Enhancing Executive Function in Preschool Children: Generalizability and Long-term Effects of Cognitive-Motor Training

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Introduction
Executive function (EF) is a set of psychological processes that enables goal-directed behavior (Diamond, 2013). EF longitudinally predicts academic achievement, learning-related classroom behaviors, and occupational success (Tangney et al., 2018). Three core components of EF are working memory, cognitive flexibility, and inhibitory control. This study focuses on inhibitory control: the ability to override strong, but inappropriate behavioral tendencies (Blair & Diamond, 2008).

Several studies have tried using computer training interventions to improve EF, but found that performance does not transfer to non-trained inhibitory control tasks (Engle et al., 2014; Rueda et al., 2005; Thorell et al., 2009). However, intervention studies with adolescents, older adults, and atypical populations provide evidence that Exergames (concurrent cognitive and motor stimulation) improve EF (Best, 2012; Benzing & Schmidt, 2018; Eggenberger, 2016; Hilton et al., 2014; Van Santen et al., 2018). Despite the potential applications of Exergames, little is known about the short- and long-term effects on EF in children below school age.

Research Questions
The primary objective of this study is to investigate whether an Exergame (high physical activity + high cognitive engagement), a Sedentary game (low physical activity + high cognitive engagement), and Exercise game (high physical activity + low cognitive engagement) impact EF in preschool aged children.
1. Will Exergame training improve children’s performance on a trained EF task and transfer to a non-trained EF task?
2. Does Exergame training transiently facilitate EF performance or does it have a more fundamental impact resulting in longer-term changes?
3. Does training generalize to EF-related behaviors in a real-world context in a classroom setting?

Design
Participants: 81 children (22 boys, 13 girls) ages 4-5 (M = 5.03 yrs, SD = 7 months), recruited from the Children’s School at CMU in Pittsburgh, PA. The school represents economic and racial diversity with children being 54% White, 24% Asian or Pacific Islander, 5% African American, 12% Middle-Eastern, 5% Hispanic, and 28% of children attending with financial aid. Between-subject design; children randomly assigned to 1 of 4 conditions: Exergame (n = 20), Sedentary (n = 10), Exercise (n = 10), or Passive Control (n = 21). Children trained for two 20-minute consecutive sessions to replicate the training duration of prior Exergame studies. The game is projected onto a wall with a connected non-slip game step mat (144 x 96 x 48 inches).

Procedure
A) Exergame: Participants responded by stepping left or right on the game mat depending on the direction that the central target was facing. The target was a picture of a fish (either facing left or right) that was surrounded by 4 other “distractor” fish.
B) Sedentary: Exact same game as the Exergame condition, except children were sitting and responded by pressing left or right on the game mat’s arrows.
C) Exercise activity: The target still as a center fish, but it was not surrounded by 4 other “distractor” fish. The target fish faced left and right in a continuous pattern to engage children in repetitive exercise without engaging inhibitory control.

Measures
EF assessments were administered before (pretest), after (posttest), and 1 month after (delaytest) the intervention.

Flanker Task (Eriksen & Eriksen, 1974): children are shown an image of five fish and told to press the respective key the middle fish (central target) is facing. The target is surrounded by flankers (two fish on either side) that will either all be facing the same way as the middle fish (congruent), or facing the opposite direction (incongruent).

Day-Night Task (Gerstadt, Hong, & Diamond, 1994): children are instructed say “day” when shown a sun card and to say “night” when shown a moon card. The opposite condition then had children say “day” when shown a moon card and say “night” when shown a sun card.

Behavior Rating Inventory of Executive Function (BRIEF) is used as an inventory scale completed by teachers to evaluate everyday behaviors that are associated with EF; 68 questions 5 subcategories:
- Emotional Control
- Working Memory
- Inhibition
- Plan/Organize
- Shift

Limitations
• underpowered. Only n = 20 in Sedentary and Exercise conditions
- The Exergame improved performance on a non-trained EF task and teacher ratings of EF, more so than a Sedentary game and Exercise.
- Exergame training before entering formal schooling may enhance EF development in children as young as 4 to 5-years old.
- Additional established EF tasks can be transformed into physically active Exergames to investigate whether the effects are generalizable outside of the Flanker Task.

Discussion

Future Directions
- Examining hemodynamic changes in prefrontal connectivity from pretest to posttest using fNIRS
- Running replication experiment with adults (see VR study adjacent to this poster)
- Examining BRIEF subsets
- Examining effects on academic achievement measures

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