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COGNITIVE DEVELOPMENT

Color–object interference in young children: A Stroop effect in children 3½–6½ years old

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Abstract

The Stroop color–word task cannot be administered to children who are unable to read. However, our color–object Stroop task can. One hundred and sixty-eight children of 3½–6½ years (50% female; 24 children at each 6-month interval) were shown line drawings of familiar objects in a color that was congruent (e.g., an orange carrot), incongruent (e.g., a green carrot), or neutral (for objects having no canonical color [e.g., a red book]), and abstract shapes, each drawn in one of six colors. Half the children were asked to name the color in which each object was drawn, and half were to name each object. Children's predominant tendency was to say what the object was; when instructed to do otherwise they were slower and less accurate. Children were faster and more accurate at naming the color of a stimulus when the form could not be named (abstract shape) than when it could, even if in its canonical color. The heightened interference to color-naming versus object-naming was not due to lack of familiarity with color names or group differences: Children in the color condition were as fast and accurate at naming the colors of abstract shapes as were children in the form condition at naming familiar objects.

Keywords: Shape bias; Inhibition; Executive function; Color–form; Attention; Binding

In the classic Stroop task (MacLeod, 1991; Stroop, 1935), the names of colors are printed in the ink of another color (e.g., the word "green" printed in red ink). Participants are asked to read the word or name the ink color. This task has been a source of many important insights into adult cognition, attentional control mechanisms, and the neural bases of cognition.

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Its use with young children, however, has been limited by the requirement to be able to read (indeed, to be a well-practiced reader). We have circumvented that requirement by using simple line drawings of objects rather than words. As in the standard Stroop task, we have *a congruent condition* (familiar objects, such as a carrot, drawn in their usual color [e.g., orange]), *an incongruent condition* (familiar objects drawn in an anomalous color [e.g., a green carrot]), *a neutral condition* (familiar objects that have no particular color associated with them drawn in a color [e.g., a red book]), and *a baseline color-naming condition* (un-nameable abstract shapes drawn in a color). With this task we have begun to investigate the existence and characteristics of Stroop-like color–object interference effects in preschoolers and young school-age children. We hope this task will open for study with young children many questions that can be explored with a Stroop paradigm.

The classic color–word Stroop effect relies on the strong overlearned tendency of experienced readers to attend to the meaning of a word and to pay less attention to surface features such as font style or color. When instructed to name the color of the ink in which a word is printed, adults must inhibit the strong tendency to attend to what word it is. Past research indicates that children and adults have a similar prepotent tendency to attend to what an object is rather than to its color.

1. Why should object-naming be prepotent over color-naming?

A stimulus is considered to “be” what its object classification or name is, while color is but one of its surface attributes. Children and adults are inclined to classify and sort by shape (or object kind) rather than by color (Colby & Robertson, 1942; Kagan & Lemkin, 1961; Mittler & Harris, 1969; Siegel & Vance, 1970; Smiley & Weir, 1966; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976) and to generalize a new word or fact to other stimuli of the same shape or object kind rather than to other stimuli of the same color (termed “the shape bias” by Landau, Smith, & Jones, 1988; see also Gelman & Markman, 1987; Smith, Jones, Gershkoff-Stowe, & Samuelson, 2002).

One hypothesis for the source of the shape bias is that word-learning predisposes people to it. For example, Jones (2003) has hypothesized that “the young child who successfully acquires and uses early object category names experiences positive reinforcement for the pairing of various aspects of the name-learning context with attention to shape. The result is an acquired attentional bias—a shape bias” (p. 477). However, it is equally possible that the shape bias may be largely independent of language. Bloom (2000; Diesendruck & Bloom, 2003) suggests that shape really does provide a reliable cue to object kind and that children probably pick up on that. Gelman and Markman (1987) make the important point that it is not really shape (rather than color or size) to which children are preferentially attending, but to what something is, to which natural kind category it belongs, rather than to more superficial features such as color or size.

What is clear is that over development children come to attend preferentially to form more and more. There is much evidence that during early childhood there is a progression from preferential focusing on color to preferential focusing on shape, with 3–4½ years of age being the peak of the preference for color or a transition period of equal preference for color and form (Brian & Goodenough, 1929; Brown & Campione, 1971; Colby & Robertson, 1942; Corah, 1964; Descoudres, 1941; Kagan & Lemkin, 1961; Melkman & Deutsch, 1977; Siegel & Vance, 1970; Suchman & Trabasso, 1966; Tobie, 1926). For example, Suchman and Trabasso (1966) found that when they asked children to "point to the two that are the same," children of 2.8–3.9 years preferred color, children of 3.9–4.5 showed no net preference, and children of 4.5–5.5 years preferred form, with the difference between form and color preference increasing significantly and linearly with age. Using a similar question ("Is there another just like that?"), Colby and Robertson (1942) found more color choices by children of 3.5–4.5 years than by any older age group, though form-preference predominated even among preschoolers, increasing significantly and linearly with age. Brian and Goodenough (1929) report a later break point for the shift from color to form dominance. They found that children of 3.0 through almost 6.0 years tended to match by color, with 4.5 years being the peak for color dominance. Beginning at 6.0 years form dominance appeared, increasing significantly and linearly with age. Brian and Goodenough (1929) tested younger children than most investigators. They report that 2-year-olds preferred form; hence their study is often cited as an exception to the general finding that color preference precedes form preference. However, (a) so much of their data for 2-year-olds had to be discarded because of perseverative pointing to the same choice trial after trial and (b) so many aspects of their protocol might have made form salient to very young children, that their results are difficult to interpret. Certainly, their results are fully consistent with the conclusion that from 3 to 3½ years onward the progression is from preferentially attending to color to preferentially attending to form. Brian & Goodenough (1929) and Landau et al. (1988) also report that the shape bias is extremely strong in adults, far stronger than in young children. Colby and Robertson (1942) report that a shape bias of adult-like strength is seen by about 9 years of age.

