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Research Article

Monitoring and Cognitive Appraisal as Moderators of Cognitive Control and Mental Health: An Experimental Study in a Geriatric Population

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This study explores how monitoring and cognitive appraisal influence the relationship between cognitive control and mental health in a geriatric clinical population. Sixty inpatients undergoing pre-rehabilitative treatment were randomly assigned to either a cognitive control training group or a control group with no training. This is the first experimental study linking cognitive control, monitoring, and cognitive appraisal with mental health. Cognitive control, monitoring, and cognitive appraisal were assessed using the AX-continuous performance test (AX-CPT), whereas self-efficacy, treatment beliefs, and mental health were measured through validated self-report instruments. Results indicated that cognitive control can be improved by targeted training and is positively associated with mental health outcomes. Moreover, cognitive appraisal moderated the link between cognitive performance and mental health, offering a potential explanation for the limited convergence between behavioral and self-reported data. These findings suggest that appraisal processes may play a central role in shaping mental health and could inform future clinical interventions, though further research with larger and more diverse samples is required to confirm these preliminary results.

Trial Registration: ClinicalTrials.gov identifier: NCT07137676

Keywords: affective neuroscience; cognitive control; mental health; self-efficacy; treatment beliefs

1. Introduction

Human goal-directed behavior is defined by its future-oriented nature and the capacity to flexibly adapt to changing contexts and reconfigure behavioral dispositions in response to shifting goals [1]. In psychological terms, the pursuit of eudaemonia—long-term well-being and self-realization—requires sustained cognitive control mechanisms that support enduring commitment to mental health, in contrast to hedonic drive satisfaction, which reflects short-term gratification. The ability to inhibit immediate behavioral impulses that conflict with long-term goals may thus be conceptualized as behavioral cognitive control. Cognitive control represents a promising yet underutilized construct for understanding the interplay between mental health, cognition, and treatment outcomes, particularly in clinical and therapeutic contexts. Although it has been extensively studied in cognitive neuroscience and identified as a transdiagnostic mechanism across various mental disorders—including depression, anxiety, and attention deficit hyperactivity disorder (ADHD) [1]—its specific relationship to mental health, understood as a distinct but related continuum to psychopathology, remains insufficiently explored [2]. Despite the growing body of research on cognitive control, its direct association with mental health has not yet been empirically addressed. Conceptualizing mental health as a separate continuum alongside mental illness is thus a promising avenue in advancing a resource-oriented understanding of psychological functioning beyond the mere absence of pathology. Furthermore, monitoring and cognitive appraisal as major mechanisms and predecessors of cognitive control are considered to explain varying levels of mental health.

2. Cognitive Control

The dual mechanisms framework (DMC) proposes that cognitive control operates through two distinct modes: "reactive control" and "proactive control" [3]. Proactive cognitive control is defined as "the ability to regulate, coordinate, and sequence thoughts and actions in accordance with internally maintained behavioural goals" ([3], p. 1). In contrast, reactive control is engaged only after a high-interference event occurs, with attention mobilized as a mechanism for late-stage correction [3, 4]. Successful cognitive functioning relies on a combination of both strategies, as proactive and reactive control are complementary; both functions entail their advantages and disadvantages [3]. Braver [3] suggested that individuals tend to favor either proactive or reactive control as a default mode. This intraindividual variability in cognitive control offers a framework for understanding how cognitive control changes in specific states of mental health. A primary obstacle in neurosciences is the discrepancy between self-reported and behaviorally compiled data. Correspondingly, investigating inter- and intraindividual differences in cognitive control by considering monitoring and cognitive appraisal—which signal what mode of control is employed—is thus a promising avenue in advancing the relation between mental health, neuropsychiatric disorders, and cognition.

3. Cognitive Monitoring

A fundamental question is how the brain knows when to execute cognitive control in the first place rather than allowing control by prepotent stimulus–response (S-R) associations [5]. What is needed is a mechanism to monitor ongoing performance which determines when additional control signals are required, which then increases cognitive control activity required to pursue a desired goal [5]. Computational neural models of cognitive control incorporate simple S-R associations, and behavioral complexity is introduced through cognitive monitoring signals modulating the expression of goal-directed behavior ([5, 6]; Brown et al. 2007; [7]). Correspondingly, a goal must be activated in appropriate circumstances and the activity level must be further increased to a more proactive control mode—which requires more activity in contrast to reactive cognitive control—as conditions become more difficult and complex [5, 8]. Reactive monitoring relies on the error-related negativity (ERN) of the mPFC [5, 9, 10] and detects errors ex post facto as an indication that greater levels of activity—or mental effort—are required. In the prospect of potential errors, proactive cognitive control can be realized by greater activation levels of the anterior cingulate cortex (ACC) and the mPFC as a response to conflicts between correct versus incorrect responses ([11, 12]; MacDonald et al. 2000).

4. Cognitive Appraisal

Cognitive appraisal refers to the subjective interpretation by an individual of stimuli from the environment and is a major component of various theories of mental health, emotion, stress, and coping. Cognitive appraisal was defined by Lazarus and Folkman et al. [13] as the way in which an individual responds to and interprets life stressors. Abnormal patterns of cognitive appraisal have been identified as major predictors of mental disorders and Webb et al. [14] postulated that an individual's ability to reframe stimuli and experiences is "one of the most effective strategies for emotional regulation". With respect to reactive–proactive performance monitoring, cognitive appraisal is the ACC's ability to learn which of several motor controllers should be given authority and to decide whether a task warrants the activation of the more effortful proactive control mode. The *response selection model of ACC* [15] postulates that initially, the ERN results from a magnitude of the negative temporal difference error driven by unexpected error feedback from an unprecedented event. As learning in the model proceeds, an error prediction can enable the ACC to recognize error patterns and to model error-likelihood predictions following incorrect-versus-correct responses to a stimulus [5]. Brown and Braver [16, 17] hypothesized that ascending projections from midbrain dopamine neurons to the ACC may actively inhibit the firing of the ACC and transient depressions below baseline fire rates of midbrain neurons may disinhibit the ACC, which subsequently releases ERN. In summary, monitoring and cognitive appraisal are relevant to recognizing error-related feedback, which allows an individual to decide, based on the error-likelihood prediction model, how much mental effort is required not only to successfully navigate toward a task, but also for active engagement as a reaction to adverse and unprecedented circumstances, which fosters mental health.

5. Mental Health and Psychopathology

Whether an individual is susceptible to psychopathology because of disrupted monitoring and cognitive appraisal or is prone to a more positive mental state might be a function of how cognitive control and emotional regulation develop and form regular behavioral regulation patterns—such as a hyperreactive cognitive control style (see [8], [18], and [19])—based on the first and gradually maturing responses to emotional stimuli. The capabilities to exert cognitive control increase with development and coincide with the maturation of brain regions in the prefrontal cortex. Tang et al. [20] showed that although neuroimaging methods offer certain advantages in explaining specific neuroanatomic differences between healthy and clinically ill patients, behavioral paradigms may be more effective in predicting lifetime psychopathology through emotional conflict resolution tasks. Specifically, individuals exhibiting higher levels of mental health and those free from lifetime psychopathology demonstrate superior emotional conflict compared to individuals with a lifetime diagnosis [20]. Correspondingly, the lifetime prevalence of psychological disorders can be traced back to infantile behavioral tendencies such as behavioral inhibition, hypersensitivity to conflict, and emotional regulation skills, which require adequate appraisal and monitoring [20]. Electrophysiological studies have evidenced that successful monitoring and appraisal are often associated with increased activity in the dmPFC (see [21]). To summarize, the same brain regions responsible for cognitive control might be responsible for successful conflict monitoring and cognitive appraisal, which is a necessary predecessor of emotional regulation. Emotional regulation, in turn, is associated with adaptive behavioral responses and may thus correspond to long-term endeavors that favor positive mental health outcomes.

