Immediate and Long-Term Efficacy of Training Executive Functions in Healthy Older Adults

A Systematic Review and Meta-Analysis

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An Ageing Population

- Rapid growth of older population
- Increasing rates of cognitive decline
  - Normal cognitive decline
  - Pathological decline
    - mild cognitive impairment (MCI)
    - dementia
- Research needed to
  - improve cognition in older adults
  - help maintain intact cognition
Computerised Cognitive Training (CCT)

• What is CCT?
  - Involves frequent and repeated engagement in cognitive tasks using a digital device
  - CCT targets specific cognitive domain(s), e.g.:
    - working memory training, attention training, processing speed training (single-domain CCT)
    - combination of multiple cognitive domains (multi-domain CCT)
      - e.g., working memory + attention + processing speed training

• Typical CCT Study
  - includes at least one training group and one control group
  - pre-test—intervention—post-test design
    - sometimes includes follow-up testing → long-term efficacy
  - effect of training or ‘training effect’ = improvement_{training} > improvement_{control}

• How Does CCT Work?
  - repeated practice on cognitive task
    → underlying cognitive + neural processes more efficient
    → improved behavioural performance
Cognitive Training & ‘Transfer’

- **Goal of CCT**
  - Improve performance on trained tasks → improve performance on everyday functional activities
    - Training gains need to be generalisable or ‘transfer’

- **Measuring CCT Efficacy**
  - Extent that training promotes transfer
    - e.g., Taxonomy of Transfer (Noack et al., 2009)
    - Far-transfer → generalisable to everyday tasks

- **Efficacy of CCT currently under debate**
Executive Functions (EFs)

• What are EFs?
  • Top-down mental processes essential for performing everyday activities
  • 3 core EFs:
    1. Working Memory: ability to simultaneously hold and actively manipulate stimuli in mind before recall
    2. Inhibition: ability to suppress automatic responses or irrelevant stimuli
    3. Cognitive Flexibility: ability to switch between multiple tasks, mental sets, or perspectives
  • Core EFs form the foundation for higher-order cognitive functions

• Case for EF Training
  • EF tasks + tasks requiring EFs show early decline—observed in middle-age
  • EFs critical in performing numerous cognitive processes
    • prospective memory ➔ medication adherence, health and social appointments
    • financial decision making ➔ managing bills and finances
    • driving ability
Current Meta-Analytic Investigation

Is CCT targeting EFs effective in improving cognitive performance in older age?

• Aims
  • To examine immediate and long-term efficacy of CCT targeting EFs in healthy older adults
    • 2 meta-analyses conducted:
      1. pre-test—post-test (immediate)
      2. pre-test—follow-up (long-term)
  • To explore whether any factors moderate CCT efficacy

• Intervention
  • Type of training (focal domains)
  • Adaptive difficulty
    • Adaptive = adjusts difficulty
    • Nonadaptive = fixed difficulty

• Training Schedule
  • Length of training sessions
  • Number of training sessions
  • Length of total training
**Literature Search & Data Analysis**

- **Procedure & Reporting**
  - *Cochrane Handbook for Systematic Reviews of Interventions*

- **Systematic search**
  - Scopus
  - ProQuest
  - Science Direct
  - Ovid
  - PubMed

- **Included Studies**
  - 61 studies → immediate efficacy (pre-test to post-test)
  - 16 studies → long-term efficacy (pre-test to follow-up)

- **Analyses**
  - *Comprehensive Meta-Analysis (CMA) Version 3.3*
  - **Effect Sizes (size of training effect)**
    - Calculated as Hedge’s $g$
      - +ve effect size = CCT improvement > control improvement
      - -ve effect size = control improvement > CCT improvement
    - Corrected for publication bias (non-significant findings not published)
Immediate Efficacy (Pretest-Posttest) Trained Outcomes

- **Analysis**
  - trained tasks
  - 24 studies
  - 678 participants

- **Effect Size**
  - Significant, large training effect

Figure 1. Forest plot depicting effect sizes for trained outcomes (pretest-posttest).
Immediate Efficacy (Pretest-Posttest)

Near-Transfer

Near-transfer → untrained tasks from same trained domain

• **Analysis**
  - near-transfer tasks
  - 55 studies
  - 1,792 participants

• **Overall Effect Size**
  - Significant, small training effect

• **Moderator Analyses**
  - Type of training
    - Multi-domain training → sig.
    - Video game training → sig.
    - Working memory training → sig.
    - Inhibition training → ns.
    - Cognitive flexibility training → ns.

• No other significant moderators
Immediate Efficacy (Pretest-Posttest) Far-Transfer

Far-transfer $\rightarrow$ untrained tasks from untrained cognitive domains

• Analysis
  • far-transfer tasks
  • 55 studies
  • 1,833 participants

• Overall Effect Size
  • Significant, small training effect

• Moderator Analyses
  • Type of training
    • Multi-domain training $\rightarrow$ sig.
    • Video game training $\rightarrow$ sig.
    • Working memory training $\rightarrow$ ns.
    • Inhibition training $\rightarrow$ ns.
    • Cognitive flexibility training $\rightarrow$ ns.
  • Training adaptiveness
    • Adaptive $\rightarrow$ sig.
    • Nonadaptive (fixed difficulty) $\rightarrow$ ns.
  • Length of training sessions
    • Sessions 30min+ $\rightarrow$ sig.
    • Sessions under 30min $\rightarrow$ ns.
Maintenance of Training Gains

Immediate Efficacy (reanalysed) (pre-test to post-test)

- Trained outcomes
  - Same 8 studies
  - Significant, large training effect

- Near-transfer outcomes
  - Same 16 studies
  - Significant, small training effect

- Far-transfer outcomes
  - Same 12 studies
  - Significant, small training effect

Long-Term Efficacy (pre-test to follow-up)

- Trained outcomes
  - 8 studies
  - Significant, large training effect

- Near-transfer outcomes
  - 16 studies
  - Significant, small training effect

- Far-transfer outcomes
  - 12 studies
  - Significant, small training effect

Effect Size

- Trained outcomes: $0.89 \leftrightarrow 0.85$
- Near-transfer outcomes: $0.33 \leftrightarrow 0.25$
- Far-transfer outcomes: $0.35 \leftrightarrow 0.25$
Immediate Efficacy: Individual Domains

- **Attention**
  - 16 studies
  - Effect of training nonsignificant

- **Executive functioning**
  - 31 studies
  - Small, significant training effect

- **Fluid Intelligence**
  - 32 studies
  - Effect of training nonsignificant

- **Language**
  - 8 studies
  - Effect of training nonsignificant

- **Memory**
  - 19 studies
  - Small, significant training effect

- **Processing Speed**
  - 22 studies
  - Small, significant training effect

- **Visuospatial Ability**
  - 5 studies
  - Moderate, significant training effect
Summary & Conclusions

• **Immediate & Long-Term Efficacy of CCT Targeting EFs**
  - Improved cognitive performance
    - Trained, near-transfer, far-transfer outcomes
  - Improvements maintained over time
  - Improved some cognitive domains but not others
  - Optimal training conditions for future research:
    - Multi-domain
    - Adaptive
    - 30min+ training sessions

• **Conclusions**
  - Intact cognition—EFs in particular—critical for functional independence in later life
  - CCT interventions targeting EFs:
    - Show promise in promoting long-lasting cognitive improvements
    - Promote far-transfer
  - Further research needed
    - Does far-transfer translate to functioning in real-world, everyday activities?