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The Shape School: Assessing Executive Function in Preschool Children

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Age-related changes in executive function were examined on a new task, the Shape School, in 70 preschool children (32–68 months old). The Shape School is a colorful storybook designed to examine inhibition and switching processes in young children. Results confirmed that task efficiency varied significantly with age, with older age groups outperforming younger groups. Furthermore, inhibition efficiency improved significantly between 3 to 4 years of age, whereas switching skills showed developmental improvement from 4 to 5 years of age. These results suggest that the Shape School is sensitive to maturational effects and that performance can be parsed into inhibition and switching processes. The Shape School may be useful in clinical populations in order to elucidate developmental brain–behavior relations in preschool children.

Interest in executive function in developmental neuropsychology has burgeoned recently (Fletcher, 1996). Although several tasks have been developed that assess executive skills in adults and in school-age children, few tasks are appropriate for use in preschool children (3–5 years old). Welsh, Pennington, and Grossier (1991) successfully employed the Tower of Hanoi in preschoolers (Simon, 1975). The Tower of Hanoi, however, is a complex task, dependent on diverse cognitive skills (i.e., working memory and rule application; Roberts & Pennington, 1996). Tasks that are sensitive to executive function deficits in older children (i.e., Stroop Color–Word task [Stroop, 1935] and the Contingency Naming test [Taylor, Albo, Phebus, Sachs, & Bierl, 1987]) use basic inhibition—and switching from—more salient, automatic cognitive processes. In this vein, Gerstadt, Hong, and Diamond

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(1994) developed the Day–Night test, intended for use with young children. Study results indicated that the task was too difficult for those under 5 years old, perhaps related to insufficient automaticity of the word–picture associations (e.g., day–sun). On the Day–Night test (Gerstadt et al., 1994), the child must inhibit and switch simultaneouslv. In young children, it may be that these cognitive processes differ maturationally and contribute uniquely to executive skill development. The purpose of this study was to develop an executive function task for use with preschool children, sensitive to maturation, but in which inhibition and switching processes are separated.

METHOD

Seventy children who ranged in age from 32 months to 68 months participated in the study. Children were recruited from two local preschools and through birth announcements in the local paper. All participating children were White, from families with middle- to upper-middle income levels. There were 35 boys and 35 girls. All participants were full term at birth, with unremarkable developmental histories.

The Shape School involved four conditions: control, inhibit, switch, and both. The Shape School was presented to the child in a storybook format. The story began with a depiction of a school yard with colorful circle and square figures playing. In the control condition, the child was told that the pupil's name is the figure color (i.e., red, yellow, or blue). The story continued with the pupils "lining up" to go into school from the play yard. The child was instructed to name the pupils in order (i.e., name the figures' colors) as fast as possible without making any errors. In the inhibit condition, the figures had two facial expressions, either happy or frustrated, depending on whether the pupil "was ready for lunch." The child was instructed, in this condition, to name the pupils who were ready for lunch (i.e., happy-faced) and not to name those frustrated-faced pupils who were not ready.

The switch and both conditions were administered to children older than 48 months because these conditions also utilized the principle of shape, in addition to color, which younger children may not process automatically. Twenty-nine children were administered these two conditions, in addition to the control and inhibit conditions. In the switch condition, another classroom was added to the story. These pupils wore hats, where their name was the figure shape. In this condition, all pupils had neutral faces (as in the control condition). The child was told that all pupils were going to story time. The child was instructed to name the pupils (i.e., color for hatless pupils, shape for hatted pupils). The final condition, both, involved inhibition and switching. Pupils with happy and with frustrated faces, and with and without hats were included. The child was told that not all pupils were ready for art. The child then was instructed to name the happy-faced pupils who were ready (i.e., color or shape) and not to name those with frustrated faces. There were 15

figures in each condition. The dependent measure for each condition was an efficiency score, calculated from accuracy indexes and naming speed [efficiency = (the number of correct – the number of errors) / total time].

The Shape School was administered in a quiet laboratory testing room as a part of a larger neuropsychological battery. The entire battery took about 1 hr (45 min for the younger children and 75 min for the older children). Breaks were administered to maintain cooperation and interest. Testing was scheduled at times reported by parents not to interfere with regular naps or meals.

A cross-sectional design was used to address whether Shape School performance varied with age. The children were grouped by age in yearly increments, with 13 children in the 3-year-old group (32–41 months), 37 children in the 4-year-old group (42–53 months), and 20 children in the 5-year-old group (54–68 months). Separate analyses of variance for each condition were conducted on the efficiency scores. For the control and inhibit conditions, two planned contrasts also were conducted to examine performance among the three age groups (i.e., 3-year-olds vs. 4-year-olds; 4-year-olds vs. 5-year-olds), using a Bonferroni-adjusted critical value of .025.

