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ATTENTION, RESPONSE INHIBITION, AND FACE-INFORMATION PROCESSING IN CHILDREN: THE ROLE OF TASK CHARACTERISTICS, AGE, AND GENDER

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The aim of the study was to assess: (a) developmental changes in attention, response inhibition, and face-information processing using the new Balloons task and (b) to evaluate the association between measures derived from the task with reported behavior problems. One hundred and thirty-four typically developing children (53 boys and 81 girls) were tested with the Balloons. Their parents and teachers completed the Child Behavior Checklist. Our results validate the Balloons as a reliable task with significant effects of manipulations in difficulty level (speed, processing load, and processing type). The results suggest that face-information processing undergoes significant changes during the age period between 7 and 13 years with significant gender differences. Modest but significant correlations were found between the Balloons' measures and behavior problems.

Keywords: ***Face processing; Executive function; Development; Emotion.***

Brain maturation and particularly the growth of the prefrontal cortex is a major developmental process that occurs during childhood and adolescence (Blakemore & Choudhury, 2006; Giedd et al., 1999). This maturation is considered crucial to the development of sophisticated skills such as planning, response inhibition, and attention regulation, all related to executive functioning (P. Anderson, 2002; Barkley, 1997; Nigg, 2000; Welsh & Pennington, 1988; Welsh, Pennington, & Groisser, 1991). All these skills are needed for smooth, goal-directed, and dynamic interaction with the complex social world. Compromised executive functioning (EF) has been associated with psychopathology in children and adults (e.g., Barkley, 1997; Bishop, 1993; Pennington & Ozonoff, 1996; Sergeant, Geurts, & Oosterlaan, 2002). In children, executive dysfunction has been associated with compromised impulse control or response inhibition, difficulty in monitoring and regulating behavior, poor planning and goal-directed behavior.

There is a growing body of knowledge demonstrating that the maturation of different aspects of EF is an ongoing process, starting in infancy throughout childhood into early

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adulthood (P. Anderson, 2002; V. A. Anderson, Anderson, Northam, Jacobs, & Catroppa, 2001; Ardila, Rosselli, Matute, & Guajardo, 2005; Davidson, Amso, Anderson, & Diamond, 2006; De Luca et al., 2003; Espy, Bull, Martin, & Stroup, 2006; Kerr & Zelazo, 2004; Klenberg, Korkman, & Lahti-Nuuttila, 2001; Leon-Carrion, Garcia-Orza, & Perez-Santamaria, 2004; Luciana, Conklin, Hooper, & Yarger, 2005; Romine & Reynolds, 2005; Sabbagh, Xu, Carlson, Moses, & Lee, 2006; Zelazo, Muller, Frye, & Marcovitch, 2003). These studies have demonstrated that different executive functions (or at least their estimation by specific instruments) develop at different rates with diverging developmental slopes at different ages (e.g., P. Anderson, 2002; Davidson et al., 2006; Huizinga, Dolan, & van der Molen, 2006; Welsh et al., 1991). For example, Davidson et al. found that the ability to inhibit dominant response is quite developed in children as young as 4 years old while the development of cognitive flexibility (set shifting) is much more gradual and is still not fully developed at the age of 13 years. Based on a literature review, Anderson concluded that attentional control develops rapidly in early childhood whereas cognitive flexibility, goal setting, and information processing mature later, prior and during the adolescent period. In contrast, using different tests De Luca et al. found that cognitive flexibility was at adult levels in children as young as 8 years (De Luca et al., 2003). It appears that understanding of the development of EF is dependent to some extent on the specific tasks and measures used to define it.

The search for valuable EF measures has led to a variety of tests tapping into specific skills associated with set-shifting and set maintenance, planning, working memory, inhibition, and organization of behavioral contingencies across time (P. Anderson, 2002; Davidson et al., 2006; Pennington & Ozonoff, 1996). Many tasks have been considered as relevant to EF; these tasks can be categorized according to the main executive function they purportedly measure. For example, the Wisconsin Card Sorting Test (WCST; Heaton, Chelune, Talley, Kay, & Curtiss, 1993) and the Trail-Making Test Part B (TMT; Reitan, 1971) are considered as measures of cognitive set shifting or flexibility. The Tower of London (Shallice, 1982) and the Tower of Hanoi (Welsh, 1991) are referred to as tasks that measure planning capacity. The Stroop test (Homack & Riccio, 2004) and Go/No-Go task (Simmonds, Pekar, & Mostofsky, 2008) assess behavioral inhibition.

While all these and additional tasks address different aspects of EF, and developmental improvement has been demonstrated on these tasks during childhood, adolescence, and young adulthood, they also have significant limitations: (a) Most of these tasks have been developed for adults and their applicability for a wide age range including young children is limited; (b) Most of these tasks focus only on one aspect of EF and therefore a battery of different tests is required for a more comprehensive assessment; (c) Many of these tasks have only one level of difficulty. Because EF skills develop rapidly during childhood, a developmental task must have the ability to adjust its level to different age groups (P. Anderson, 2002); (d) While some tasks include time pressure in the form of instructions such as “Perform as fast as you can,” in most tasks there is no built-in task-induced time pressure that would force rapid response and inhibition and would thus pose a greater challenge to EF under stress; (e) Concerns have been raised that traditional EF tasks lack ecological validity that has proven to be a major impediment in identifying EF profiles in children with developmental disorders, such as autism (Gioia & Isquith, 2004; Gioia, Isquith, Kenworthy, & Barton, 2002; Kenworthy, Yerys, Anthony, & Wallace, 2008); (f) Most EF tasks do no include specific assessment of neutral and emotional information processing and how emotional information affects EF. It appears crucial to assess EF under conditions of high motivation, negative consequences, emotion processing, or other stressors that better challenge the underlying skills (Dahl, 2004; Kerr & Zelazo, 2004; Luna & Sweeney, 2004; Steinberg, 2004).

This last point addresses an important issue. Although there is growing literature on the development of face-emotion processing and its relevance to social adjustment, there is almost no cross-talk between the literature on EF and the literature on face-information processing. Identifying emotional expressions is a crucial function in social context and may have significant impact on behavior and emotion regulation. We hypothesized that integrating assessment of face-information processing in EF tasks would provide information with better ecological validity.

Face-Emotion and Face-Gender Processing

Face-emotion recognition, or more specifically the ability to process information regarding facial expressions, plays an important role in social interactions and social adaptation (Herba & Phillips, 2004; McClure, 2000). This specific ability has been linked to adjustment and psychopathology in adults (Bediou et al., 2005; Langenecker et al., 2005; Leppanen, 2006; Phillips, Drevets, Rauch, & Lane, 2003) and in children (Celani, Battacchi, & Arcidiacono, 1999; Crick & Dodge, 1994; Custrini & Feldman, 1989; Edwards, Manstead, & Macdonald, 1984; Leppanen & Hietanen, 2001; Nowicki & Duke, 1992).