6. Emotional Regulation

Contrary to more traditional formulations of emotional regulation that emphasize the difficulty to maintain competent functioning, newer perspectives highlight how emotions organize and construct social communication and interaction, goal achievement, personality process, and cognitive processes from an early age [22]. Neurofunctionalists view emotional arousal as a capacity that can undermine healthy functioning, which is detrimental to competency, but also a major motivator that can act as a “behavior motivator” [22]. Emotional regulation is thus central to the realization of cognitive control. Specifically, proactive cognitive control, when measured behaviorally, should decrease if the motivation to enact the required competency is low. In this case, reactive cognitive control—which requires less cognitive resources and is thus preferred by individuals with either low motivation or fewer cognitive abilities—should step in to spare performance. In highly predictable contexts, individuals with low motivation profit from a more active reactive cognitive control. In low predictable contexts, however, more cognitive resources are required to successfully navigate toward the desired goal. Correspondingly, Alker [8] demonstrated that individuals endorsing reactive cognitive control as a standard mode of control tend to endorse maladaptive coping strategies, such as avoidance behaviors and emotional dysregulation. That is, individuals endorsing reactive cognitive control lose the ability to adapt and navigate toward new situations and circumstances and are prone to avoid distress and its detrimental consequences as their self-efficacy diminishes with aggravating detrimental coping strategies.

7. Cognitive Control and Self-Efficacy

Self-efficacy is of high relevance with respect to how much effort is invested in a demanding task. Reactive cognitive control is more automatized and requires less mental effort compared to proactive cognitive control, which is a more conscious mode of functioning [3]. An individual who frequently endorses a reactive mode of cognitive control spares mental effort. However, the frequent use of reactive cognitive control as a habit leads to a hyperalert state of mind, which is strongly related to negative affect in the face of stress, lower resilience, and high levels of anxiety, depression, and debilitation [23]. An individual with high self-efficacy will invest more mental effort in diverse circumstances because of the individual's belief systems. That is, an internal locus of control or the belief to be in control of external and internal events is associated with levels of mental effort that predispose them toward a habitual use of proactive cognitive control as a default mode of action [3, 24]. Conversely, an external locus of control will lead to the feeling of hopelessness, which means that individuals endorsing such a worldview will be less likely to invest mental effort, thus predisposing them toward reactive cognitive control as a standard mode of functioning and to a hyperalert mind [25].

8. Cognitive Control and Treatment Beliefs

Cognitive control is relevant for patients and psychological as well as medical experts to adhere to and achieve relevant aims [26, 27]. For example, Keng et al. [28] found that individuals exhibiting more adaptive health behaviors possess better self-related and optimistic health beliefs, including better health-related outcomes and lower levels of psychopathology. An individual's belief in whether a treatment will be successful is closely related to self-efficacy beliefs [24, 29]. Individuals exhibiting a higher extent of perceived self-efficacy are more likely to exert mental effort in treatment settings, which is vital for treatment success [30, 31]. The relation between proactive and reactive cognitive control and treatment beliefs has not been researched before [3]. This study explores the impact of cognitive control, that is, proactive versus reactive cognitive control, self-efficacy beliefs, and treatment beliefs on mental health and vice versa (for further literature, see [32, 33]).

9. Medical and Psychotherapeutic Settings

In medical and psychotherapeutic settings, cognitive control can inform clinical practice by providing relevant insights into how cognition relates to psychopathologic disorders. For instance, cognitive control examination showed predominant deficits in working memory for patients with schizophrenia, ADHD, and Parkinson's disease. Additionally, the AX-continuous performance test (AX-CPT) has been used to investigate the impact of stress, fatigue, the effect of motivation, and mental effort and aging on cognitive performance, making it a versatile tool in psychiatry, psychology, neuroscience, and neurology. Cognitive control as a transdiagnostic indicator is thus one of the best indicators in investigating the intersection between psychiatry, psychology, neuroscience, and neurology. The division of cognitive control into its two subfunctions, proactive and reactive cognitive control, allows exploration of the hitherto unknown relation between cognition and mental health status. Until now, the relation between psychopathology and cognition has been explored, but not toward mental health in consideration of emotional regulation strategies. The overall goal of this research is to delineate these relations including mental health as a separate but related continuum of psychopathology.

10. Cognitive Control Training

Cognitive control training has been associated with significant improvements in overall cognition. However, the relation between proactive cognitive control, treatment beliefs, self-efficacy, and mental health remains unclear. A method to investigate and train cognitive control is the AX-CPT. The AX-CPT is a cognitive control task designed to assess, whether individuals are more predisposed toward a proactive versus reactive cognitive control as a default mode of action. In this task, the participants are presented with a series of either red or white letters, with the target of a red X and Y combination. The participants are asked to entirely ignore the white letter while pressing on a two-key keyboard, the left key if a red X is presented and to press the left key if a red A is followed by a red X. In all other cases, the participants are asked to press the right key. The AX-CPT is employed in both clinical and research settings to explore cognitive processes in patients with neurological and psychiatric disorders, as well as in healthy populations.

11. Present Study

Following the theoretical model of cognitive control and mental health [8], this study experimentally investigates how cognitive control is related to mental health. The corresponding research question is "How is cognitive control related to mental health?" The included variables are denoted as proactive cognitive control, reactive cognitive control, self-efficacy, treatment beliefs, and mental health. The presumed relations between the aforementioned variables are illustrated in Figure 1.

12. Monitoring and Cognitive Appraisal

In addition to psychological and motivational variables, such as self-efficacy, motivation, mental effort, and treatment beliefs, monitoring is here conceived of as an individual's (1) ability to monitor, (2) cognitive appraisal as the knowledge of one's own cognitive capabilities, and the ability to (3) evaluate, reflect, and adapt cognitive functioning to the requirements of the cognitive task. In this article, the terms "monitoring" and "cognitive appraisal" are used deliberately and strategically. This broader formulation not only encompasses real-time assessment, but also includes declarative knowledge about cognition and the regulation of cognitive strategies beyond momentary performance.

13. Hypotheses

An experiment will be conducted to experimentally test the hypotheses that proactive cognitive control is (causally) related to mental health, and that reactive cognitive control is (causally) negatively related to mental health, and that motivational factors such as treatment beliefs and self-efficacy are positively related to proactive cognitive control and mental health and negatively related to reactive cognitive control as standard modes of cognitive control.

Correspondingly, the following hypotheses are stated below and illustrated in Figure 2:

Primary hypotheses:

1. Proactive cognitive control can be modified by cognitive training. Proactive cognitive control can be experimentally modified by repeated administration of a cognitive task. The cognitive task is the administration of the AX-CPT.
2. Effectiveness of AX-CPT training:
3. The AX-CPT training leads to overall improvement of cognitive control.
4. Mental health, motivational factors, and cognitive control.
5. Proactive cognitive control is related with mental health, treatment beliefs, and self-efficacy.
6. Cognitive appraisal moderates the relation between cognitive performance and high levels of mental health.

14. Methods

14.1. Participants. This study includes an experimental design with two groups: an experimental group and a control group. Cohen [34] and Field [35] recommend at least 20 participants per group in an experimental design. Correspondingly, 30 participants of both the experimental ($n = 30$) and the control group ($n = 30$) were recruited in geriatric unit of the St. Franziskus-Hospital in Winterberg, Germany (Figure 3). Patients of the geriatric unit undergo a 2-weekly prerehabilitative treatment and are treated multiprofessionally with medical, physiotherapeutic, occupational-therapeutic, sociotherapeutic as well as clinical, and neuropsychological treatments. The difference between control and experimental intervention was the regular administration of the AX-CPT in the experimental group on a 2-day one-time basis. The administration entailed—-depending on the medical status—three to five training sessions.

15. Materials

15.1. Mental Health Continuum-Short Form (MHC-SF). The MHC-SF is a 14-item self-report measure assessing emotional, psychological, and social well-being. It has demonstrated high internal consistency and a validated three-factor structure [10, 36]. Responses are rated on a six-point Likert scale (1 = *never* to 6 = *everyday*). Mental health is conceptualized as distinct from psychopathology, existing on a separate but related continuum [10].