RESULTS

The means and standard deviations of the Shape School measures by age group are presented in Table 1. Visual examination of performance indicated that, in the control and the inhibit conditions, the children named the stimuli correctly at near perfect levels at all ages. Naming speed, however, decreased with age group for all conditions.

There were significant, overall age group effects on efficiency for all four Shape School conditions (all $ps < .05$). In the control condition, efficiency varied significantly with age group, $F(2, 69) = 10.67, p < .001$. Results from the a priori contrasts revealed that the 4-year-old children were significantly more efficient than 3-year-old children, $F(1, 69) = 16.33, p < .001$. There were no differences in efficiency in the control condition between 4-year-old and 5-year-old children. A similar pattern of age-related performance was observed for the inhibit condition, with a significant overall age group effect, $F(2, 65) = 32.53, p < .001$, and 4-year-old children significantly outperforming 3-year-olds, $F(1, 65) = 50.71, p < .001$. Four- and 5-year-old children were comparably efficient in the inhibit condition. In the switch condition, efficiency score varied with age group, $F(1, 27) = 4.14, p < .05$, with greater efficiency observed in the older children. Efficiency also varied with age group in the both condition, with the 5-year-old children outperforming the 4-year-olds, $F(1, 26) = 5.01, p < .05$.

DISCUSSION

These results suggest that the Shape School may be an effective measure of executive function in preschool children. In contrast to the Day–Night test (Gerstadt

TABLE 1
Shape School Performance by Age Group

	Age 3		*Age 4*		*Age 5*	
Measure	*M*	*SD*	*M*	*SD*	*M*	*SD*
Control condition[a]						
Time (sec)	48.02	21.45	27.65	14.37	23.70	13.35
Number correct	14.77	0.60	14.75	1.32	14.80	0.52
Efficiency score	0.35	0.14	0.64	0.28	0.73	0.25
Inhibit condition[b]						
Time (sec)	85.38	44.73	31.82	15.67	23.65	8.51
Number correct	14.00	1.00	14.20	1.61	14.80	0.70
Efficiency score	0.20	0.10	0.53	0.26	0.70	0.22
Switch condition[c]						
Time (sec)	—	—	58.77	21.66	44.53	15.20
Number correct	—	—	13.54	1.45	14.38	1.09
Efficiency score	—	—	0.24	0.07	0.36	0.13
Both condition[c]						
Time (sec)	—	—	68.64	39.14	44.06	16.96
Number correct	—	—	12.46	2.57	14.38	1.15
Efficiency score	—	—	0.22	0.14	0.37	0.15

Note. Switch and both conditions were not administered to children under 48 months of age.
[a] $n = 13$, 37, and 20 for ages 3, 4, and 5. [b] $n = 13$, 35, and 20 for ages 3, 4, and 5. [c] $n = 13$ and 16 for ages 4 and 5.

et al., 1994), children as young as 32 months successfully completed the Shape School. Task performance also differed among 3-, 4-, and 5-year-old children, with the older age groups outperforming the younger. These findings suggest that the Shape School is sensitive to age-related differences in executive skill.

Shape School performance indicated that executive skill may comprise both inhibit and switch processes in preschoolers. Four-year-old children inhibited more efficiently than 3-year-olds; in contrast, switching efficiency improved between 4 and 5 years of age. Whether these process differences are a function of task limitations or actual skill differences is unknown. Comparisons of Shape School performance to performance on other executive skill tasks would assist in answering such questions. These findings also suggest that the pattern of development of inhibition and switching skills may differ as a function of age. This conclusion may be speculative, in part, because the switch condition was not administered to the 3-year-old age group. A longitudinal design is necessary to adequately answer whether inhibition and switching skills develop at different ages or maturational rates.

Interestingly, the number of stimuli named correctly were high, especially in the control and inhibit conditions. Naming speed showed consistent developmental improvement across age and condition. The efficiency score, taking into account both naming accuracy and speed, therefore, represents an effective measure of

performance. Welsh and colleagues (1991) also used similar efficiency indexes in their study of executive function in preschool children. The efficiency score may be particularly sensitive to performance differences in young children, whose implementation of verbal instructions may be more variable than that of older children.

These findings should be considered in the context of the sample characteristics. This sample did not include children of ethnic minority status, and overrepresented children from middle- to upper-middle family income strata. Shape School performance may differ in more disadvantaged samples. These results represent, however, expected task performance in a low-risk sample. Preschool children with various clinical conditions affecting executive function may show different patterns of performance on the Shape School. One advantage of the Shape School, relative to other executive function measures, is the ability to examine inhibition and switching skills separately. Various patterns of Shape School performance, then, may reflect important developmental differences in brain–behavior relations.

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