Developmental studies have explored facial-expression processing in infants, adolescents, and adults (De Sonneville et al., 2002; Deruelle & Fagot, 2005; Herba, Landau, Russell, Ecker, & Phillips, 2006). Face-emotion recognition exists in babies even when they are as young as few months old (Kahana-Kalman & Walker-Andrews, 2001; Leppanen, Moulson, Vogel-Farley, & Nelson, 2007; Striano & Vaish, 2006; Walker-Andrews, 1997). Studies have consistently demonstrated that face-expression processing improves with age (De Sonneville et al., 2002; Durand, Gallay, Seigneuric, Robichon, & Baudouin, 2007; Herba & Phillips, 2004; Herba et al., 2006; McClure, 2000; Vicari, Reilly, Pasqualetti, Vizzotto, & Caltagirone, 2000), and it has been suggested that this improvement (manifested in both speed and accuracy) is gradual with no specific age-phase shifts (Herba & Phillips).

In children, the associations between compromised face-emotion processing and psychopathology have mostly been demonstrated in severe disorders such as autism (Bolte et al., 2006; Celani et al., 1999; Golarai, Grill-Spector, & Reiss, 2006; Sasson, 2006). We identified only three studies associating face-emotion processing and child behavior in normal children (Custrini & Feldman, 1989; Edwards et al., 1984; Leppanen & Hietanen, 2001). These studies demonstrated association between face-emotion processing and social-behavior adjustment in school-age children. In the first study, children with high-sociometric status performed better on a face-emotion recognition task in comparison to children with low-sociometric status (Edwards et al.). In the second study, a similar finding was reported but only in girls (Custrini & Feldman). The third study also found significant correlations between face-emotion processing accuracy and social adjustment only in girls (Leppanen & Hietanen). Therefore, face-information processing appears to be associated with social skills at least in girls.

Interestingly, sex differences in facial-expression processing have been reported from infancy through adulthood (Hampson, van Anders, & Mullin, 2006; McClure, 2000). Although the reports on sex differences have not been consistent, a meta-analysis of studies in this area concluded that, in comparison to boys, girls have better performance on tasks involving facial expression processing (McClure). These sex differences have been attributed

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to sex differences in socialization processes and in brain maturation and activation patterns (see McClure for a comprehensive review).

Face-gender recognition is a related research area that has received less attention in both adults (Cellerino, Borghetti, & Sartucci, 2004; Cellerino et al., 2007) and children (Hoss, Ramsey, Griffin, & Langlois, 2005; Sugimura, 2006; Wild et al., 2000). It has been suggested that during development face-gender recognition is advancing from procedural process (piecemeal analysis of specific features) in early childhood to a global-configural analysis during the early school years and this progress is manifested in a significant increase in processing speed during these years (Wild et al.). Gender differences in face-gender processing have been reported in a few studies in adults (Cellerino et al., 2004). Similar to face emotional expression processing, women presented higher efficiency in face-gender processing. Studies in children have either not assessed or not reported any gender differences in face-gender processing.

We believe that in real social situations, face-information processing occurs within a context of significant cognitive load, time pressures, and complex attentional and inhibitory demands. The purpose of the present study was to assess simultaneously the development of both face-gender and face-emotion processing in school-age children using a task that involves components of EF such as selective attention and response inhibition under conditions of increasing cognitive load and time pressure. We chose both face-gender and face-emotion processing to allow assessing the specific role of emotion recognition (in comparison to gender). To achieve this goal, we developed a special task that enables administration to a wide age range and challenges each child with increasing difficulty levels by manipulating speed and cognitive load. The task involves processing of neutral and face information. Based on the reviewed literature, our main hypotheses were: (a) task characteristics such as speed and visual load as well as target demands would have a significant impact on performance; (b) developmental trends would be reflected in improved performance with age on both face-gender and face-emotion processing tasks; (c) girls would outperform boys on face-processing-related tasks; and (d) poor performance on these tasks would be associated with reported behavior problems in these children.

METHOD

Participants

One hundred and thirty-four children (53 boys and 81 girls) participated in this study. The children were sampled from three age groups: second grade students (n = 53; age: range = 7.13–8.99 years, M = 8.16, SD = 0.49), fourth grade students (n = 47; age: range = 9.0–10.99 years, M = 10.05, SD = 0.70), and sixth grade students (n = 34; age: range = 11.08–12.33 years, M = 11.70, SD = 0.35). The sample consisted mostly of children from middle- and upper-class families. Most of the parents had full-time jobs (fathers: 90.71%; mothers: 49.31%) and were well educated (number of years of formal education: M = 16.27, range = 10–30). The number of rooms in the household reflected the socioeconomic status (M = 4.52, range = 3–8). Most of the children (86.39%) were living with both parents in relatively small households (number of family members: M = 4.53, range = 1–7). Forty percent of the children were firstborn. In close to 25% of the families, one of the parents or both immigrated to Israel from other countries, but all these transitions had occurred more than 10 years prior to the study.

Because our goal was to assess a broad picture in total class samples of healthy school children, only narrow exclusion criteria were employed. Children with acute physical illness or children receiving medication that can influence cognitive or neurobehavioral functioning were excluded from the study. According the Israeli norms of the Child Behavior Checklist (see below) 8 children were identified as having a total behavior problem score in the clinical range, 6 with clinically significant externalizing behavior problems, and 9 with internalizing behavior problems.

Procedure

The study was approved by the Israel Ministry of Education and by the University Ethics Committee. It was defined by the school authorities as a school project and informed consent was obtained from the children and their parents. Each was rewarded with a $15 voucher (for an office and school supply store) for completing the study.

All parents signed informed consent and the children confirmed their assent. The parents were asked to complete a battery of questionnaires that included family background material and the Child Behavior Checklist (CBCL; Achenbach & Edelbrock, 1983). Within 2 to 4 weeks following the completion of the questionnaires, the children were tested with the Balloons, a new task assessing attention, response inhibition, and face-information processing specially developed for this study. All the tests were administered individually in a quiet room at the school.

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Measures

The Balloons Task. The Balloons task is a computerized game-like test that was designed to assess face-information processing under conditions of increasing task demands. It was planned with the aim of developing a task that would cover a wide age range (from 4 years of age to adults) by having increasing task demands and challenges. The overall goal is to pop balloons by pointing with the mouse and clicking on target balloons. The task is divided into three segments and the definition of the target balloons changes from segment to segment. The game begins with the first rule presented: "Click only on the green balloons." After the rule is presented, balloons (in three different colors) start appearing on the screen, moving up from the bottom of the screen until they disappear. The goal is to click on all target balloons and only on them. Missing a target balloon is defined as an omission error, and clicking on a nontarget balloon is considered an error. Whenever the player clicks on a target balloon the number of points increases by one, whereas clicking on a nontarget balloons results in a one-point deduction. The goal of the children is to achieve as many points as they can, knowing that the more points they achieve, the bigger the prize they would get.

