# Cognitive Control in Young and Older Adults

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The dual mechanisms of control framework (DMC) proposes two modes of cognitive control: proactive and reactive control. The proactive control mode is an early selection process that actively maintains task context over time to minimize interference whereas the reactive control mode is a late correction process that serves to resolve interference, at the time of its occurrence. Young adults primarily use a more proactive control mode, but older adults tend to use a more reactive control.

Keywords: proactive control ; reactive control ; mood ; aging ; AX-CPT

## 1. Introduction

Cognitive control is the ability to coordinate and accomplish task goals, particularly in the presence of interfering or conflicting goals [1]. According to the dual mechanisms of control framework (DMC) [2], there are two cognitive control modes that can be engaged to resolve interference. The proactive control mode is an early selection process that actively maintains task context over time to minimize interference, prior to its occurrence. In contrast, the reactive control mode is a late correction process that serves to resolve interference, at the time of its occurrence, through reactivation of task context.

Proactive and reactive control have been assessed using the AX-version of the Continuous Performance Test (AX-CPT) [2][3], in which participants view sequentially presented letter stimuli that serve as valid cues, invalid cues, valid probes, or invalid probes. Each cue is followed by a probe. For 70% of trials, a “target” response is expected in response to a valid probe (“X”), but only when it follows a valid cue (“A”; i.e., AX target trial). Thus, the valid cue becomes a reliable signal for the upcoming valid probe, creating a strong tendency to respond “target” to the forthcoming probe. The remaining 30% of trials are evenly distributed across three non-target trial types: cue-lure (AY), probe-lure (BX), and control (BY). Using proactive control can result in poor performance on cue-lure AY trials (i.e., more errors or longer RT). In contrast, using reactive control can result in poor performance on probe-lure BX trials. Relative to proactive control, reactive control is less resource-demanding because it is exerted only when needed and does not require continuous maintenance of task context. Past research shows an age-related shift from proactive to reactive control [2][4]. Specifically, older adults perform more poorly on probe-lure than cue-lure trials (signaling reactive control), whereas young adults perform more poorly on cue-lure than probe-lure trials (signaling proactive control).

Past research has also examined the effects of mood, reward, and incentive manipulation on cognitive control performance, primarily in young adults [5][6][7][8][9][10]. With regards to the effect of reward, it was revealed that performance-contingent reward (i.e., reward based on task performance) increased the use of cue information and thus facilitated proactive control, whereas random rewards (i.e., unconditional reward not related to performance) reduced proactive control [7][8]. Similarly, penalty-based monetary incentive has been found to lead to increased reactive control [11]. Considering the evidence for maintained or even enhanced emotional processing/regulation in older adults [12] and a growing interest in emotion-cognition interactions with aging [13], it is reasonable to predict that mood might impact older adults’ ability to engage in proactive control.

Additionally, it has been evidenced that older adults’ proactive control could be improved through external environmental (e.g., extended task practice [11]) or cue-oriented strategy training, such as explicit cue-focus instruction in the AX-CPT [4]. Given that face cues have been shown to facilitate recall for older adults [14] and face stimuli are naturally associated with socially meaningful affect, induced mood may facilitate face cue maintenance and thus enhance proactive control use. Thus, the use of face cues in the AX-CPT may provide an optimal condition to detect the mood effect on cognitive control. This face-cue paradigm would also address a prevailing concern of the poor social ecological validity of cognitive control tasks, such as the standard AX-CPT [15], which typically uses only letters.

## 2. Research Findings

The results of Experiment 1 replicated the proactive and reactive bias in young and older adults, respectively, with a standard letter-cue AX-CPT. Using a more socially meaningful face-cue AX-CPT, Experiment 2 revealed an age-equivalent proactive control bias in the RT analysis. Nevertheless, cognitive control did not seem to vary by mood induction. It should be noted, however, that similar to previous work [1][4][16][17], the age effect varied across RT and error rate analyses.

### 2.1. Mood Manipulation

The mood rating analyses aimed to validate the effectiveness of the mood induction manipulation in differentially changing mood into the expected valence direction for both young and older adults [18]. Across experiments and induction conditions, it was observed that young adults stayed in their post-induction mood throughout the time course whereas older adults' mood quickly returned closer to baseline. This may suggest that older adults are generally faster in mood regulation [19].

### 2.2. Age Differences in Cognitive Control

Consistent with the DMC, older adults showed a reactive control bias, compared to young adults who showed a proactive control bias in the standard AX-CPT. This age effect remained intact after controlling for most related demographic and background variables (e.g., FTP or DASS scores). Similar to some previous works [2][4][16][17], age differences varied across RT and error rate data. For example, Braver and colleagues [16] showed that young adults committed greater cue-lure errors relative to older adults (indicative of proactive control), but reactive control in older adults is typically observed in RT data, through a relatively delayed response to probe-lure (BX) trials as task goals are largely reactivated upon probe presentation.

However, the results of Experiment 2 indicated that this age-related decline in proactive control is partially amenable. Though the exact mechanisms are unclear, two speculations are offered: (a) the marked distinction between a face cue and a letter probe may have directed processing towards the cue and away from the probe; (b) the dichotomous nature (female or male) of face cues may have made it easier to process and maintain the cue/contextual information. In support of these speculations, past studies have shown that cognitive control mode changes with task demands. For example, individuals with high working memory capacity can behave in a reactive manner when a high proportion of cues become invalid [20]. Finally, face cues may elicit deeper processing in the brain relative to letter cues, considering greater activation observed when preparing to remember facial cues in a face working memory paradigm [21]. It has been shown that proactive control is associated with increased and sustained activity in the anterior prefrontal cortex [22]. Taken together, the results suggested that face cues were probably sufficiently powerful in directing subsequent responses and thus helped older adults sustain proactive control processes. However, these speculations need to be further tested.

### 2.3. Mood and Cognitive Control

Although research has revealed significant (though mixed) effects on cognitive control of positive mood/valence and rewards in young adults [5][9] and the motivation/reward effects in older adults [23], the effect of mood (negative or positive) is minimal or absent in the current study. The lack of a negative mood effect is inconsistent with the result of improved task switching performance under negative mood [24]. However, it is somewhat consistent with earlier literature [25]. This has been explained by the lack of relationship between negative affect and dopamine, which is assumed to underlie information regulation in cognitive control [26].

Despite an established relationship between positive mood and dopamine [27] as well as the age-associated positivity effect [12], the current study did not find any significant effect of positive mood on cognitive control in either young or older adults. This seems to be inconsistent with other studies that have found emotion effects in older adults on processes that are presumably related to cognitive control [18][28][29] and those that have found reduced proactive control in young adults under positive mood or performance-contingent reward [7][8][30][25].

## 3. Conclusions

Although the mood effect was absent, the current study provided some promising evidence that older adults' proactive control could be improved through task-specific manipulations, such as using socially meaningful dichotomous face cues. Elucidating factors that can attenuate age-related declines has valuable implications for interventions, particularly as they relate to neurodegenerative disease. Specifically, given the known involvement of reactive and proactive inhibitory control

processes in directing cessation or adaptive behaviors, respectively, in Parkinson's disease [31], it may be interesting to compare cognitive control and inhibitory processes in aging. Future work may help identify similar compensatory mechanisms or environmental modifications that could be applied to facilitate older adults' cognitive and everyday functioning.

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