15.2. General Self-Efficacy Scale (SWE). The SWE is a 10-item scale measuring perceived self-efficacy (Schwarzer and Jerusalem [37]). It shows strong internal consistency across

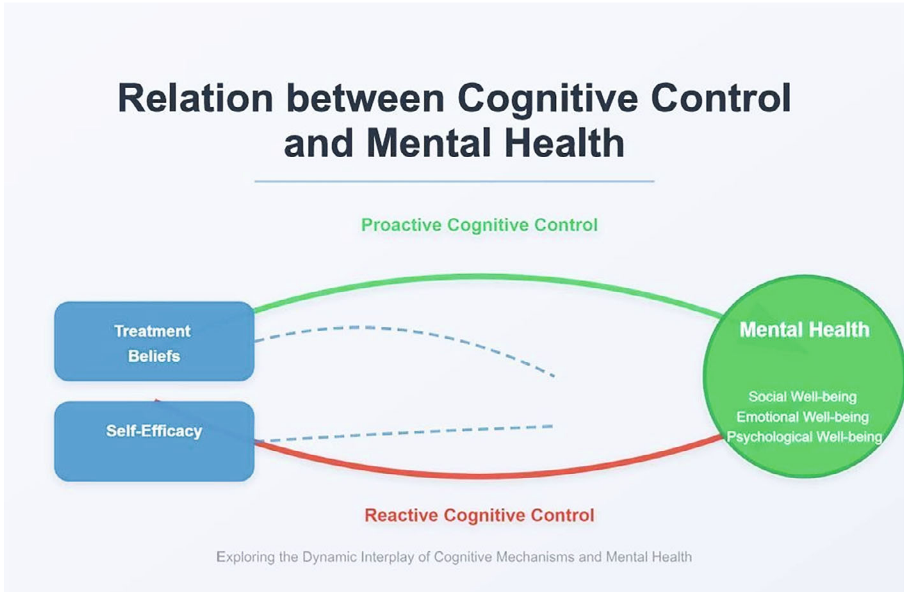

Figure 1: Exploring the dynamic interplay of cognitive control and mental health. Note that treatment beliefs presumably interact positively with proactive and negatively with reactive cognitive control, whereas high self-efficacy beliefs are associated with a stronger proactive and weaker reactive cognitive control. Low levels of these motivation (i.e., treatment and self-efficacy beliefs) factors have the opposite impact. Higher motivational factors presumably increase proactive cognitive control and decrease reactive cognitive control, whereas the former has a positive and the latter a negative impact on mental health.

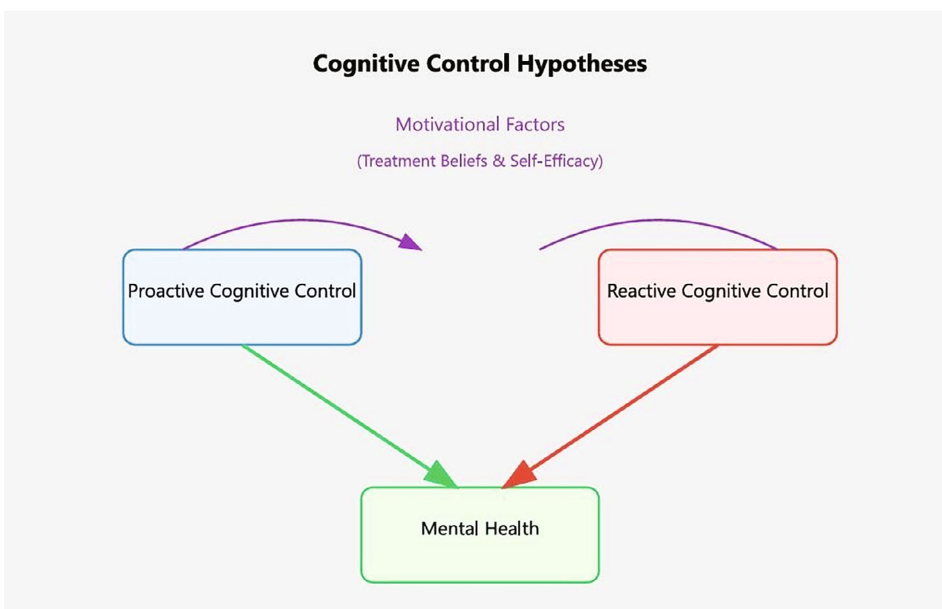

Figure 2: Cognitive control hypotheses.

international samples ($\alpha = 0.76 - 0.90$; [38]) and robust criterion validity [39]. Items are rated on a four-point Likert scale (1 = *not at all true* to 4 = *exactly true*).

15.3. Palermo Questionnaire. This instrument assesses treatment beliefs in rehabilitative contexts, focusing on expectations, perceived effectiveness, and engagement [40]. It offers insight into subjective treatment concepts relevant to rehabilitation outcomes [41]. Responses are provided on a Likert scale.

15.4. Cognitive Control and Flexibility Questionnaire (CCFQ). The CCFQ is an 18-item measure of cognitive control and emotional regulation, emphasizing cognitive flexibility as a marker of proactive control [42]. Items are rated on a Likert scale, with higher scores indicating greater cognitive adaptability.

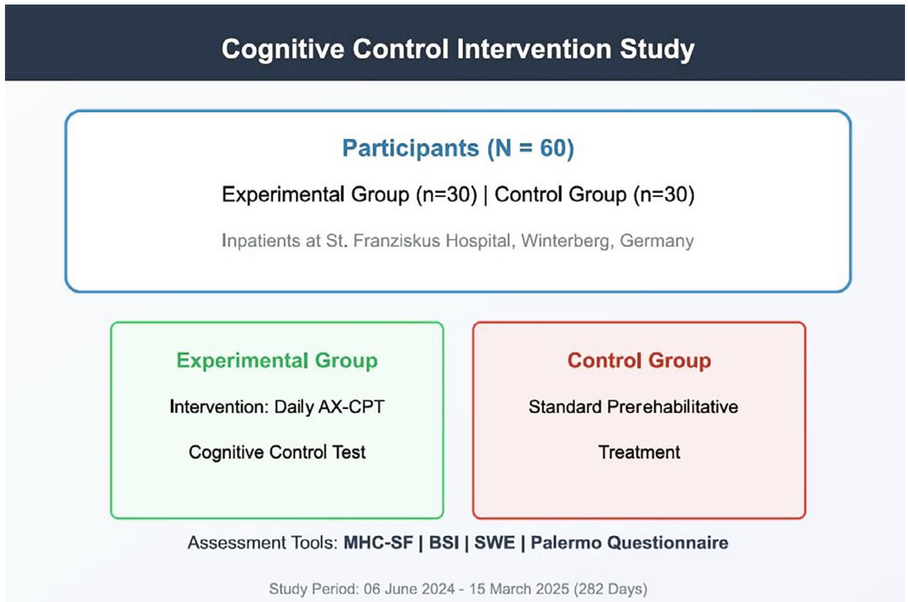

FIGURE 3: Control intervention study.

15.5. AX-CPT. The AX-CPT assesses context processing and goal maintenance. The participants respond to letter sequences, with correct responses required only for the target pair "A" followed by "X." Nontarget trials (AY, BX, and BY) test inhibitory control and goal maintenance [3, 43]. The task is widely used in clinical research to evaluate cognitive control mechanisms.

15.6. Proactive and Reactive Cognitive Control. Cognitive control was assessed using the AX-CPT, which distinguishes between proactive and reactive control modes [3]. Proactive control involves the sustained maintenance of goal-relevant information to guide behavior in anticipation of upcoming demands. In contrast, reactive control is recruited transiently in response to interference or unexpected stimuli, enabling flexible adjustment and error correction.

In the AX-CPT, participants respond to cue–probe letter sequences. A target response is required only when the cue "A" is followed by the probe "X" (AX trials). Nontarget trials (AY, BX, and BY) assess the ability to inhibit prepotent responses and adapt to context. For example, correctly withholding a target response on a BX trial (nontarget cue followed by target probe) reflects reactive control, as it requires overriding an automatic response tendency.

To quantify the balance between proactive and reactive control, the proactive behavioral index (PBI) was calculated following standard procedures [44]. The PBI combines error rate (ER) and reaction time (RT) contrasts between AY and BX trials (see Figure 4):

$$\mathrm{PBI} = \left(\frac{\mathrm{ER}_{BX} - \mathrm{ER}_{AY}}{\mathrm{ER}_{BX} + \mathrm{ER}_{AY}}\right) + \left(\frac{\mathrm{RT}_{AY} - \mathrm{RT}_{BX}}{\mathrm{RT}_{AY} + \mathrm{RT}_{BX}}\right).$$

Higher PBI values indicate a stronger reliance on proactive control. This metric was used to test hypotheses regarding individual differences in cognitive control dynamics.

