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Preschool Program Improves Cognitive Control

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Abstract

Cognitive control skills important for success in school and life are amenable to improvement in at-risk preschoolers without costly interventions.

Executive functions (EFs), also called cognitive control, are critical for success in school and life. Although EF skills are rarely taught, they can be. The Tools of the Mind (Tools) curriculum improves EFs in preschoolers in regular classrooms with regular teachers at minimal expense. Core EF skills are (i) inhibitory control (resisting habits, temptations, or distractions), (ii) working memory (mentally holding and using information), and (iii) cognitive flexibility (adjusting to change) (1,2).

Significance

EFs are more strongly associated with school readiness than are intelligence quotient (IQ) or entry-level reading or math skills (3,4). Kindergarten teachers rank skills like self-discipline and attentional control as more critical for school readiness than content knowledge (5). EFs are important for academic achievement throughout the school years. Working memory and inhibition independently predict math and reading scores in preschool through high school [e.g., (3,6,7)].

Many children begin school lacking in EF skills (5). Teachers receive little instruction in how to improve EF and have preschoolers removed from class for poor self-control at alarming rates (8,9). Previous attempts to improve children's EF have often been costly and of limited success (10-12). Poor EFs are associated with such problems as ADHD, teacher burnout, student dropout, drug use, and crime (2). Young lower-income children have disproportionately poor EFs (13,14). They fall progressively farther behind in school each year (15).

The Study

The opportunity to evaluate Tools of the Mind (Tools) and another curriculum arose when a low-income, urban school district agreed to randomly assign teachers and children to these two curricula. Our study included 18 classrooms initially and added 3 more per condition the next year. Quality standards were set by the state. All classrooms received exactly the same resources and the same amounts of teacher training and support (2). Stratified random assignment of teachers and assistants minimized confounds due to teacher characteristics.

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EF-training curriculum: Tools

The Tools curriculum (16) is based on Vygotsky's insights into EF and its development. Its core is 40 EF-promoting activities, including telling oneself out loud what one should do ("self-regulatory private speech") (17), dramatic play (18), and aids to facilitate memory and attention (19). Tools teachers spent ~80% of each day promoting EF skills. Tools has been refined through 12 years of research in preschools and kindergartens. Only when EFs were challenged and supported by activities throughout the day did gains generalize to new contexts (2).

District's version of Balanced Literacy curriculum (dBL)

The curriculum developed by the school district was based on balanced literacy and included thematic units. Tools and dBL covered the same academic content, but dBL did not address EF development. [For teacher training and fidelity, see (2).]

Participants

Data are reported on 147 preschoolers (62 in dBL and 85 in Tools) in their second year of preschool (average age: 5.1 years in both) who received dBL or Tools for 1 or 2 years. Those who entered in year 2 had attended other preschools for a year. All came from the same neighborhood and were randomly assigned to Tools or dBL with no self-selection into either curriculum. All came from low-income families; 78% with yearly income <$25,000 (2). After year 1, so convinced were educators in one school that Tools children were doing substantially better than dBL children that they halted the experiment in their school, reducing our sample of dBL children.

Measures of EF

Outcome measures (the Dots task and a Flanker task) were quite different from what any child had done before. These measures are appropriate for ages 4 through adults, assess all three EF components, and require prefrontal cortex (20-21). They were administered in May and June of year 2.

In all conditions of the Dots task (20), a red heart or flower appeared on the right or left. In the congruent condition, one rule applied ("press on the same side as the heart"). Dots-Incongruent also required remembering a rule ("press on the side opposite the flower") plus it required inhibition of the tendency to respond on the side where the stimulus appeared. In Dots-Mixed, incongruent and congruent trials were intermixed (taxing all three core EFs). Children were given a lot of time to respond [over five times as long as preschoolers usually take (20)].

The central stimulus for our Flanker task was a circle or triangle. Memory demands were minimized by a triangle atop the right-hand key and at the bottom right of the screen, with similar aids for the left-hand circle response. The image to focus on was the small shape in the center; the distractor (or flanker) to be ignored was the larger shape surrounding it. Congruent (e.g., ○inside ○) and incongruent (e.g., Δ inside ○) trials were intermixed. Next came "Reverse" Flanker, where children had to focus on the outside shape, inhibiting attention to the inside, plus flexibly switching mindsets and attentional focus. The rules were still "press right for Δ and left for ○." Again, children were encouraged to take their time and not to rush.

