022) replicated these results, although showing a superior effect for hot EFs. In this case, they found positive correlations between the affective measure of flexibility using Genet's AST paradigm and their trait-resilience measures. However, their cold measure of flexibility using a non-affective variant of TST with digits as stimuli, only correlated with one resilience measure (CD-RISC). As for the study conducted by Grol and colleagues, they used the same AST paradigm as Genet & Siemer (2011) and found positive correlations with self-reported resilience. On the contrary to these findings on affective flexibility, Afek et al. (2021) found that resilience levels were correlated to their cold measure of inhibition using the go-no-go task with nature images, but this correlation was not significant with their hot go-no-go task variant including emotional faces.

In summary, there are scarce but mostly consistent results of a higher relation with resilience of a better cognitive performance in the hot aspect of flexibility (Genet & Siemer, 2011; Grol & De Raedt, 2018; Rademacher et al., 2022), in comparison to the cold aspect of it (Genet & Siemer, 2011; Rademacher et al., 2022). These results differ when the measure comprised the inhibition component, not replicating the results of the flexibility measures. In this case, the results were opposite, the cold measure of inhibition was a better predictor of resilience, in comparison the hot inhibition component, that did not show a significant effect (Afek et al., 2021).

4 | DISCUSSION

In this work, we aimed to review the existing empirical research that has to date analysed the relations between performance in the EF components proposed by Miyake et al. (2000) (i.e., inhibition, WM updating and cognitive flexibility capacities) and resilience levels in its different forms (i.e., trait, process, outcome). Further we wanted to explore if there were differences in these relationships depending on whether EFs were referred to the processing of non-affective (i.e., cold EFs) or affective information (i.e., hot EFs). The results of this review, discussed below, help to integrate extant evidence to identify crucial factors such as EF performance (i.e., inhibition, WM updating and flexibility) that can facilitate the promotion of resilience in any of its different forms.

4.1 | Relations between EFs and trait resilience

Results of studies testing relations between the three components of EFs (i.e., inhibition, WM updating and flexibility) and self-reported assessments of trait resilience consistently support their positive associations (Afek et al., 2021; Bemath et al., 2020; Genet & Siemer, 2011; Grol & De Raedt, 2018; Otero et al., 2020; Rademacher et al., 2022; Weiland et al., 2012). More specifically, results first point out that individuals characterised by higher levels of resilience are those ones who exert better WM updating. That is, they can more efficiently update the incoming information entering their cognitive buffer, as well as perform better in blocking out information that is not relevant for their current contextual demands (i.e., inhibition), and are more flexible in adapting to changes in task demands (Afek et al., 2021; Bemath et al., 2020; Genet & Siemer, 2011; Grol & De Raedt, 2018; Otero et al., 2020; Rademacher et al., 2022; Weiland et al., 2012). These results point out that EFs can be key cognitive processes for the promotion of resilient behaviours. Specifically, flexibly switching between, both affective and/or non-affective information seems to be a key cognitive aspect associated with higher resilience despite the experience of stress (Genet & Siemer, 2011; Grol & De Raedt, 2018; Otero et al., 2020; Rademacher et al., 2022; Samuelson et al., 2020; Shields et al., 2017). In the same way, some research suggests that the facility to effectively inhibit irrelevant negative information may facilitate resilient behaviours (Afek et al., 2021), although research in this EF is still scarce and further studies are required. Finally, empirical evidence also supports that being able to effectively update incoming information to the cognitive buffer is related to resilience. In the latter case, existing evidence only refers to WM updating tasks using non-affective information, thus so far it can only be concluded that cold forms of WM performance are related to resilience (Bemath et al., 2020; Weiland et al., 2012). Additionally, it is important, to consider the variability in WM tasks used in the reviewed studies, since each study included a different WM measure to address this cognitive process. Thus, the design of each task might have influenced the results of the associations between WM updating and resilience. Further, studies may aim at replicating these results using the same measures to provide more robust and reliable evidence of the associations between WM and resilience considering that one study did not find significant results.

These results integrate evidence that was missing with respect to previous research that has been mainly interested in only analysing how impaired executive functioning confers risk for stress-related disorders (Villalobos et al., 2021), which has been much more extensively studied (e.g., Nikolin et al., 2021; Nuño et al., 2021; Quigley et al., 2022; Stange et al., 2017). Therefore, the current systematic review adds a missing piece of evidence that further support a potential central role of EFs as mechanisms of facilitation of resilience to stress (Parsons et al., 2016), for which to date no systematic reviews and/or meta-analyses had been performed.