15.6.1. Procedure. The data collection period encompassed 511 days. It started on December 16, 2023, and ended on March 9, 2025. The questionnaire was administered to all participants within the first and the last 24 h of the pre-rehabilitative treatment as pretests and posttests, respectively. Ethical approval for the study was obtained from the ethics committee of the St. Franziskus-Hospital (2024-01k). The hypotheses were tested using nonparametric tests to evaluate the relation between all the variables included in the study and changes in participants' pretest and posttest scores. The participants were selected based on their status as inpatients and participation in the pre-rehabilitative treatment at the geriatric unit of the St. Franziskus-Hospital Winterberg, located in Germany. The pre-rehabilitative treatment is ideal for experimental studies in experimental and applied neuropsychology because the treatment encompasses 14–21 days, making it possible to administer the treatment in a short-term time period and thus observe experimentally induced effects. The administered questionnaires and the obtained data were part of the regular clinical assessment (Table 1).

15.6.2. Data Analysis. This study employed an experimental pretest–posttest design, in which participants were randomly assigned to either the experimental or control condition. The primary objective was to examine whether cognitive control training using the AX-CPT can modify the behavioral indicator of proactive cognitive control while improving overall cognitive control, thereby positively influencing self-efficacy, treatment beliefs, and mental health outcomes. The participants were recruited from the geriatric unit at St. Franziskus-Hospital in Winterberg, Germany, where they underwent a 2-week premultiprofessional rehabilitative therapeutic treatment. The study measured key psychological and cognitive variables, including the PBI,

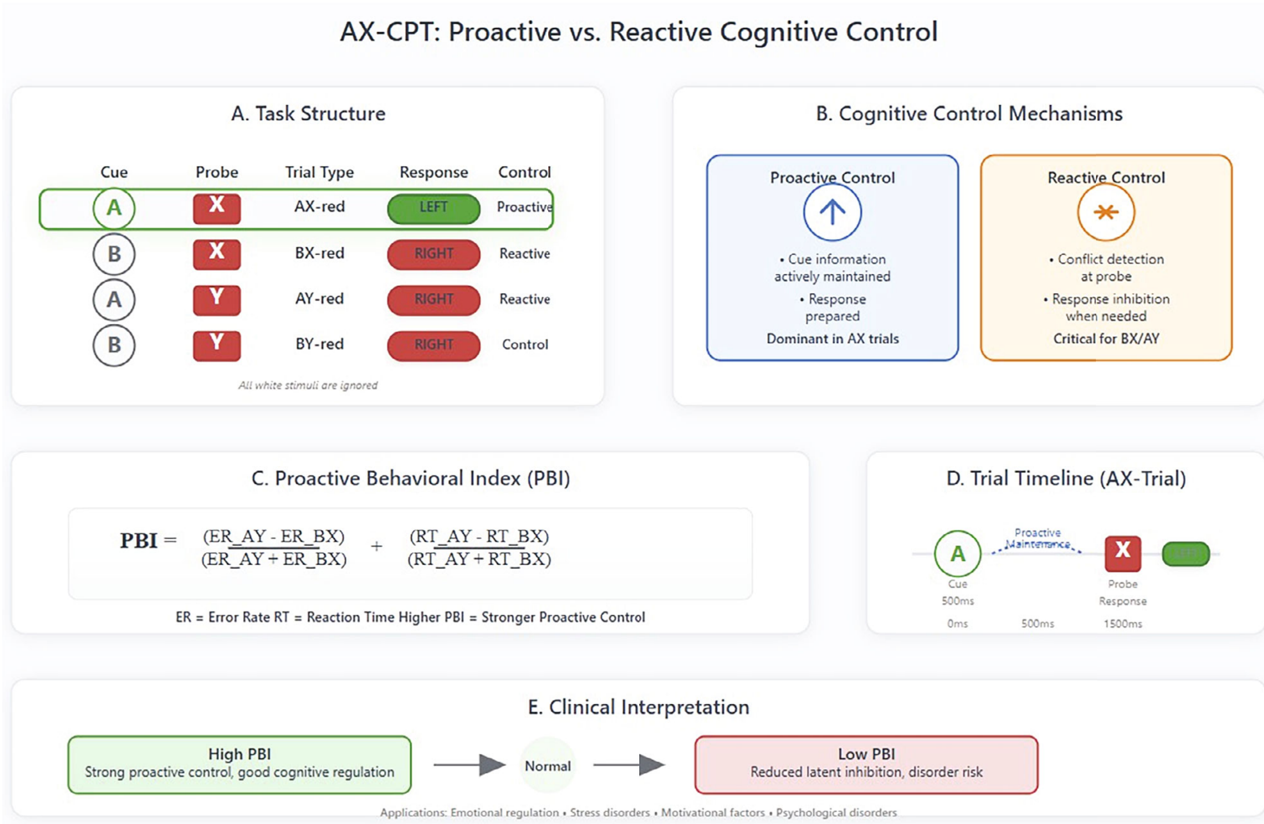

Figure 4: AX-CPT: proactive versus reactive cognitive control.

TABLE 1: Questionnaires, number of items, variables, subscales, and measures of the study.

Questionnaires	Number of items	Variable	Subscales and measures
CCFQ	9	Cognitive control	Appraisal and coping
CCFQ	9	Emotional regulation	Flexibility
			Cognitive control over emotion
	18	Self-reported cognitive	Appraisal and coping
		Control	Flexibility
			Cognitive control over emotion
SWE	11	General self-efficacy	Self-efficacy
PALERMO	5	Treatment beliefs	Treatment beliefs
MHC-SF	14	Mental health	Social well-being
			Psychological well-being
			Emotional well-being

self-efficacy (SWE), mental health (MHC-SF), psychological symptom severity (BSI-18), treatment beliefs (Palermo), and cognitive appraisal (CCFQ).

The statistical analysis followed a multistep approach, beginning with descriptive statistics to summarize mean values, standard deviations, and distribution properties. Correlation analyses (Pearson/Spearman) were conducted to examine relationships between PBI and psychological symptoms (BSI-18), as well as to exclude potential group differences at pretest. The Kolmogorov–Smirnov test was performed to assess the normal distribution of variables. As the results indicated significant deviations from normality ($p < 0.05$), nonparametric tests were applied.

To test Hypothesis 1, which posited that cognitive control training would lead to an increase in proactive control whereas reducing reactive control, a Mann–Whitney U test was conducted to compare PBI scores between the experimental and control groups. Given the dichotomous nature of group allocation and non-normal data distribution, this test was deemed the most appropriate for assessing differences in cognitive control regulation due to repeated AX-CPT exposure. The analysis investigated whether participants in the experimental condition exhibited a stronger reliance on proactive cognitive control relative to those in the control condition.

Hypothesis 2 explored whether overall cognitive performance and ability can be improved by the repeated administration of the AX-CPT. A Mann–Whitney *U* test comparing the median of the average percent as indicator of cognitive ability and performance between the control and experimental group at posttest was conducted due to the non-normal distribution. Hypothesis 3 explored the association between PBI and psychological disorders, particularly whether lower proactive control at posttest correlated with higher levels of mental health. A Spearman correlation was performed across all 60 participants, independent of group allocation, assessing whether how cognitive control and its subfunctions are related to mental health. The relationships between the variables were examined and evaluated using Spearman's one-sided correlation coefficient.

Hypothesis 4 examined the moderation effect of cognitive appraisal in the relationship between cognitive control and psychological symptoms. The experimental condition, which involved performance feedback, was expected to enhance monitoring and cognitive appraisal capabilities, and consequently, cognitive appraisal was hypothesized to moderate the relationship between cognitive performance and psychological disorders. To test this, a moderated regression analysis was conducted using the PROCESS macro for SPSS (Version 4.2), designed to assess interaction effects in conditional process models. A Preacher and Hayes moderation analysis was employed to determine whether proactive behavioral tendencies significantly altered the strength and direction of the relationship between cognitive task achievement and psychological symptoms.

The dependent variable in this analysis was high levels of mental health, whereas the predictor variable was cognitive task achievement (percent correct), and the moderator variable was cognitive appraisal. The upper half of a median split was used to categorize high levels of mental health. A Model 1 moderation structure was specified within the PROCESS macro, incorporating bootstrapped confidence intervals (95%) to enhance the stability of parameter estimates. Given the non-normality of data distribution, the analysis employed 5000 bootstrap resampling iterations, ensuring the robustness and reliability of parameter estimates. To further interpret interaction effects, simple slope analyses were conducted at low (16th percentile), moderate (50th percentile), and high (84th percentile) levels of self-reported proactive behavioral tendencies, providing insights into how the relationship between cognitive performance and high levels of mental health varies based on cognitive appraisal.