Three task parameters are manipulated to control the difficulty level: (a) The number of balloons simultaneously presented on the screen (four, six, or eight); (b) The balloons motion speed (1, 2, 3): In the first speed level, each balloon moves from the bottom of the screen to the top within 2 seconds, in the second speed level within 1.2 seconds, and in the third speed level within 0.7 seconds; and (c) The rule defining the target balloons in a specific segment (see Figure 1): (1) The first rule refers to color: "Click only on the green balloons!"; (2) The second rule refers to gender ("Click only on the balloons that contain a picture of a girl"); and (3) The third rule refers to emotion ("Click only on the balloons that contain a picture of an happy face").

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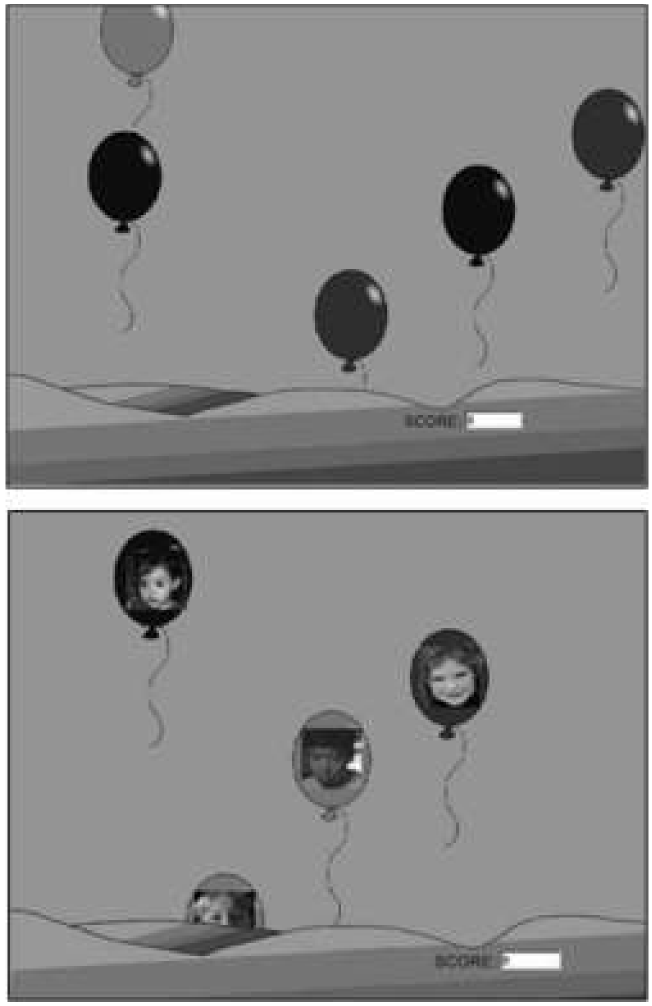

Figure 1 The screen during the color (top panel) and the gender/emotion (bottom panel) rules.

The task progresses from one level to the other according to a predetermined sequence, which is described in Table 1. The game begins with the color rule, four balloons and speed one; the next level is the color rule, four balloons and speed two; and so on. The progression to the next level occurs when the child succeeds clicking four target balloons without clicking any nontarget balloons. If the child did not succeed in doing so, and 20 target balloons have already passed, the speed changes to one (the slowest) and the balloons number or rule changes to the subsequent level. For example, if the child played in level 1.2.2 without succeeding to click four target balloons with no mistakes, then the level changed to 1.3.1 (see Table 1). As can be seen in Table 1, all the combinations of the three dimensions of difficulty levels exist.

The balloons position on the x-axis is determined randomly. The pictures of children that appear on the balloons (see Figure 1) are randomly selected from a set of 24 pictures, taken from existing Internet picture galleries that are equally distributed between boys and

Table 1 The Game Sequence.

			Segment Rule	Balloons	Speed
1.	1.1	1.1.1.	Color	4	1
		1.1.2.	Color	4	2
		1.1.3.	Color	4	3
	1.2.	1.2.1.	Color	6	1
		1.2.2.	Color	6	2
		1.2.3.	Color	6	3
	1.3.	1.3.1.	Color	8	1
		1.3.2.	Color	8	2
		1.3.3.	Color	8	3
2.	2.1.	2.1.1.	Gender	4	1
		2.1.2.	Gender	4	2
		2.1.3.	Gender	4	3
	2.2.	2.2.1.	Gender	6	1
		2.2.2.	Gender	6	2
		2.2.3.	Gender	6	3
	2.3.	2.3.1.	Gender	8	1
		2.3.2.	Gender	8	2
		2.3.3.	Gender	8	3
3.	3.1.	3.1.1.	Emotion	4	1
		3.1.2.	Emotion	4	2
		3.1.3.	Emotion	4	3
	3.2.	3.2.1.	Emotion	6	1
		3.2.2.	Emotion	6	2
		3.2.3.	Emotion	6	3
	3.3.	3.3.1.	Emotion	8	1
		3.3.2.	Emotion	8	2
		3.3.3.	Emotion	8	3

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girls, happy, sad, and neutral pictures, as determined by consensus judgments in a pilot assessment.

Four outcome variables were calculated: (a) *Y* – the average position of the correct balloons on the y-axis when clicked. The value of Y range between 0–400. High value of Y indicates quick response; (b) *Hit Percent* – the percentage of correct balloons from the total number of balloons that were clicked (i.e., total number includes correct clicks on target + wrong clicks on nontarget balloons or commission errors); (c) *Omissions* – the number of correct balloons that were omitted by the participants; (d) *Success* – the proportion of levels that were successfully completed by the participants (ranging from 0 = none to 1 = all).

Each of the variables were calculated for the different Balloons number levels, different speed levels, and different segments.

The Child Behavior Checklist. The Child Behavior Checklist (CBCL) is the most commonly used questionnaire for assessing behavior problems in children (Achenbach & Edelbrock, 1983). The questionnaire is completed by the parents and has well-established psychometric properties. The CBCL has been translated to Hebrew and validated in Israel (Zilber, Auerbach, & Lerner, 1994). Eight behavior problem scales are derived from the CBCL: (a) Delinquent behaviors; (b) Aggression; (c) Attention problems; (d) Social withdrawal; (e) Somatic complaints; (f) Thought disorders; (g) Anxiety-Depression; and (h)

Social problems. In addition, two broadband factors, related to externalizing and internalizing problems, and a total problem score are calculated.

Data Analysis Plan

Data analysis covered three major topics according to the hypotheses: (a) test-retest reliability of the Balloons and assessment of the effects of its built-in manipulations: speed, number of balloons, and target (color, gender, emotion); (b) assessment of the role of the main child characteristics (age and gender) in performance (including interactions with task characteristics); and (c) the associations between performance on the Balloons and reported behavior problems.