Independently, NIEER administered academic measures to Tools children only. These are described in (2).

Results

We report accuracy rather than speed because, for young children, accuracy is the more sensitive measure (23). We conducted multiple regression analyses with age, gender,

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curriculum, and years in curriculum as independent variables. Interaction terms were insignificant and were dropped. On Dots-Congruent, which had minimal EF demands, children performed similarly regardless of curriculum, year in a curriculum, or gender, though older children performed better.

When an inhibition demand was added (Dots-Incongruent), Tools children significantly outperformed dBL children (see the figure, left of above). Dots-Mixed taxed all three EF skills and was too difficult for most dBL children: Almost twice as many Tools as dBL children achieved >75% correct on training trials (see the figure, right of above).

Our Flanker task, like Dots-Incongruent, taxed inhibition (with minimal memory or flexibility demands). Tools children significantly outperformed dBL children (figure above). On Reverse Flanker, dBL children performed near chance (65% correct), but Tools children averaged 84% correct (see figure, above). Thus, the most demanding Dots and Flanker conditions showed the largest effects; those effects are socially significant because they are sizeable.

Tasks that were more demanding of EFs correlated more strongly with standardized academic measures. For example, “Get Ready to Read” scores correlated 0.05, 0.32, and 0.42 with Dots-Congruent, -Incongruent, and -Mixed, respectively (2).

Conclusions

Some think preschool is too early to try to improve EFs. Yet it can be done. EFs can be improved in 4- to 5-year-olds in regular public school classes with regular teachers. Being in Tools accounted for more variance in EFs than did age or gender and remained significant when we controlled for those. These findings of superior scores by Tools children compared with closely matched peers on objective, neurocognitive EF measures are consistent with teachers’observations (24).

Although play is often thought frivolous, it may be essential. Tools uses mature, dramatic play to help improve EFs. Yet preschools are under pressure to limit play.

If, throughout the school day, EFs are supported and progressively challenged, benefits generalize and transfer to new activities. Daily EF “exercise” appears to enhance EF development much as physical exercise builds bodies (2).

The more EF-demanding the task, the more highly it correlated with academic measures. Superior academic performance has been found for Tools children in other schools and states, with other teachers and comparison curricula (24,25). EFs [especially self-discipline (inhibition)] predict and account for unique variance in academic outcomes independent of and more robustly than does IQ (2,3,26).

Tools successfully moves children with poor EFs to a more optimal state. It is not known how much it would help children who begin with better EFs.

No study is perfect, and ours is no exception. Before and after measures of EFs, as well as academic measures in dBL children, would have strengthened it. Strengths include random assignment and use of objective measures. No authors or testers had a stake in either curriculum. Many competing explanations have been ruled out (2).

Most interventions for at-risk children target consequences of poor EFs rather than seeking prevention, as does Tools. We hypothesize that improving EFs early may have increasing benefits over time and may reduce needs for costly special education, societal costs from

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unregulated antisocial behavior, and the number of diagnoses of EF disorders [e.g., ADHD and conduct disorder (2)].