Beyond these general conclusions regarding the link between higher trait resilience and better EF performance, specific studies have also been identified that offer new insights on how EFs can contribute to specific forms of resilient outcomes and processes in the face of specific adversities.

4.2 | Relations between EFs and process and outcome forms of resilience

Results informing about associations between EFs and process and outcome resilience are more scarce, as only 3 of the reviewed articles measured resilience in these forms. The two studies that had longitudinal designs, thus informing about process resilience, showed contrasting effects of their EFs measure, with one showing a significant role of flexibility to account for better recovery from an adverse situation in military deployed to Afghanistan (Samuelson et al., 2020). However, Gordon et al. (2022) did not find significant relations between inhibition performance and mental health recovery from a major adverse such as breast cancer in cancer survivors. These results could be related to the claims that suggest that military personnel show higher levels of resilience on average, due to the trainings they receive to effectively manage stress (e.g., Galatzer-Levy et al., 2018). Thus, it should be examined in greater depth in future investigations whether different EFs have distinct contributions to distinct processes of resilience, as a function of the type of adversity experienced or type of population. Future studies should analyse if the overall associations between EF performance and higher resilience are consistent across different samples and stressful situations or if specific characteristics of the sample and/or the stressful situation studied (e.g, military deployment, chronic diseases, unemployment) show distinct roles of EF components and their dimensions to promote resilience.

Additionally, Twamley et al. (2004) found significant relations between WM and flexibility performance after the exposure to traumatic events in childhood and existing mental health levels (i.e, outcome resilience). Overall, initial evidence points out that flexibility and WM updating can be both involved in the facilitation of resilient outcomes and processes, but that this role is not evident in the case of inhibition. However, these results should be taken carefully, given the small number of studies, particularly in the ones analysing inhibition performance, and the heterogeneity of the designs, methods and measures used among the studies (see Table 2). Based on other longitudinal studies that have provided evidence for impairments in inhibition and WM updating as consistent predictors of stress-related depression and/or anxiety, it could be expected that better executive functioning in both components could also protect against stress-related outcomes in mental health through time (see Feng et al., 2022; Sanchez-Lopez et al., 2019). Also, there is further evidence that EFs, when reported through questionnaires, can be related to process-resilience (Galatzer-Levy et al., 2018; Wu et al., 2021). In any case, results for outcome and process resilience are scarcer and more heterogeneous as compared to the reviewed studies that have considered EFs performance in relation to trait-resilience and more research is therefore needed to extend the existing results.

4.3 | Differences between hot and cold EFs in relation to resilience

Finally, we wanted to analyse if any differences in the relations between resilience variables and EFs performance would be found depending on whether performance in the tasks included hot and cold aspects of processing. Such distinction is important for resilience research, as it is understood that adaptive stress responses occur amid emotionally arousing contexts, specifically, depending on how individuals process and manage negative information (Abdul-Raheem et al., 2021; Falquez et al., 2016). Thus, including emotional stimuli in the evaluation of EFs can add more ecological validity and clearer guidelines on specifically relevant forms of EFs with a role to promote resilience.

The current evidence identified in this systematic review has mostly shown that the relationship between performance in EFs and resilience is greater in those tasks that involve the processing of emotional stimuli. For instance, Grol & De Raedt (2018) and Rademacher et al. (2022) found that participants scoring higher in trait resilience showed better performance in affective flexibility. Thus, the influence of emotional information is observed not only in cognitive performance, but also in its relationship with resilience markers, potentially facilitating a better adaptation to the demands of the environment. Different conclusions can be drawn, however, from the study of Afek et al. (2021). In this case, it was the neutral but not the affective condition of the inhibitory task used the one that predicted higher levels of resilience, while Genet & Siemer (2011) found no differences between their hot and cold measures of flexibility to predict higher levels of trait-resilience. As for Afek et al. (2021), these authors argued that resilience is related to emotion regulation but not necessarily related to emotion identification and therefore, since the task they used only involved processes of emotion identification, it might be the case that the emotional stimuli used did not capture the phenomenon of affective facilitation and its relation to resilience. Nonetheless, further research is clearly needed to extend current findings and clearly establish whether hot components of EFs have a superior contribution or not for the promotion of resilient responses to stress.