Test-retest reliability was assessed using correlations between measures derived from two separate administrations of the tests. The assessment of task and child characteristics were based on analyses of variance with task characteristics as repeated, within-subjects, independent variables, and child characteristics as between-subjects, independent variables.

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RESULTS

Task Characteristics

The Balloons was administered twice to each child and therefore test-retest reliability for the main variables could be calculated using simple correlations between the main global measures on the first and second administration. The test-retest correlations were: .78, .60, .37, .39; for Y, Hit Percent, Omissions, and Success, respectively (all significant at $p < .0001$).

To check the main effect of the independent variables (Speed, Balloons, and Segment) ANOVA tests for repeated measures were conducted on each of the dependent variables. The study design was Age × Gender × (Speed/Balloons/Segment) for each of the dependent variables: Y, Hit Percent, Omissions, and Success. Figure 2 presents the main results of these analyses.

Increase in speed (main effect) was associated with the following effects: a decrease in Y (slower reaction time), $F(2, 132) = 389.21$, $p < .0001$; an increase in Hit Percent, $F(2, 132) = 48.75$, $p < .0001$; an increase in Omissions $F(2, 132) = 9.07$, $p < .0005$, and a decrease in Success, $F(2, 132) = 25.18$, $p < .0001$.

Increase in the number of balloons also had a significant impact on performance and was associated with the following effects: an increase in Hit Percent, $F(2, 132) = 17.58$, $p < .0001$; increase in Omissions, $F(2, 132) = 163.44$, $p < .0001$, and increase in Success, $F(2, 132) = 8.46$, $p < .0001$. The number of balloons did not affect the position in which the balloons were clicked (Y).

Significant Number × Speed interactions were found on three of the four performance variables: Y, $F(4, 130) = 5.21$, $p < .001$; Hit Percent, $F(4, 130) = 2.90$, $p < .05$; and Success, $F(4, 130) = 4.44$, $p < .005$.

Task Target

The next set of analyses was conducted to assess the role of the specific target of each segment. In the first segment, the target balloons were defined by the color (green

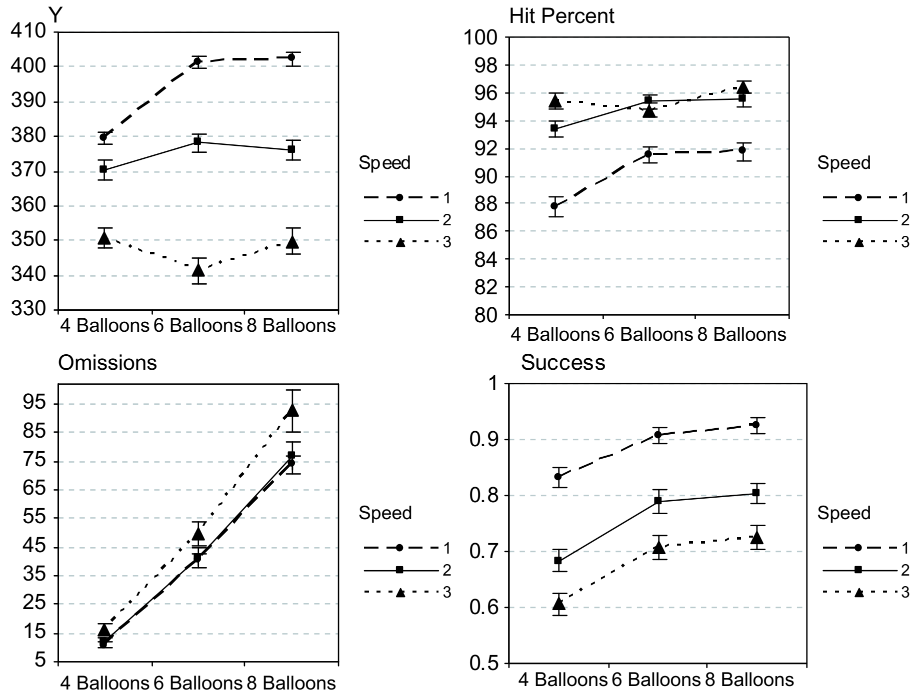

Figure 2 Task performance according to task characteristics of the balloons' number and speed (means and standard errors).

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balloons), in the second segment the target balloons were defined by gender (balloons containing pictures of boys in contrast to girls), and in the third segment the target balloons were defined by emotion (balloons containing a picture of a happy face as opposed to sad or neutral faces). Main effects for segment target were found on all performance measures (see Table 2). Response time was significantly faster (higher Y) on the color task in comparison to both gender and emotion tasks. Number of correct responses (Hit Percent) was higher on the color task than on the gender task, which was significantly higher that the emotion task. Number of omissions was significantly smaller in the color task in comparison to the gender tasks, which had fewer omissions than the emotion task. Finally, success rates were higher in the color task in comparison to the gender task, which had higher success rates than the emotion task.

Table 2 Performance According to Task (Color, Gender, or Emotion): Means and Standard Deviations and ANOVA Results[1].

	Color	Face Gender	Face Emotion	$F(2, 264)$
Y	$401.30 \pm 21.71_a$	$362.66 \pm 27.49_b$	$358.81 \pm 29.94_b$	231.15*
HitPer	$99.41 \pm 1.28_a$	$82.2 \pm 9.11_b$	$86.01 \pm 10.77_c$	149.91*
Omissions	$.40 \pm 1.57_a$	$7.75 \pm 11.04_b$	$43.78 \pm 22.52_c$	373.11*
Success	$.99 \pm .04_a$	$.63 \pm .28_b$	$.53 \pm .29_c$	137.12*

[1]Means with different subscripts (a, b, c) are significantly different in post hoc analysis.
*$p < .0001$.