This methodological approach allowed for a comprehensive investigation of how performance feedback increases cognitive appraisal, that is, the relation between self-perception and cognitive performance, according to Flavell's [45] definition of cognitive appraisal as an individual's knowledge about their own cognition and control of cognition proceeding from accurate monitoring.

16. Results

The descriptive analyses and initial correlations for all considered variables are presented in Tables 2, 3, and 4.

Table 2 provides an overview of the descriptive statistics, detailing the range, mean, and standard deviation. The pretest correlations show no significant relationship between group allocation and the examined variables. However, correlations observed at the posttest stage tended to become stronger.

The distribution of self-reported PBI scores deviated from normality, with a skewness of −1.138 (SE = 0.221) and a kurtosis of 0.421 (SE = 0.438). Emotional regulation scores also showed a non-normal distribution, exhibiting a skewness of 0.452 (SE = 0.221) and a kurtosis of −0.160 (SE = 0.438). Similarly, cognitive control scores were not normally distributed, with a skewness of −1.055 (SE = 0.221) and a kurtosis of 1.569 (SE = 0.438).

Scores related to treatment beliefs demonstrated non-normal characteristics as well, with a skewness of −1.031 (SE = 0.221) and a kurtosis of −0.111 (SE = 0.438).

Self-efficacy scores were also found to be non-normally distributed, with a skewness of −0.490 (SE = 0.221) and a kurtosis of 0.115 (SE = 0.438). Mental health scores showed a non-normal distribution (Figure 5), indicated by a skewness of −1.015 (SE = 0.221) and a kurtosis of 0.749 (SE = 0.438). In contrast, behavioral PBI scores approximated a normal distribution, with a skewness of −0.024 (SE = 0.221) and a kurtosis of 0.284 (SE = 0.438). Finally, the AX-CPT percentage scores displayed a pronounced non-normal distribution, with a skewness of −2.058 (SE = 0.221) and a kurtosis of 6.842 (SE = 0.438).

16.1. Reliability of the Measurement Data. The overall survey demonstrated strong internal reliability, as evidenced by a Cronbach's alpha of $\alpha = 0.88$, indicating a good to excellent level of internal consistency.

16.2. Use of Nonparametric Tests. Nonparametric tests were used to account for the non-normal distribution, including Spearman correlation, to draw reasonable conclusions based on the results.

Hypothesis 1. *The first hypothesis was that the PBI can be experimentally modified by repeated exposure. The Mann–Whitney U test showed a significant difference between control (median = 36.73) and experimental group (median = 24.26) and thus indicate that PBI can be modified (Table 5).*

Hypothesis 2. *The second hypothesis was that cognitive control can be modified by repeated exposure to the cognitive task. The hypothesis was confirmed. Individuals in the experimental group exhibited an improvement in overall cognitive control. The difference between pretest and posttest in the control group was nonsignificant. The difference in the experimental group was highly significant ($p < 0.001$). The Mann–Whitney U test showed a significant difference between control (median = 19.80) and experimental group ($M = 41.30$)*

TABLE 2: Descriptive statistics for the overall dataset.

Variable	N	Minimum	Maximum	Mean	Standard deviation
Self-reported					
Cognitive appraisal	120	1.44	7	5.68	1.49
Emotional Regulation	120	1.67	6	3.40	0.91
S-cognitive Control	120	1.83	6.22	4.54	0.89
Treatment Beliefs	120	1	5	5.08	1.19
Self-efficacy	120	1.55	3.64	3	0.48
Behavioral	120	1.67	5.60	4.43	0.87
B-PBI	120	−0.82	0.21	−0.27	0.21
Cognitive control (%)	120	5	100	77	13.77

Note: S-cognitive control = self-reported. B-PBI and B-cognitive control = behavioral data.

TABLE 3: Zero-order correlations for all included variables of the complete dataset.

	1	2	3	4	5	6	7	8
Self-reported								
1. S-PBI	1							
2. Emotional regulation	−0.083	1						
3. S-cognitive control	0.758**	0.497**	1					
4. Treatment beliefs	0.467**	−0.262**	−0.197*	1				
5. Self-efficacy	0.380**	−0.328*	0.192*	0.446**	1			
6. Mental health	0.427**	−0.278**	0.208*	0.486**	0.578**	1		
Behavioral								
7. B-PBI	−0.185*	0.041	−0.081	−0.114	−0.185*	0.013	1	
8. B-cognitive control	0.149	−0.001	0.098	0.021	0.029	−0.039	−0.635**	1

Note: S-PBI and S-cognitive control = self-reported. B-PBI and B-cognitive control = behavioral data. Single asterisk (*) indicates data smaller than 0.05 while double asterisks (**) indicates data smaller than 0.01.

TABLE 4: Zero-order correlations for all included variables at posttest.

	1	2	3	4	5	6	7	8
Self-reported								
1. Cognitive appraisal	1							
2. Emotional regulation	−0.22*	1						
3. S-cognitive control	0.711**	0.442**	1					
4. Treatment beliefs	0.336*	−0.418**	0.027*	1				
5. Self-efficacy	0.371**	−0.334*	0.171	0.576**	1			
6. Mental health	0.336**	−0.420**	0.045	0.576**	0.521**	1		
Behavioral								
7. B-PBI	−0.196	−0.034	0.118	0.269	0.084	−0.039	1	
B-cognitive control	0.257*	0.134	0.294*	−0.024	−0.034	−0.003	−0.558**	1

Note: S-cognitive control = self-reported. B-PBI and B-cognitive control = behavioral data. Single asterisk (*) indicates data smaller than 0.05 while double asterisks (**) indicates data smaller than 0.01.

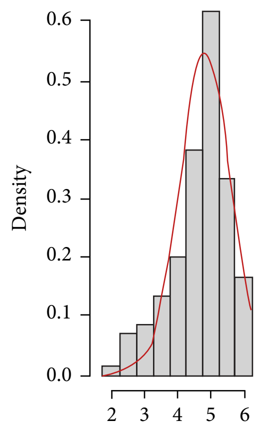

FIGURE 5: Scores on mental health were non-normally distributed because a small but significant part of the geriatric sample exhibited an exceedingly positive mental health.

TABLE 5: Descriptive statistics of behavioral PBI at posttest.

	N	Mean	Standard deviation	Minimum	Maximum
PBI	60	−0.2960	0.221	−0.82	0.21

and indicates that cognitive control can be experimentally modified (Table 5).

Medians and ranks for the Mann–Whitney *U* test are illustrated in Tables 6 and 7.

Hypothesis 3. *The third hypothesis was that mental health, motivational factors, cognitive control, and proactive cognitive control are related with mental health, treatment beliefs, and self-efficacy. The hypothesis was partly supported. Although self-reported measures were mostly strongly correlated with each other, the relation between cognitive appraisal and behavioral measures were mostly nonsignificant and not always in the expected direction. For example, the relation between cognitive appraisal and behavioral PBI was marginally significant (p = 0.067). The relationship was negative.*

Hypothesis 4. *To examine whether cognitive appraisal moderates the relationship between cognitive performance and mental health, a moderated logistic regression analysis was conducted using the PROCESS procedure for SPSS (Hayes 2022). A total of 5000 bootstrap samples were used to address potential non-normality issues. The overall model was statistically significant, $\chi^2(3) = 10.78$, p = 0.013, explaining 21.93% of the variance in mental health. The results establish both cognitive performance and cognitive appraisal as major indicators of mental health. Higher cognitive performance was positively associated with better mental health (b = 0.3440, SE = 0.1945, Z = 1.7683, p = 0.0770), indicating that enhanced cognitive efficiency contributes to psychological stability. Similarly, cognitive appraisal showed a significant positive association with mental health (b = 0.6123, SE = 0.3098, Z = 1.9764, p = 0.0481), suggesting that individuals with better cognitive appraisal capabilities experience better mental health outcomes.*

TABLE 6: Ranks for the Mann–Whitney *U* test.

Condition	*N*	Median	Sum of ranks
Experimental group	30	24.27	728
Control group	30	36.73	1102
Total	60		

TABLE 7: Mann–Whitney *U* test.