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

References and Notes

1. Diamond, A. Lifespan Cognition: Mechanisms of Change. Bialystok, E.; Craik, F., editors. Oxford Univ. Press; New York: 2006. p. 70-95.
2. See supporting online material for more information
3. Blair C, Razza RP. Child Dev 2007;78:647. [PubMed: 17381795]
4. McClelland MM, Morrison FJ, Homes DL. Early Child. Res. Q 2000;15:307.
5. Rimm-Kaufman SE, Pianta RC, Cox MJ. Early Child. Res. Q 2000;15:147.
6. Bull R, Scerif G. Dev. Neuropsychol 2001;19:273. [PubMed: 11758669]
7. Gathercole SE, Tiffany C, Briscoe J, Thorn A, ALSPAC team. J. Child Psychol. Psychiatry 2005;46:598. [PubMed: 15877766]
8. Lewin T. Research finds a high rate of expulsions in preschool. New York Times May 17;2005 :A12.
9. Gilliam, WS. Prekindergarteners Left Behind: Expulsion Rates in State Prekindergarten Systems. Yale Child Studies Center; New Haven, CT: 2005.
10. Kerns KA, Eso K, Thompson J. Dev. Neuropsychol 1999;16:273.
11. Dowsett SM, Livesey DJ. Dev. Psychobiol 2000;36:161. [PubMed: 10689286]
12. Rueda MR, Rothbart MK, McCandliss BD, Saccomanno L, Posner MI. Proc. Natl. Acad. Sci. U.S.A 2005;102:14931. [PubMed: 16192352]
13. Noble KG, et al. Dev. Sci 2007;10:464. [PubMed: 17552936]
14. Noble KG, et al. Dev. Sci 2005;8:74. [PubMed: 15647068]
15. O'Shaughnessy T, et al. Remedial Spec. Educ 2003;24:27.
16. Bodrova, E.; Leong, DJ. Tools of the Mind: The Vygotskian Approach to Early Childhood Education. ed. 2. Merrill/Prentice-Hall; New York: 2007.
17. Luria, AR. Reading in the Psychology of Cognition. Anderson, RC.; Ausubel, DP., editors. Holt, Rinehart and Winston; New York: 1965. p. 350-363.
18. Vygotsky LS. Soviet Psychol 1967;7:6.
19. Vygotsky, LS. Mind in Society: The Development of Higher Psychological Processes. Harvard Press; Cambridge, MA: 1978.
20. Davidson MC, et al. Neuropsychologia 2006;44:2037. [PubMed: 16580701]
21. Rueda MR, et al. Neuropsychologia 2004;42:1029. [PubMed: 15093142]
22. Durston S, et al. Neuroimage 2003;20:2135. [PubMed: 14683717]
23. Diamond A, Kirkham N. Psychol. Sci 2005;16:291. [PubMed: 15828976]
24. Barnett, WS., et al. Educational effectiveness of the Tools of the Mind curriculum: A randomized trial. National Institute of Early Education Research, Rutgers University; New Brunswick, NJ: 2006.
25. Saifer, S. paper presented at the 17th Annual Conference of the European Early Childhood Education Research Association; Prague, Czech Republic. 29 August 2007;
26. Duckworth AL, Seligman MEP. Psychol. Sci 2005;16:939. [PubMed: 16313657]
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1. . "Buddy reading"
Two preschoolers engaged in Tools activity. The ear linedrawing held by one guides her attention (2).

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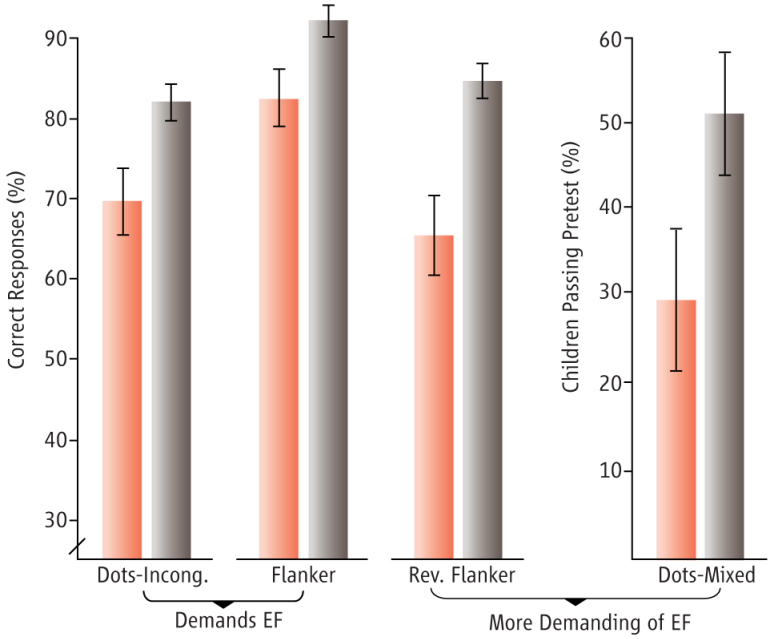

2. . Tools children (blue) performed better on measures of EF than dBL children (red) did
(A) The dependent measure is percentage of correct responses. Dots-Incongruent, Flanker, and Reverse Flanker tasks are described in the text. **(B)** The dependent measure is percentage of children passing the pretest for this task. Statistics are reported in the SOM (2).