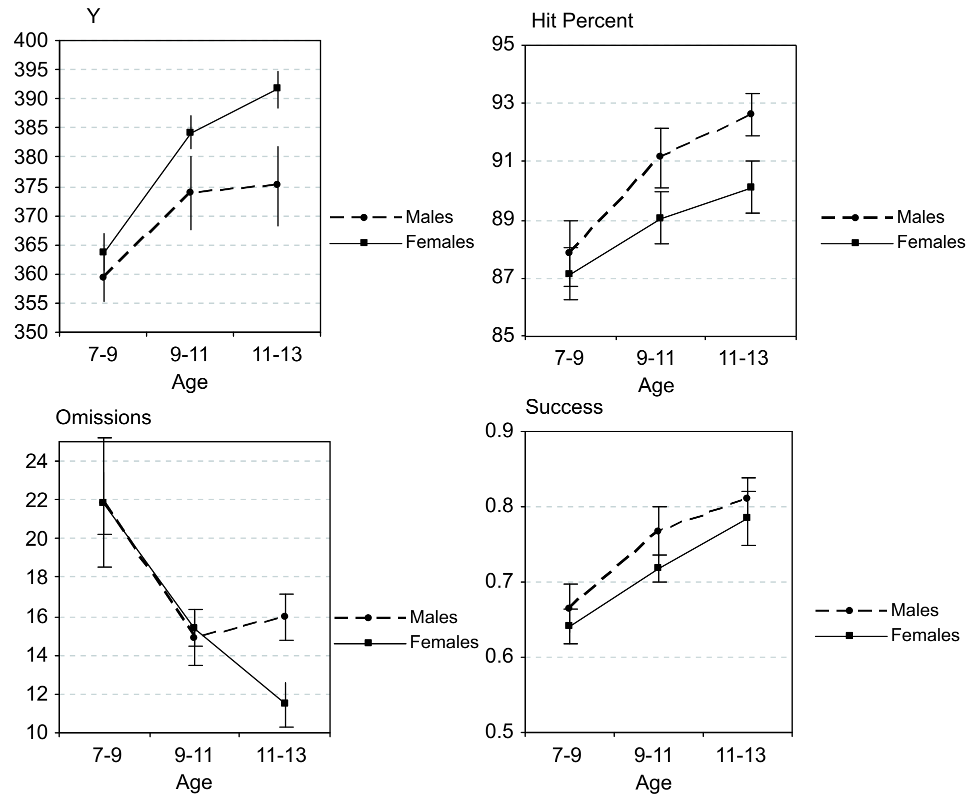

Figure 3 Task performance according to child characteristics age and gender (means and standard errors).

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Child Characteristics

To assess the main and interaction effects of age and gender, two-way MANOVA (Multivariate Analysis of Variance) tests were conducted with four dependent variable. The MANOVA revealed two significant main effects: a significant gender effect, $F(4, 125) = 3.14$, $p < .05$ and a main age effect, $F(8, 250) = 7.83$, $p < .0001$, (see Figure 3).

Separate ANOVAs for each variable revealed that older children responded faster (Y), $F(2, 128) = 15.85$, $p < .0001$; had higher Hit Percent, $F(2, 128) = 7.45$, $p < .001$, made less omissions, $F(2, 128) = 11.32$, $p < .0001$, and completed more levels (Success), $F(2, 128) = 12.33$, $p < .0001$.

Gender differences were found on two of the variables: Girls responded faster than boys $F(1, 128) = 8.90$, $p < .0001$, but they made more errors indicated by a lower Hit Percent, $F(1, 128) = 4.28$, $p < .05$. There were no significant gender differences on the variables Omissions and Success.

Interactions between Task and Child Characteristics

Interesting significant interactions between the segment task and child characteristics were found (see Figure 4). There was a significant Segment by Gender interaction on

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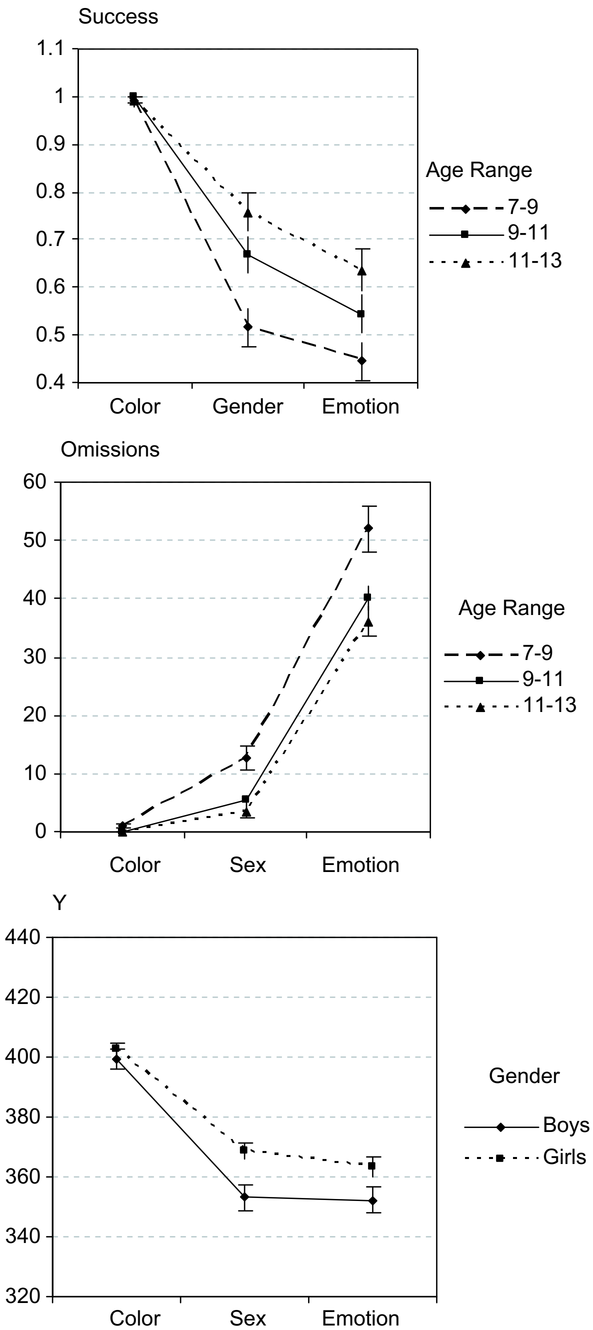

Figure 4 Interactions between segment target (color, gender, or emotion) and child characteristics.

the Y measure (speed of responding), $F(2, 256) = 5.2, p < .001$. Post hoc analyses revealed that gender differences were significant only on the face-gender and face-emotion tasks and nonsignificant for the color task. A significant Age by Segment interaction was found for the Success and Omission variables, $F(4, 256) = 3.43, p < .01$; and $F(4, 256) = 3.75$,

Table 3 Pearson Correlations between Balloons Measures and Child Behavior Checklist Scores[1].

	Total		Color		Gender		Emotion	
	Speed	Success	Speed	Success	Speed	Success	Speed	Success
Delinquency	.18 *	−.07	.06	−.08	.24 **	−.07	.11	−.03
Aggression	.23 **	−.20 *	.08	−.22 *	.28***	−.18 *	.15	−.09
Attention	.04	−.18 *	−.12	−.15	.11	−.11	.04	−.14
Withdrawal	−.01	−.24 **	−.08	−.01	.07	−.19 *	−.03	−.16
Somatic	.18 *	−.02	.09	−.03	.15	.08	.17	−.10
Thought	−.01	−.13	.00	−.04	.07	−.18 *	−.08	−.02
Anxiety-Depress	.16	−.28***	−.03	−.09	.23 **	−.19 *	.14	−.22 *
Social	.01	−.20 *	−.01	−.14	.03	−.09	.00	−.18 *
Externalizing	.23 **	−.18 *	.08	−.20 **	.30***	−.16	.16	−.09
Internalizing	.15	−.25***	−.02	−.07	.21 *	−.14	.13	−.22 *
CBCL Total	.19	−.24 **	.02	−.15	.26***	−.16	.14	−.18 *

[1]Age and sex were partialled out.
*$p < .05$. ** $p < .01$. *** $p < .005$.