	Behavioral PBI
Mann–Whitney *U* test	263
Wilcoxon *W*	728
Z	−2.765
Two-sided *p* value	0.006

Critically, the interaction term between cognitive performance and proactive control was marginally significant ($b = -0.0068$, SE = 0.0037, $Z = -1.8355$, $p = 0.0664$), pointing to a more intricate relationship between objective cognitive control mechanisms and subjective self-regulation strategies. Further analysis of conditional effects revealed distinct patterns at low (16th percentile, 36.0), moderate (50th percentile, 57.0), and high (84th percentile, 63.0) levels of cognitive appraisal. At low levels, cognitive performance was positively associated with mental health ($b = 0.0993$, SE = 0.0642, $Z = 1.5467$, $p = 0.1219$), suggesting that individuals with minimal proactive tendencies still benefit from higher cognitive efficiency. At moderate levels, the effect reversed ($b = -0.0435$, SE = 0.0294, $Z = -1.4778$, $p = 0.1395$), indicating that increased cognitive performance might correspond with higher mental health problems, possibly due to heightened awareness of psychological distress. At high levels, a stronger negative association emerged ($b = -0.0843$, SE = 0.0465, $Z = -1.8140$, $p = 0.0697$), highlighting that individuals with strong proactive tendencies may experience an intensified awareness of distress, amplifying mental health challenges.

These findings suggest that the relationship between cognitive performance and mental health is not linear but rather contingent upon varying levels of cognitive appraisal. Although cognitive efficiency may generally contribute to mental health, its effects appear to differ depending on the level of self-reported cognitive appraisal, underscoring the importance of considering individual differences in self-regulation strategies when assessing cognitive contributions to mental health outcomes.

17. Discussion

17.1. Cognitive Control and Mental Health. Too much detail on peripheral stimuli can impede the ability to process central and goal-relevant information [8, 46], which is a precursor of cognitive control—particularly proactive cognitive control. Without an effective filter mechanism, individuals lose the ability to pool and consolidate the focus required for achievement and a fulfilled, happy life (see Figure 6). Accordingly, integrating cognitive control—especially its proactive form—is a fundamental impact factor in understanding the relationship between cognition and mental health. Monitoring and cognitive appraisal appear to moderate this relationship, as they influence the alignment between cognitive tendencies and mental health outcomes. Although broader frameworks such as Maslow's hierarchy of needs or evolutionary psychology offer context, they remain peripheral to the study's core findings and are therefore, not emphasized further.

17.2. Monitoring and Cognitive Appraisal. The findings of this study highlight the intricate relationship between cognitive control, monitoring, and self-cognitive appraisal in shaping mental health outcomes. Cognitive appraisal—the ability to reflect on and regulate one's cognitive processes—largely determines whether individuals adopt proactive versus reactive cognitive control strategies. Monitoring, in turn, influences the extent to which individuals accurately assess their cognitive abilities, which enables and precedes cognitive appraisal. These findings align with the DMC [3], which distinguishes between proactive and reactive cognitive control. Proactive control, characterized by sustained goal-directed attention, has been associated with improved mental health outcomes, whereas reactive control, which is engaged in response to interference, has been linked to heightened stress and cognitive difficulties. Neuroscientific research supports the link between evaluative cognitive appraisal and proactive control as a more effortful, less automatic process [47]. This activation enables individuals to maintain task goals and regulate attention, reducing susceptibility to stress-related cognitive impairments. The role of monitoring and appraisal in this context is consistent with metacognitive models (Martiadis et al. 2023), which emphasize the importance of meta-awareness in mental health.

17.3. Self-Perception and Mental Health. Self-perception plays a pivotal role in moderating the relationship between cognitive control and mental health outcomes. Individuals with high self-efficacy—the belief in one's capacity to manage challenging situations—are more likely to employ proactive cognitive control strategies [24]. Bandura [24] and Schwarzer & Renner [31] consistently demonstrated that self-efficacy enhances adaptive coping and fosters psychological resilience. In contrast, distortions in self-perception may result in mismatches between actual cognitive performance and subjective evaluations. The Dunning–Kruger effect [48] exemplifies how those with lower cognitive abilities tend to overestimate their competence, whereas high-performing individuals may underestimate their capabilities. These inaccuracies can impair monitoring and cognitive appraisal, intensify cognitive dissonance, and exacerbate psychological distress. Although these phenomena are relevant, they are not central to the present findings and are therefore acknowledged but not elaborated upon.

17.4. Monitoring and Cognitive Appraisal in Mental Health. Monitoring and cognitive appraisal—the capacities to observe, interpret, and evaluate one's own cognitive functioning—are increasingly recognized as central mechanisms in the promotion and preservation of mental health. Cognitive appraisal distortions, as highlighted by Seow et al. [49], reflect maladaptive evaluative processes that impair the accuracy of self-assessment. Alterations in monitoring and appraisal have been implicated across a wide range of psychiatric and neurological conditions, with extensive empirical evidence linking these dysfunctions to maladaptive behavior and diminished psychological well-being. Mental health in this framework extends beyond the mere absence of psychopathology. It includes resource-oriented factors such as resilience, distress tolerance, self-actualization, and life satisfaction—dimensions that are influenced by the individual's capacity for self-evaluation and cognitive regulation. The present study identifies a moderating role of self-perception—operationalized through monitoring and appraisal—in the relationship between cognitive control tendencies and mental health outcomes. These findings are consistent with metacognitive literature (Martiadis et al. 2023), which links impairments in monitoring and meta-awareness to symptom severity and reduced well-being.

Hypothesis 1 Resignation in life might be the underlying cause of apathy and diminished social participation. Mental effort might be decisive in determining which control mode is standardly employed. Although reactive and proactive cognitive control represent complementary mechanisms, a pertinent question within this context is whether cognitive control is amenable to modification. A successful intervention necessitates that cognitive control—and mental effort—are malleable. Thus, the first hypothesis was that cognitive control can be modified by repeated exposure. The hypothesis was confirmed. Individuals in the experimental group exhibited a strong improvement in overall cognitive control. In contrast to proactive cognitive control, which diminished successively with each cognitive trial, reactive cognitive control appeared to increase, probably predominantly due to the highly predictive context. Cognitive tasks suffer from the notorious artificiality that entails high levels of predictability. High predictability leads to lower levels of mental effort; that is, reactive cognitive control, as higher predictability necessitates fewer resources to efficiently engage in the task. However, real-life contexts are far more complex—with a higher variety—and require more mental effort due to a lesser degree of predictability.

In Hypothesis 2, although short-term efficiency of reactive cognitive control may lead to overendorsement in highly predictable contexts, it may have a positive impact on cognition, as long as reactive cognitive control is held at bay in the long term. Again, predictability is vital for which cognitive control mode is standardly employed. Proactive cognitive control requires more cognitive resources and plays a pivotal role in maneuvering through complex real-life contexts. It is typically less engaged in highly predictable situations, where task demands are low and reactive control suffices. Conversely, reactive control requires fewer resources and might be more frequently endorsed in a highly predictive context,