In this sense, due to the variability in the current results, we cannot conclude that there is robust evidence supporting differences in the performance of hot versus cold aspects of EFs. A larger number of studies is warranted to derive strong conclusions on this issue. These future studies should include both affective and non-affective EFs measures to inform about possible differences in their relation to resilience variables. At this moment, it is not clear whether higher levels of resilience are related to better performance in both, hot and cold, EFs, and whether hot EFs may, in any case, have specific or stronger contributions to resilience processes and outcomes.

Evidence from research studying EF impairments associated to stress-related disorders have already demonstrated that both depressed and anxious individuals perform worse in tasks that include negative emotional stimuli than in similar tasks using non-affective stimuli (see Nikolin et al., 2021; Quigley et al., 2022). It might be the case, that more resilient individuals do not show such pattern of difficulties when switching between affective and non-affective information and show a facilitation in the inhibition of such negative information, while also updating the incoming information in a more appropriate and adaptive way. However, it could be also possible that specific forms of hot EFs accounting for resilience were not referred to efficient negative processing but to facilitated processing of positive information, as suggested by findings by Grol & De Raedt (2018). More research is thus needed to extend knowledge on this crucial issue of mechanisms of resilience that can guide future interventions to promote them.

4.4 | Limitations

Beyond the general main conclusions that have been highlighted in this systematic review, several limitations regarding the extant research that has reviewed should be noted.

The first limitation refers to the conceptualisation of EFs and resilience used across the different studies. As aforementioned, we operationalised EFs using the definitions and distinctions of the Miyake's et al. (2000)'s unity/diversity model. Therefore, we conducted the classification of the tasks included in this review according to the definition of each component by this framework. It must be noted that some of the articles included provided a different classification of their EFs tasks, thus reporting their results as evidence for a different component than the one used to organise our findings. For example, Twamley et al. (2004) referred to their use of the WCST as a global measure of general EF. In contrast, based on our definition following Miyake's et al. (2000)'s framework, we classified the use of the WCST as a flexibility task, given that the core of the task is to be able to detect changes in the pattern of classification of the cards and flexibly switch among rules. Also, Afek et al. (2021) classified their use of the ANT as an attentional control task, while according to the framework used in this review this task would assess specific aspects of cognitive inhibition. Therefore, this highlights the possibility of alternative approximations and classifications of EF components according to distinct conceptualisation of EFs. Research in the field of EFs has greatly varied in its conceptualisation and so the designs of the tasks that measure such components may vary among each other based on their theoretical framing.

Furthermore, a significant heterogeneity exists in the measures used to assess the components of EFs in extant research analysing their relations to resilience. As observed in Table 2, only the TST and its affective variant have been repeatedly used in 3 studies assessing flexibility (Genet & Siemer, 2011; Grol & De Raedt, 2018; Rademacher et al., 2022). The rest of authors used different tasks to assess the same cognitive processes in each of the studies, also using different assessments of resilience. Although these EFs tasks have all been validated in previous research, they are often based on different theoretical backgrounds for the study of EFs. Historically, different theoretical approaches have been proposed to define and categorise EFs. Initial approaches viewed EFs as a single central process that modulates mental activity (Baddeley, 1992; Duncan, et al., 1995; Norman & Shallice, 1986). Other subsequent proposals defined EFs as cognitive processes that are grouped independently of each other (Stuss, 1992). The latest main set of models conceptualise EFs as independent components that work in an integrated, global manner (Miyake et al., 2000). As observed, adequately defining EFs from a theoretical perspective (and thus defining methods to assess global or specific EFs) has posed some challenges over time. We highlight the diversity of conceptualizations and measures identified in the present review, which points out the need of using up to date new conceptualizations of separate operations of executive function. This relates to the difficulty to address the overlapping nature of the EF components. That is, the study of the components of EFs has historically been challenging when it comes to identifying and isolating its components (Anderson, 2010). Although there are numerous theoretical models that aim to disentangle the components of the EFs, an exhaustive analysis of these models and the tests designed based on them, have revealed the difficulty of individually measuring each EF component without the influence of the other ones (Anderson, 2010). In short, it could be questioned to what extent the procedures identified in this review that are used to obtain indicators of separate forms of inhibition, WM updating, or flexibility actually provide such single isolated operative measures. It may be necessary to advance research that informs the development of more solid theoretical frameworks on which are the components that conform EFs and develop reliable measures that allow measuring these constructs separately, without overlapping them. In sum, we note that the variability of tasks included in this systematic review can be due to the fact that many of them were designed based on earlier models of EFs. This variability of frameworks and the derived assessment tasks limits the ability to protocolise EF evaluation in standardized measures that allowed to test separate EFs, and further research extending this evidence to more precise conceptualizations of EFs is warranted.