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$p < .005$, respectively. Post hoc analysis indicated that significant age-related differences existed only on the face-gender and face-emotion tasks.

Associations between Balloons Measure and Behavior Problems

To assess the relationships between the performance on the different tasks of the Balloons and behavior problems, Pearson correlations were calculated between the two main variables of the Balloons (Y and success) and the CBCL scales after partialling out gender and age (see Table 3). The correlations were calculated for the total Balloons scores and the scores for each task. Significant correlations were mainly found between the total scores of the Balloons and the CBCL factors and total score as well as with almost all the CBCL specific scale scores. Examination of the correlations of the CBCL scales with the scores of the specific Balloons' tasks revealed that most of the significant correlations are related to the face-gender and face-emotion tasks. If we restrict the analysis to broadband factors of internalizing and externalizing behavior problems and to the total measures of the Balloons (to control for multiple correlations) the correlation between externalizing and Y (speed of response) and the correlation between internalizing and success remain significant after Bonferroni corrections.

No correlations were found between the Balloons measures and any of the socioeconomic parameters or the academic level reported by the teachers.

DISCUSSION

Before addressing the specific developmental results, it is important to examine the task characteristics. Test-retest reliability was high for the speed and hit percent but was only modest for omissions and success. It is possible that some training effects reduced the reliabilities on these measures. As anticipated, task characteristics as increasing time pressure (speed of the balloons) and cognitive load (number of simultaneously presented balloons) did have significant effects on performance associated with increased difficulty levels.

This was manifested on all measures including the speed of performance and accuracy measures (hit percent, success, and number of omissions). Increasing the speed of the balloons led to reduced speed of performance and compromised accuracy (a decrease in completed stages – success and increase in omissions). Interestingly, increasing the speed of the balloons led to an increase in Hit Percent, meaning that the percentage of correct balloons from the total number of balloons that were clicked increased when the speed increased. Thus, they demonstrated better inhibition ability with increased speed. Nevertheless, while the students made less clicking mistakes, they also missed more target balloons and overall their success in the game decreased. Increasing balloon numbers led to an increase in omissions but increased success rates. Furthermore, the specific task (color, gender, or emotion) played a role in determining performance. The performance measures indicate that the color task, which does not require face processing, was easier than the other two tasks (gender and emotion) and it was performed significantly faster with a higher hit rate, higher success rates, and with a smaller number of omissions. The gender and the emotion tasks were performed with similar speed but in comparison to the gender task the emotion task was performed with a higher hit rate, a higher number of omissions, and a lower success rate.

From a developmental perspective, our results suggest that face-information processing undergoes significant changes during the age period between 7 and 13 years. On the Balloons, this was manifested in faster performance and better accuracy indices. These results are consistent with previous research demonstrating developmental trends in face-emotion processing (De Sonneville et al., 2002; Durand et al., 2007; Herba & Phillips, 2004; Herba et al., 2006; McClure, 2000; Vicari et al., 2000). However, to the best of our knowledge, this is the first study to show simultaneously that very similar developmental trends exist for face-gender processing.

Gender differences were also significant on both face-processing tasks: Girls performed faster but tended to have more compromised accuracy. The advantage of females in face-processing tasks has been demonstrated earlier in face-emotion recognition (Hampson et al., 2006; McClure, 2000) and to some extent in face-gender recognition (Cellerino et al., 2004). Gender differences have not been consistent across studies and limited information exists for children on this topic. Our results suggest that these gender differences are complex and that on the Balloons task, which creates time pressure, the girls did perform faster but their faster performance may have led to some decrement in accuracy.

Modest but significant correlations were found between the Balloons variables and the CBCL scales. The global picture indicates that, when age is controlled for, faster responses and lower success rates are associated with elevated scores of behavior problems. In particular, it appears that faster responses alone are more associated with externalizing disorders, whereas the combination of faster responses and reduced accuracy (or lower success rates) is associated with internalizing problems. These results suggest that response inhibition may play a role in these associations between faster responses and reported behavior problems (Barkley, 1997; Kooijmans, Scheres, & Oosterlaan, 2000; Nigg, 2000; Oosterlaan, Logan, & Sergeant, 1998). However, it is important to emphasize that these results are based on multiple correlations and the correlations obtained were modest. Considering the fact that these correlations were obtained in typically developing children with a narrow range of behavior problems, it would be important to examine these findings in clinical populations with children exhibiting higher levels of behavior problems.

Although these preliminary findings appear promising, it is important to emphasize the limitations of the study. Our developmental findings were based on cross-sectional

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rather then a longitudinal design that would enable more solid developmental conclusions (Kraemer, Yesavage, Taylor, & Kupfer, 2000). Furthermore, our design included no other measures of inhibition, attention. or everyday measure of executive functioning that could support the construct validity of the Balloons measures.

Notwithstanding these limitations, our results provide initial support to the reliability and validity of the Balloons task for assessing executive functioning on a task that combines, face-information processing, rule-governed behavior, increasing difficulty level, cognitive load, and time pressure. This is evident in the sensitivity of the task to age- and gender-related differences and in some preliminary indications that performance on the task may predict of behavior problems.

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REFERENCES

Achenbach, T. M., & Edelbrock, C. S. (1983). *Manual for the Child Behavior Checklist and Revised Child Behavior Profile*. Burlington: University of Vermont, Department of Psychiatry.

Anderson, P. (2002). Assessment and development of executive function (EF) during childhood. *Child Neuropsychology, 8*(2), 71–82.

Anderson, V. A., Anderson, P., Northam, E., Jacobs, R., & Catroppa, C. (2001). Development of executive functions through late childhood and adolescence in an Australian sample. *Developmental Neuropsychology, 20*(1), 385–406.

Ardila, A., Rosselli, W., Matute, E., & Guajardo, S. (2005). The influence of the parents' educational level on the development of executive functions. *Developmental Neuropsychology, 28*(1), 539–560.

Barkley, R. A. (1997). Behavioral inhibition, sustained attention, and executive functions: Constructing a unifying theory of ADHD. *Psychological Bulletin, 121*(1), 65–94.

Bediou, B., Krolak-Salmon, P., Saoud, M., Henaff, M. A., Burt, M., Dalery, J., et al. (2005). Facial expression and sex recognition in schizophrenia and depression. *Canadian Journal of Psychiatry-Revue Canadienne De Psychiatrie, 50*(9), 525–533.

Bishop, D. V. (1993). Annotation: Autism, executive functions and theory of mind: A neuropsychological perspective. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 34*(3), 279–293.