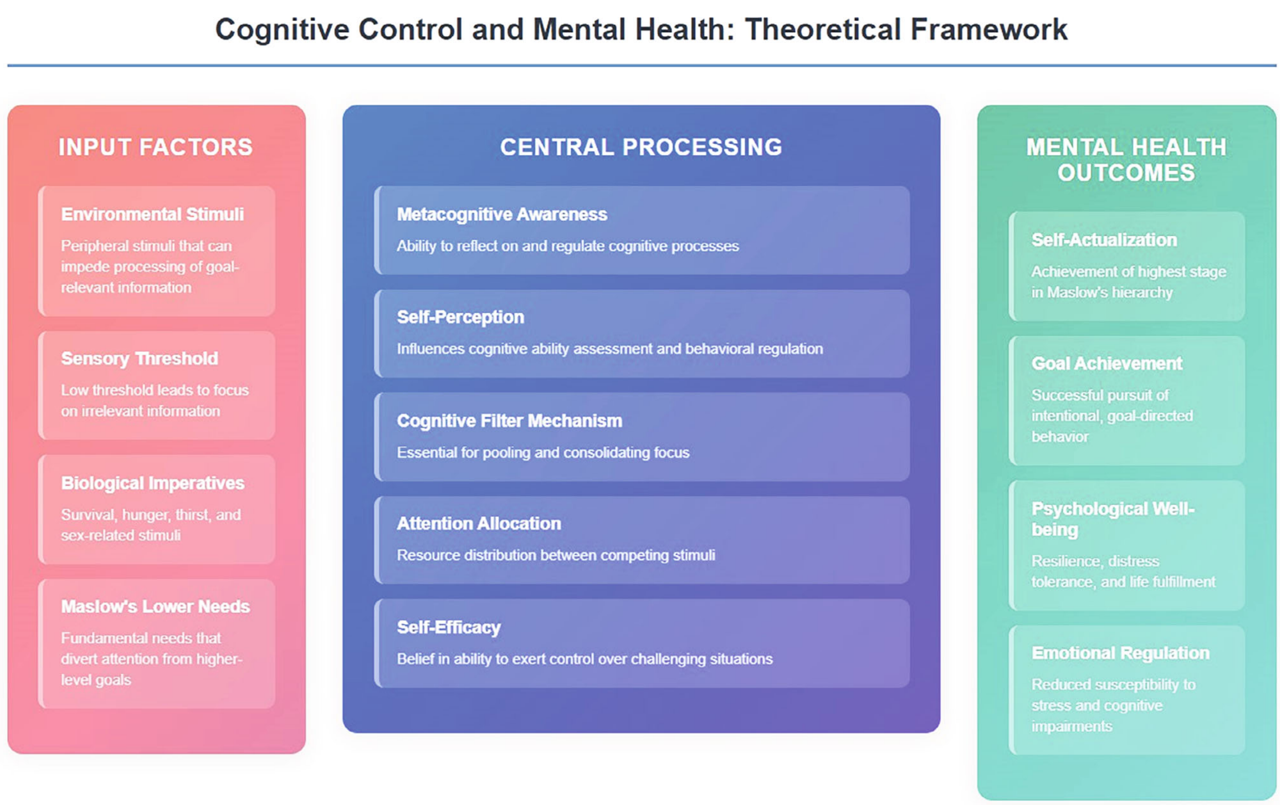

Figure 6: Cognitive control and mental health theoretical framework.

necessitating less mental effort to effectively engage in the task. Correspondingly, it was hypothesized that after repeated exposure to the cognitive task, cognitive performance would increase as predictability allowed individuals to effectively engage in the task, even with reactive control. The hypothesis was supported.

The third hypothesis (Hypothesis 3) was that the PBI is related to mental health, treatment beliefs, and self-efficacy. The hypothesis can be partly supported. Although there was a positive relation toward the self-reported measures, the relation with behavioral measures was insignificant. In addition, psychological and motivational variables such as self-efficacy, motivation, mental effort, treatment beliefs, and cognitive appraisal contribute to the alignment between more objective behavioral data and more subjective self-reported information. Neuropsychological biases, conditions, and disorders—such as anosognosia, the Dunning–Kruger effect, and the influence of social desirability—can distort the extent to which behavioral and self-reported data correspond. The long debate, dating back centuries, on why behavioral and self-reported data display nonsignificant or small correlations can be reconciled by postulating that whether cognitive control is related to mental health or the development of psychological disorders might be a function of cognitive appraisal. A lack of cognitive appraisal might thus be, by and of itself, a sufficient explanation for the missing correlation between subjective and objective data in the realm of neuropsychology and cognitive sciences.

The fourth hypothesis (Hypothesis 4) was that self-reported cognitive control as an indicator of cognitive appraisal moderates the relation between cognitive ability and high levels of mental health. The hypothesis was confirmed. The findings of this study highlight the intricate relationship between cognitive control, monitoring, and cognitive appraisal in shaping mental health outcomes. Based on the findings, it can be postulated that cognitive appraisal—the ability to reflect on and regulate one's cognitive processes—is a major indicator not only in determining the relation between cognition and mental health, but also in establishing cognitive appraisal as a major determinant of mental health.

17.5. Bridging Behavioral and Self-Reported Data. A major challenge in cognitive neuroscience and clinical psychology is the observed lack of correlation between behavioral data and self-reported cognitive control. This discrepancy suggests that objective cognitive performance and introspective evaluation operate via distinct neurobiological mechanisms (see Figure 7). Behavioral data reflect executive functioning and attentional control, whereas self-reported assessments are shaped by cognitive appraisal and emotional biases [3, 26]. To address this gap, structured cognitive appraisal training could refine individuals' ability to accurately assess their cognitive performance, reducing discrepancies between objective execution and subjective evaluation [31]. Additionally, integrating real-time hybrid assessments—where individuals provide introspective judgments immediately after cognitive tasks—may help bridge the gap between behavioral metrics and cognitive appraisal [43]. These approaches are consistent with recent metacognitive assessment frameworks (Martiadis et al. 2023).

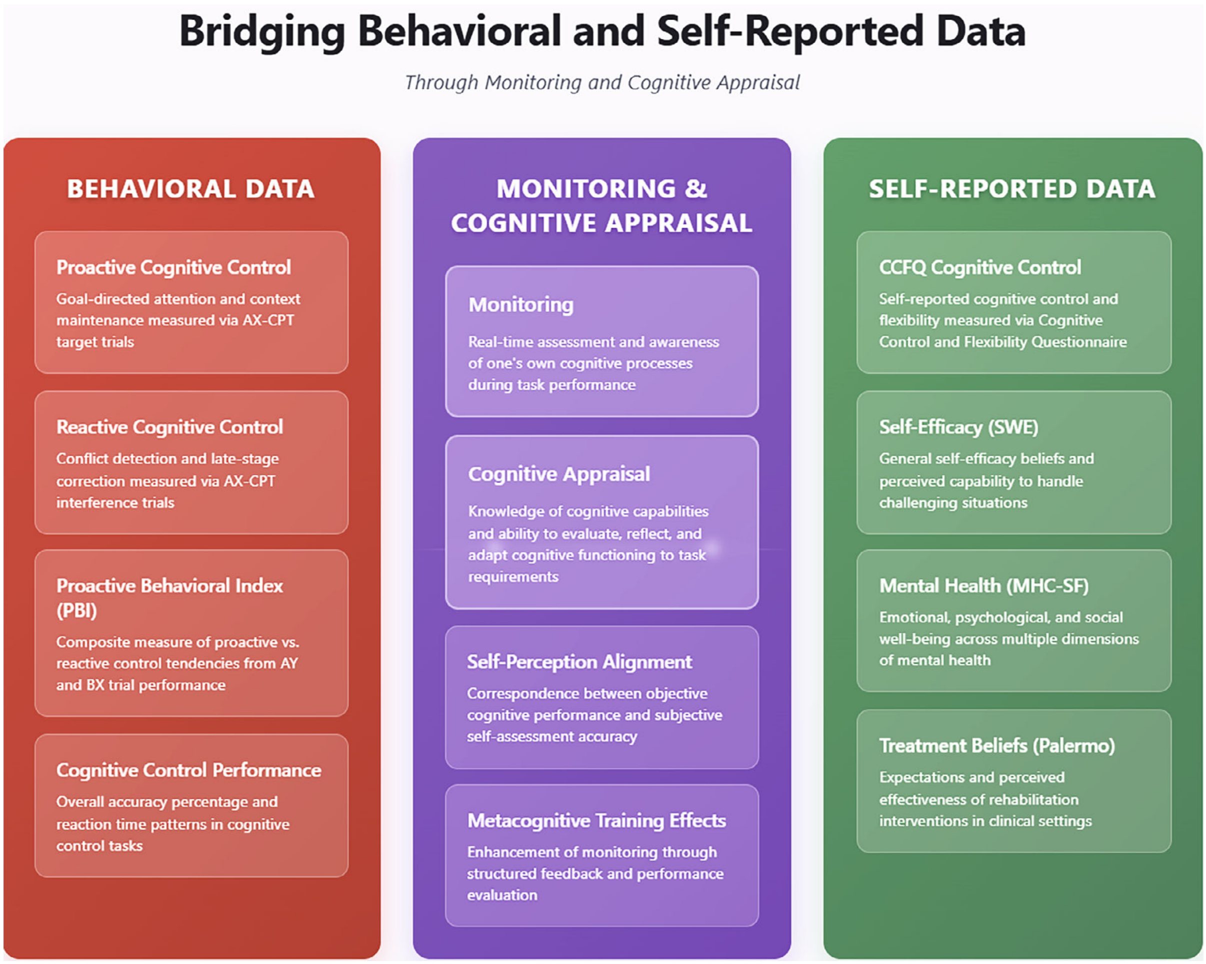

Figure 7: Bridging behavioral and self-reported data through monitoring and cognitive appraisal.