Second, similar issues have been observed in the classification of the forms of resilience. Whereas Rademacher et al. (2022) stated that they measured resilience as an outcome using the BRS, as a self-reported way to address one's perception of resilience, this would not fit into an outcome-based form of resilience, as operatised in the current review. Since, there is no exposition to an adverse situation and the design of the study is not longitudinal, we opted to classify Rademacher's et al. (2022) resilience measure as a trait-oriented measure of resilience, instead. Another difficulty that we have found regarding the conceptualisation of resilience is the fact that a significant number of studies that measured resilience did not mention such concept, hindering the search strategy of potential articles that might fit the inclusion criteria and failed to be included. As an illustrative example of this, the number of studies identified

through other search strategies, complementary to the systematic review in PsychInfo and PubMed was relatively high. Thus, we tried to maximise the search string by including concepts that may be potentially related to resilience, however, it is possible that even despite all these efforts, some relevant studies have been missed and not included in our systematic review.

Third, there was a significant disproportion of studies that included a measure of trait-resilience ($k = 8$) and those that measured process ($k = 2$) and outcome resilience ($k = 1$), leaving aside the possibility to draw solid conclusions on the relations between EFs and the latter ones. As previously mentioned, studying resilience from a single trait perspective has proven to be incomplete (Chmitorz et al., 2018; Kuldas & Foody, 2022). Therefore, it is necessary that future studies measure resilience from the perspective of processes or outcomes of maintained mental health in the occurrence of stressors and adversities, as a mean to expand and complete the current investigation on resilience and their EF mechanisms.

Fourth, most of the works reviewed focused on the study of the cold aspects of EFs, and a small number of studies considered the comparison of the cold and hot aspects of EFs. The need to study the relationship of resilience forms with specific hot aspects of EFs must be considered in future research, as this would increase the ecological validity of the EFs measures employed and would allow to consider specific emotional processes potentially involved in stress resilience.

Finally, this systematic review has been focused on reviewing studies that included adult samples (18–65 years), leaving aside other developmental periods that are also worth of study. We acknowledge the distinct characteristics that the different period of human development may hold (e.g., early childhood, adolescence, elderness, etc.) and albeit we have preferred to focus on the adult period of life, future research should consider extending the study of the relations between EF performance and resilience to this other developmental groups.

4.5 | Implications and future directions

Despite the noted limitations, extant research in the role of EFs in resilience is important as a mean to guide future research on the issue to advance further knowledge with clear important implications. To the moment, the approach to solely study and treat stress-related disorders has been mostly focused on reducing symptoms resulting from the negative effects on one's life of sustained stress, without providing patients with specific tools to cope with adverse situations adaptively and effectively. However, this approach is showing some limitations. For instance, there are issues of the generalisation of the therapeutic effects and low ecological validity in tackling stress-related psychopathology (Cook et al., 2017). Also, research in unravelling the cognitive mechanisms and processes that allow individuals to engage in healthier and more adaptive behaviours is still scarce (Kazdin, 2007, 2011).

One proposal to address such limitations, is the design of interventions aimed to promote resilience as a tool to address the prevention and treatment of mental disorders associated with stress (Chmitorz et al., 2018; Liu et al., 2020). This approach may help individuals to create healthy habits that allow more lasting therapeutic changes and thus protect against possible relapses (Kalisch et al., 2019). This new area of research is focused on the development of positive coping skills to adverse situations, seeking to promote the reinforcement of protective factors (e.g., proper functioning of EFs) and not focussing solely on addressing vulnerability factors associated to the onset and maintenance of disorders associated with stress (Chmitorz et al., 2018; Liu et al., 2020). Therefore, extant evidence on the role of EFs in the promotion of resilient processes and outcomes may be essential to support this type of interventions. It is currently assumed that an adequate executive functioning may allow individuals to modulate their behaviour to solve the problems they face in their daily life, helping them to make more adequate, quick and flexible decisions and consequently, helping them to better adapt to the adverse situations (Diamond, 2013; Parsons et al., 2016). In other words, adequate executive functioning interventions can enhance levels of resilient responses to adverse events (Blanco et al., 2023; Koster et al., 2017). There is already evidence from studies that use cognitive trainings to target specific EFs components that such trainings successfully reduce stress-related disfunctions (Blanco et al., 2023; Hoorelbeke et al., 2015; Koster et al., 2017). Therefore, identifying the specific EFs and their dimensions (i.e., hot vs. cold EFs) that facilitate different forms of resilience to stress may be capital to improve the quality and effectiveness of these interventions. This is particularly relevant, as it has been observed in the scientific literature that mental disorders associated with stress are linked to numerous problems of cognitive nature (e.g., difficulties disengaging from negative information, difficulties in flexibly switch between task demands, impaired WM updating; Visu-Petra et al., 2013; Warren et al., 2021). Thus, cognitive trainings targeting EFs in the context of stress-related disorders can significantly improve their effects by not only treating the cognitive mechanisms implicated in the onset and maintenance of depression and anxiety symptoms (Koster et al., 2017), but also targeting the cognitive mechanisms that generate alternative coping tools to better adapt to stressful situations and generate resilience. Furthermore, preventive interventions for these problems could also benefit from new evidence on EFs that maximise resilience forms, through the identification and inclusion of therapies focused on the promotion of EF protective factors of resilience, which would favour a broader approach to prevent psychological problems that are largely prevalent in today's society (Diamond, 2013).