Blakemore, S. J., & Choudhury, S. (2006). Development of the adolescent brain: Implications for executive function and social cognition. *Journal of Child Psychology and Psychiatry, 47*(3–4), 296–312.

Bolte, S., Hubl, D., Feineis-Matthews, S., Prvulovic, D., Dierks, T., & Poustka, F. (2006). Facial affect recognition training in autism: Can we animate the fusiform gyrus? *Behavioral Neuroscience, 120*(1), 211–216.

Celani, G., Battacchi, M. W., & Arcidiacono, L. (1999). The understanding of the emotional meaning of facial expressions in people with autism. *Journal of Autism and Developmental Disorders, 29*(1), 57–66.

Cellerino, A., Borghetti, D., & Sartucci, C. (2004). Sex differences in face gender recognition in humans. *Brain Research Bulletin, 63*(6), 443–449.

Cellerino, A., Borghetti, D., Valenzano, D. R., Tartarelli, G., Mennucci, A., Murri, L., et al. (2007). Neurophysiological correlates for the perception of facial sexual dimorphism. *Brain Research Bulletin, 71*(5), 515–522.

Crick, N. R., & Dodge, K. A. (1994). A review and reformulation of social information-processing mechanisms in children's social-adjustment. *Psychological Bulletin, 115*(1), 74–101.

Custrini, R. J., & Feldman, R. S. (1989). Children's social competence and nonverbal encoding and decoding of emotions. *Journal of Clinical Child Psychology, 18*(4), 336–342.

Dahl, R. E. (2004). Adolescent brain development: A period of vulnerabilities and opportunities - Keynote address. In R. E. Dahl & L. P. Spear (Eds.), *Adolescent brain development: Vulnerabilities and opportunities* (Vol. 1021, pp. 1–22). New York, USA: New York Academy of Sciences.

Davidson, M. C., Amso, D., Anderson, L. C., & Diamond, A. (2006). Development of cognitive control and executive functions from 4 to 13 years: Evidence from manipulations of memory, inhibition, and task switching. *Neuropsychologia, 44*(11), 2037–2078.

De Luca, C. R., Wood, S. J., Anderson, V., Buchanan, J. A., Proffitt, T. M., Mahony, K., et al. (2003). Normative data from the Cantab. I: Development of executive function over the lifespan. *Journal of Clinical and Experimental Neuropsychology, 25*(2), 242–254.

De Sonneville, L. M. J., Verschoor, C. A., Njiokiktjien, C., Op het Veld, V., Toorenaar, N., & Vranken, M. (2002). Facial identity and facial emotions: Speed, accuracy, and processing strategies in children and adults. *Journal of Clinical and Experimental Neuropsychology, 24*(2), 200–213.

Deruelle, C., & Fagot, J. (2005). Categorizing facial identities, emotions, and genders: Attention to high- and low-spatial frequencies by children and adults. *Journal of Experimental Child Psychology, 90*(2), 172–184.

Durand, K., Gallay, M., Seigneuric, A., Robichon, F., & Baudouin, J. Y. (2007). The development of facial emotion recognition: The role of configural information. *Journal of Experimental Child Psychology, 97*(1), 14–27.

Edwards, R., Manstead, A. S. R., & Macdonald, C. J. (1984). The relationship between children's sociometric status and ability to recognize facial expressions of emotion. *European Journal of Social Psychology, 14*(2), 235–238.

Espy, K. A., Bull, R., Martin, J., & Stroup, W. (2006). Measuring the development of executive control with the Shape School. *Psychological Assessment, 18*(4), 373–381.

Giedd, J. N., Blumenthal, J., Jeffries, N. O., Castellanos, F. X., Liu, H., Zijdenbos, A., et al. (1999). Brain development during childhood and adolescence: A longitudinal MRI study. *Nature Neuroscience, 2*(10), 861–863.

Gioia, G. A., & Isquith, P. K. (2004). Ecological assessment of executive function in traumatic brain injury. *Developmental Neuropsychology, 25*(1–2), 135–158.

Gioia, G. A., Isquith, P. K., Kenworthy, L., & Barton, R. M. (2002). Profiles of everyday executive function in acquired and developmental disorders. *Child Neuropsychology, 8*(2), 121–137.

Golarai, G., Grill-Spector, K., & Reiss, A. L. (2006). Autism and the development of face processing. *Clinical Neuroscience Research, 6*(3–4), 145–160.

Hampson, E., van Anders, S. M., & Mullin, L. I. (2006). A female advantage in the recognition of emotional facial expressions: Test of an evolutionary hypothesis. *Evolution and Human Behavior, 27*(6), 401–416.

Heaton, R. K., Chelune, G. J., Talley, J. L., Kay, G. G., & Curtiss, G. (1993). *Wisconsin Card Sorting Test manual: Revised and expanded*. Odessa, FL: Psychological Assessment Resources.

Herba, C. M., Landau, S., Russell, T., Ecker, C., & Phillips, M. L. (2006). The development of emotion-processing in children: Effects of age, emotion, and intensity. *Journal of Child Psychology and Psychiatry, 47*(11), 1098–1106.

Herba, C., & Phillips, M. (2004). Annotation: Development of facial expression recognition from childhood to adolescence: Behavioural and neurological perspectives. *Journal of Child Psychology and Psychiatry, 45*(7), 1185–1198.

Homack, H., & Riccio, C. A. (2004). A meta-analysis of the sensitivity and specificity of the Stroop Color and Word Test with children. *Archives of Clinical Neuropsychology, 19*, 725–743.

Hoss, R. A., Ramsey, J. L., Griffin, A. M., & Langlois, J. H. (2005). The role of facial attractiveness and facial masculinity/femininity in sex classification of faces. *Perception, 34*(12), 1459–1474.

Huizinga, M., Dolan, C. V., & van der Molen, M. W. (2006). Age-related change in executive function: Developmental trends and a latent variable analysis. *Neuropsychologia, 44*(11), 2017–2036.

Kahana-Kalman, R., & Walker-Andrews, A. S. (2001). The role of person familiarity in young infants' perception of emotional expressions. *Child Development, 72*(2), 352–369.

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Kenworthy, L., Yerys, B. E., Anthony, L. G., & Wallace, G. L. (2008). Understanding executive control in autism spectrum disorders in the lab and in the real world. *Neuropsychological Review, 18*(4), 320–338.

Kerr, A., & Zelazo, P. D. (2004). Development of 'hot' executive function: The children's gambling task. *Brain and Cognition, 55*(1), 148–157.

Klenberg, L., Korkman, M., & Lahti-Nuuttila, P. (2001). Differential development of attention and executive functions in 3-to 12-year-old Finnish children. *Developmental Neuropsychology, 20*(1), 407–428.