17.6. Monitoring and Cognitive Appraisal. Monitoring and cognitive appraisal—particularly regarding one's cognitive performance and its convergence with objective data—are significantly influenced by neuropsychological phenomena, disorders, and effects such as anosognosia and the Dunning–Kruger effect. These phenomena, and their relationship to cognition and the discrepancy between objective and subjective data, are discussed below. Anosognosia, or the denial of deficits, reflects a breakdown in integrating behavioral data with self-reported awareness, or an inability to adequately process behavioral feedback. The Dunning–Kruger effect, described as a form of "meta-ignorance," arises from a lack of knowledge or expertise that leads individuals to overestimate their competence. Although these effects are relevant, they are not central to the present findings and are acknowledged here primarily to contextualize the broader implications of appraisal distortions.

17.7. Stress Perception. Emerging research suggests that individuals' orientation toward stressful events—and particularly the effectiveness of their behavioral tendencies such as approach or avoidance—is a major predictor of mental health and psychopathology. Although stress is a pervasive feature of modern life, it is not the presence of stress itself but one's mindset toward it that significantly influences the outcomes in determining the consequences of stress.

17.8. Bridging Behavioral and Self-Reported Data: The Impact of Cognitive Appraisal. The observed discrepancy between behavioral performance and self-reported cognitive control presents a critical challenge in both cognitive neuroscience and clinical psychology. This convergence suggests that objective performance and self-evaluation may arise from distinct cognitive and neurobiological systems. Whereas behavioral measures assess executive function and cognitive efficiency, self-reported metrics are influenced by introspection, metacognitive insight, and emotional bias [3, 26]. This divergence is often explained by individual differences in monitoring accuracy and by neuropsychological distortions such as overconfidence, underestimation, and poor cognitive appraisal [48, 49].

To improve convergence between behavioral and self-reported data, several strategies might be considered in future studies:

1. Cognitive appraisal training: Enhancing individuals' ability to evaluate their own performance may reduce the gap between objective and subjective assessments [31].

2. Real-time hybrid assessments: Incorporating introspective judgments immediately following cognitive tasks could help align subjective evaluations with actual performance [43].

3. Neurobiological investigations: Techniques such as fMRI and EEG can help identify neural correlates of self-assessment errors, particularly in regions such as the prefrontal cortex and ACC [50].

4. Longitudinal research: Tracking changes in monitoring and cognitive appraisal over time can reveal the effects of interventions aimed at improving cognitive self-monitoring.

By recognizing cognitive appraisal as a moderating variable, future research can improve diagnostic accuracy, therapeutic outcomes, and the predictive power of cognitive assessments in both experimental and clinical settings.

17.9. Strengths. This study presents several methodological and conceptual strengths that contribute to the broader understanding of cognitive control and its relationship with mental health. First, it employs an experimental design with both control and intervention groups, enhancing the ability to infer causal relationships between cognitive control mechanisms and psychological well-being. The use of the AX-CPT ensures a precise and well-established measurement of proactive and reactive cognitive control, a task widely used in cognitive neuroscience [3]. Furthermore, the study integrates psychological constructs such as self-efficacy and treatment beliefs, extending the DMC beyond its traditional cognitive scope. This multidimensional approach allows for a more comprehensive examination of the interplay between cognition, motivation, and mental health.

From a theoretical perspective, this research contributes to the ongoing discourse on monitoring, cognitive appraisal, and self-perception, reinforcing previous findings that suggest cognitive control can be habitually modified through repeated exposure and by providing evidence that cognitive appraisal can be improved by verbal and auditory feedback [26, 47]. Furthermore, by demonstrating that proactive cognitive control is positively associated with self-efficacy and mental health, it aligns with Bandura's [24] self-efficacy theory, emphasizing the role of cognitive processes in fostering psychological resilience.

17.10. Limitations. Despite its strengths, several limitations should be considered. Firstly, the sample size ($N = 60$) is relatively small, which may limit the generalizability of findings. Although the geriatric inpatient population provides valuable insights into cognitive aging, the results may not fully extend to younger individuals or other clinical populations. Secondly, the reliance on self-reported measures introduces potential biases, such as social desirability or the Dunning–Kruger effect [48], which can distort the alignment between behavioral and subjective data.

Another limitation involves the artificial nature of cognitive tasks, which may not fully capture the complexities of cognitive control in real-world scenarios. Cognitive control tasks, such as the AX-CPT, entail high levels of predictability, whereas real-life contexts are far more dynamic and unpredictable. This discrepancy highlights the need for further research incorporating ecologically valid assessments to better reflect cognitive control processes in everyday life [43].

Finally, although this study explores the relationship between cognitive control and mental health, it does not establish a direct neurobiological mechanism underlying these effects. Future research could integrate neuroimaging techniques, such as fMRI, to examine the neural substrates of cognitive control modifications and their impact on mental health outcomes [50].

17.11. Clinical and Societal Implications

17.11.1. Redefining Mental Health Research and Diagnostics. This study contributes to the field by highlighting the relevance of cognitive appraisal in psychological assessment and therapeutic design. Historically, mental health research has tended to isolate behavioral or self-reported data. This investigation demonstrates the necessity of integrating monitoring and cognitive appraisal to bridge the divide between objective performance and subjective evaluation.

17.11.2. Implications for Research. Cognitive appraisal is more than introspection—it functions as a higher order regulatory process that is governed by monitoring, performance evaluation, and cognitive adaptation. This study underscores that divergences between behavioral and self-reported cognitive control are systematically moderated by individual differences in cognitive appraisal. As such, a shift is needed toward a dual-layered research model that incorporates both performance and meta-representational accuracy.

Future research avenues include the following:

1. Longitudinal modulation of cognitive appraisal: examining how cognitive appraisal can be cultivated through cognitive training or therapy (see Figure 8).

2. Neural network analysis: investigating the interaction between executive control regions and emotional regulation circuits.

3. Cross-domain relevance: exploring the impact of cognitive appraisal role in fields such as decision-making, educational psychology, and organizational behavior.

17.12. Clinical Applications. The inclusion of cognitive appraisal as a clinical variable has far-reaching consequences:

- Tailored interventions: Patients with accurate self-assessment may benefit from cognitive training, whereas those with distorted self-perception may need

Figure 8: Future research directions.

interventions focused on improvement of cognitive appraisal and monitoring capabilities.

- Improved diagnostics: Identifying patterns of overestimation or underestimation can increase diagnostic precision, especially in disorders such as depression, OCD, and schizophrenia.
- Enhanced neurorehabilitation: Cognitive appraisal-based assessments can inform cognitive rehabilitation strategies in cases of TBI or neurodegenerative diseases.

17.13. Societal Relevance. Beyond clinical practice, cognitive appraisal holds a societal value. Accurate self-assessment is crucial in high-stakes domains such as education, leadership, and performance under pressure. Institutions could benefit from implementing structured programs aimed at enhancing monitoring and cognitive appraisal to foster resilience, reduce burnout, and improve decision-making.

18. Conclusion

This study positions cognitive appraisal as a central construct in cognitive science, clinical psychology, and mental health care. This study demonstrated that monitoring and cognitive appraisal can explain the lacking relationship between objective and subjective, behavioral and self-reported data and that monitoring and cognitive appraisal as variables can substantially foster mental health and revolutionize mental health care and cognitive enhancement if targeted by multiprofessional teams. Furthermore, this study demonstrates that cognitive appraisal can be systematically improved by verbal feedback and signals. Signal feedback can be haptic or sound feedback (e.g., error-related sounds as employed in this study) and might be combined with verbal feedback. By embedding monitoring and cognitive appraisal in assessment and intervention, future research and clinical practice can move toward more precise, personalized, and effective mental health care.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethics Statement

This study was approved by the Ethics Committee of St. Franziskus-Hospital, Winterberg, Germany. The assessment and data collection were conducted as part of the hospital's routine geriatric pre-rehabilitative treatment procedures and were conducted with the ethical standards of the EDPR.

Consent

All participants provided written informed consent to participate in the study in accordance with the ethical standards outlined by the European Data Protection Regulation and the Declaration of Helsinki. The patients were informed of the nature of the study, its voluntary character, and that their anonymized data would be used for scientific publication purposes.

Disclosure

The corresponding author can be contacted at leonalkersci@gmail.com.

Conflicts of Interest

The author declares no conflicts of interest.

Author Contributions

L.A.: conceptualization, conducting the research, analyzing the data, and preparing the manuscript.

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