Unfortunately, the relationships between EFs and resilience continues to be a relatively underexplored field of study. As noted above, increasing the number of studies that analyse the relations of EFs with effective cognitive coping and different forms of resilience will aid in the development of adequate cognitive trainings and add-on modules for resilience interventions. To achieve that, it would be important to not only increase the number of studies studying the

relations between the components of EFs and resilient processes and outcomes, but to also do this in an integrative manner. Thus, although EFs can be distinguished into three mainly different components, as defined by Miyake and colleagues' framework, it should not be ignored that these functions operate in a unified manner (i.e, unity/diversity model of Miyake et al., 2000). As noted above, none of the reviewed studies have included a measure of each of the three components of EFs, focussing instead either in one EF component or two at most (Genet & Siemer, 2011; Twamley et al., 2004). Therefore, we propose that it is necessary to provide more robust evidence on the relations between better global functioning of EFs and processes and outcomes of resilience by using integrative designs that include all different forms of EFs (i.e., allowing to disentangle common and unique contributions of separate EFs in its different hot and cold dimensions to different indicators of resilience).

Finally, it would be interesting to find new more ecological forms of measuring resilience in the face of stress. Specifically, we propose that future studies might be use Ecological Momentary Assessment (EMA) procedures to derive more ecological measures of resilience, as it unfolds across situations of daily life. These procedures provide precise longitudinal measures that might better capture the resilience phenomenon in a more ecological way. For instance, Krause et al. (2023) have proposed such approximation, with interesting findings that associate indicators of daily resilience with stressor reactivity using both psychological and physiological measures.

In summary, our recommendations for future studies includes the need of increasing the number of studies that measure the associations between better EFs functioning and resilience, including measures of all the three EFs, in their hot and cold dimensions. Since differentiations in performance of hot and cold EFs and their relations with resilience are still not clear and extant evidence is not sufficient to derive strong conclusions, we urge to deepen into this topic. Providing sufficient and robust evidence of these relations and having clear evidence of how EFs operate to promote resilient behaviour will be informative to develop specific cognitive interventions to target hot and cold EFs, which can be promising to not only reduce stress-related symptoms but also to promote resilient behaviours when individuals cope with stress.

5 | CONCLUSIONS

This systematic review provides novel initial insights about the role of better executive functions as means to facilitate resilient behaviours and better recuperation from adverse situations. We have synthesised the main results of the extant studies in this crucial issue, and it can be concluded that there are preliminary evidence consistently supporting positive relations between a good performance in the cold aspects of EFs and resilience. Relations between the hot aspects of EFs and resilience remain more unclear due to a current small number of studies in this issue and further extensive research is clearly needed to confirm specific relations between hot EFs and resilience forms.

The findings of this systematic reviews indicate the need of expanding research interests to study cognitive processes and their role as central mechanisms of stress regulation and adaptation. Initial findings support the assumption that good executive functioning enables individuals to have a more positive adaptation to ongoing challenges and adversities. However, due to the current limited number of articles on this issue and the methodological heterogeneity among them, it is necessary to advance new research in this field, particularly designing unified protocols of integrated measures of all the components of EFs and expanding the analysis of their relations with markers of trait resilience to consider more operative forms of resilience processes and outcomes. A greater homogeneity of these designs promises to be highly informative for the design of new interventions to precisely train EFs that increase levels of resilience in populations at risk for stress-related problems.

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CONFLICT OF INTEREST STATEMENT

None.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in APA PsycInfo at https://www.apa.org/pubs/databases/psycinfo.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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