Kooijmans, R., Scheres, A., & Oosterlaan, J. (2000). Response inhibition and measures of psychopathology: A dimensional analysis. *Child Neuropsychology, 6*(3), 175–184.

Kraemer, H. C., Yesavage, J. A., Taylor, J. L., & Kupfer, D. (2000). How can we learn about developmental processes from cross-sectional studies, or can we? *American Journal of Psychiatry, 157*(2), 163–171.

Langenecker, S. A., Bieliauskas, L. A., Rapport, L. J., Zubieta, J. K., Wilde, E. A., & Berent, S. (2005). Face emotion perception and executive functioning deficits in depression. *Journal of Clinical and Experimental Neuropsychology, 27*(3), 320–333.

Leon-Carrion, J., Garcia-Orza, J., & Perez-Santamaria, F. J. (2004). Development of the inhibitory component of the executive functions in children and adolescents. *International Journal of Neuroscience, 114*(10), 1291–1311.

Leppanen, J. M. (2006). Emotional information processing in mood disorders: A review of behavioral and neuroimaging findings. *Current Opinion in Psychiatry, 19*(1), 34–39.

Leppanen, J. M., & Hietanen, J. K. (2001). Emotion recognition and social adjustment in school-aged girls and boys. *Scandinavian Journal of Psychology, 42*(5), 429–435.

Leppanen, J. M., Moulson, M. C., Vogel-Farley, V. K., & Nelson, C. A. (2007). An ERP study of emotional face processing in the adult and infant brain. *Child Development, 78*(1), 232–245.

Luciana, M., Conklin, H. M., Hooper, C. J., & Yarger, R. S. (2005). The development of nonverbal working memory and executive control processes in adolescents. *Child Development, 76*(3), 697–712.

Luna, B., & Sweeney, J. A. (2004). The emergence of collaborative brain function — fMRI studies of the development of response inhibition. In R. E. Dahl & L. P. Spear (Eds.), *Adolescent brain development: Vulnerabilities and opportunities* (Vol. 1021, pp. 296–309). New York, USA: New York Academy of Sciences.

McClure, E. B. (2000). A meta-analytic review of sex differences in facial expression processing and their development in infants, children, and adolescents. *Psychological Bulletin, 126*(3), 424–453.

Nigg, J. T. (2000). On inhibition/disinhibition in developmental psychopathology: Views from cognitive and personality psychology and a working inhibition taxonomy. *Psychological Bulletin, 126*(2), 220–246.

Nowicki, S., & Duke, M. P. (1992). The association of children's nonverbal decoding abilities with their popularity, locus of control, and academic-achievement. *Journal of Genetic Psychology, 153*(4), 385–393.

Oosterlaan, J., Logan, G. D., & Sergeant, J. A. (1998). Response inhibition in AD/HD, CD, comorbid AD/HD + CD, anxious, and control children: A meta-analysis of studies with the stop task. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 39*(3), 411–425.

Pennington, B. F., & Ozonoff, S. (1996). Executive functions and developmental psychopathology. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 37*(1), 51–87.

Phillips, M. L., Drevets, W. C., Rauch, S. L., & Lane, R. (2003). Neurobiology of emotion perception II: Implications for major psychiatric disorders. *Biological Psychiatry, 54*(5), 515–528.

Reitan, R. M. (1971). Trail-making test results for normal and brain-damaged children. *Perceptual and Motor Skills, 33*, 575–578.

Romine, C. B., & Reynolds, C. R. (2005). Model of the development of frontal lobe functioning: Findings from a meta-analysis. *Applied Neuropsychology, 12*(4), 190–201.

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Sabbagh, M. A., Xu, F., Carlson, S. M., Moses, L. J., & Lee, K. (2006). The development of executive functioning and theory of mind — A comparison of Chinese and US preschoolers. *Psychological Science, 17*(1), 74–81.

Sasson, N. J. (2006). The development of face processing in autism. *Journal of Autism and Developmental Disorders, 36*(3), 381–394.

Sergeant, J. A., Geurts, H., & Oosterlaan, J. (2002). How specific is a deficit of executive functioning for attention-deficit/hyperactivity disorder? *Behavioural Brain Research, 130*(1–2), 3–28.

Shallice, T. (1982). Specific impairments of planning. *Philosophical Transactions of the Royal Society of London, 298*, 199–209.

Simmonds, D. J., Pekar, J. J., & Mostofsky, S. H. (2008). Meta-analysis of Go/No-go tasks, demonstrating that fMRI activation associated with response inhibition is task-dependent. *Neuropsychologia, 46*, 224–232.

Steinberg, L. (2004). Risk taking in adolescence — What changes, and why? In R. E. Dahl & L. P. Spear (Eds.), *Adolescent brain development: Vulnerabilities and opportunities* (Vol. 1021, pp. 51–58). New York, USA: New York Academy of Sciences.

Striano, T., & Vaish, A. (2006). Seven- to 9-month-old infants use facial expressions to interpret others' actions. *British Journal of Developmental Psychology, 24*, 753–760.

Sugimura, T. (2006). How accurately do young children and adults discriminate the gender of natural faces? *Perceptual and Motor Skills, 102*(3), 654–664.

Vicari, S., Reilly, J. S., Pasqualetti, P., Vizzotto, A., & Caltagirone, C. (2000). Recognition of facial expressions of emotions in school-age children: The intersection of perceptual and semantic categories. *Acta Paediatrica, 89*(7), 836–845.

Walker-Andrews, A. S. (1997). Infants' perception of expressive behaviors: Differentiation of multimodal information. *Psychological Bulletin, 121*(3), 437–456.

Welsh, M. C. (1991). Rule-guided behavior and self-monitoring on the Tower of Hanoi disk-transfer task. *Cognitive Development, 62*, 59–67.

Welsh, M. C., & Pennington, B. F. (1988). Assessing frontal lobe functioning in children: Views from developmental psychology. *Developmental Neuropsychology, 4*(3), 199–230.

Welsh, M. C., Pennington, B. F., & Groisser, D. B. (1991). A normative-developmental study of executive function: A window on prefrontal function in children. *Developmental Neuropsychology, 7*(2), 131–149.

Wild, H. A., Barrett, S. E., Spence, M. J., O'Toole, A. J., Cheng, Y. D., & Brooke, J. (2000). Recognition and sex categorization of adults' and children's faces: Examining performance in the absence of sex-stereotyped cues. *Journal of Experimental Child Psychology, 77*(4), 269–291.

Zelazo, P. D., Muller, U., Frye, D., & Marcovitch, S. (2003). The development of executive function. *Monographs of the Society for Research in Child Development, 68*(3), 1–27.

Zilber, N., Auerbach, J., & Lerner, Y. (1994). Israeli norms for the Achenbach Child Behavior Checklist: Comparison of clinically-referred and non-referred children. *Israel Journal of Psychiatry and Related Sciences, 31*(1), 5–12.

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