2. Can an interference effect between color and object-kind be properly called a "Stroop effect"?

The answer depends in part on how one defines the Stroop interference effect. If it is defined specifically as the interference generated by a color–word when naming the color of the ink in which the word appears, then the answer is "no." However, the term "Stroop interference" has been applied to other paradigms besides color–word interference (e.g., digit naming versus counting the number of digits ["counting Stroop"; Bush et al., 1998], naming the direction of an arrow versus reading the direction word inside the arrow (Baldo, Shimamura, & Prinzametal, 1998), naming a line drawing versus reading the name of a different object printed inside the drawing (Rosinski, Golinkoff, & Kukish, 1975), and reading location words printed in incongruent locations ("spatial Stroop"; Lu & Proctor, 1995). Indeed, the term "Stroop interference" has been applied to paradigms that, like the present one, investigated color–form or color–object interference (Glaser & Glaser, 1993; Menard-Buteau & Cavanagh, 1984; Naor-Raz, Tarr, & Kersten, 2003). A color–object paradigm, however, differs from the other Stroop paradigms in that the two classes of potential responses are not from the same semantic category. Rather than all potential responses being colors, numbers, or locations, for example, here one set of responses is color names and the other set is object names. The similarities and differences between interference from within and between semantic categories could well be a fruitful area for future research. Research thus far indicates close parallels between Stroop color–word and color–object interference.

In an fMRI design, Banich et al. (2000; Expt. 2) found strong comparability between the classic Stroop task and the color–object Stroop task both in behavior and in neural activation patterns. They investigated color–word and color–object Stroop interference in the same subjects, alternating blocks of neutrally colored stimuli and blocks where half the stimuli were neutral and half were incongruently colored. On half the runs the Stroop color–word task was presented, and on half the Stroop color–object task, the order counterbalanced across subjects. They found that adults were significantly slower to name the color when the stimulus was incongruently colored rather than when neutrally colored, whether the stimulus was an object or word. Notably, that RT increase for incongruent versus neutral trials was comparable for color–word trials (692 ms versus 577 ms) and color–object trials (657 ms versus 569 ms). Moreover, both tasks activated similar regions of frontal cortex. On incongruent trials, whether the stimuli were words or objects, greater activation was found in dorsolateral prefrontal cortex (areas 9 and 46) and in the anterior cingulate cortex than on neutral trials, suggesting that for incongruent trials on both tasks the same anterior executive-function network is recruited. Also for both tasks, increased activation in parietal cortex bilaterally (areas 7 and 40) and the left fusiform gyrus was found for incongruent versus neutral trials. The differences in neural activation patterns were of two kinds. On incongruent color–word trials additional frontal areas were recruited. It may be that since the color–word Stroop task pits items from the same semantic category against one another (naming an ink color and reading a color–word) versus different semantic categories (object kind and color) that the color–word Stroop task taxes inhibitory or executive control more strongly, hence the additional frontal activation. The other difference found by Banich et al. was, unsurprisingly, increased activation on congruent versus neutral trials in posterior regions implicated in word-processing (e.g., left precuneus) when color–word Stroop stimuli were used but in posterior regions implicated in object-processing (e.g., inferior and middle occipital cortex, and the middle temporal gyri) when color–object Stroop stimuli were used.

Three other sets of investigators have investigated Stroop interference in adults using color–object stimuli (Glaser & Glaser, 1993; Menard-Buteau & Cavanagh, 1984; Naor-Raz et al., 2003). Menard-Buteau and Cavanagh (1984) found that young adults were significantly slower to name the colors of incongruently colored objects (e.g., a picture of a blue banana) than neutrally colored objects without canonical colors (e.g., a picture of a red book). An average difference of 60 ms per item (2400 ms per block) was found. Similarly, they found that the time to discriminate the colors of two incongruently colored objects was significantly longer than that for two neutrally colored objects.

Glaser and Glaser (1993) presented adults with outline drawings of everyday objects (each of which had a canonical color) or non-objects. The experimental conditions were to name an everyday object or its color when the object was presented congruently or incongruently colored. The control conditions were to name the color of non-objects and to name everyday objects when uncolored. In this within-subject design, all participants received all trial types, which were presented in eight single-task blocks of 36 trials each. Each of the four conditions (control and experimental crossed with object- and color-naming) was presented in two consecutive blocks, preceded by a training block and six warm-up trials. Glaser and Glaser (1993) found no difference in RT for baseline color- or object-naming, and no significant facilitation for congruent stimuli. However, they found significant interference from incongruent stimuli in both object- and color-naming. They conclude on page 28, "It is quite possible to generate Stroop-like effects between concepts and their characteristic properties. These effects show the same pattern as the effects between different concepts in the color–word/color or picture-word interference task. In particular, the interference effects do not depend on a verbal distractor."

Naor-Raz et al. (2003) showed young adults images of everyday objects congruently or incongruently colored (e.g., a yellow or purple banana). The participant's task was to name the color in which the object was drawn as quickly as possible. Only objects with canonical colors were used, no observer saw the same object both congruently and incongruently colored, no one was asked to name the objects, and no baseline or neutral trials were administered. As have all the others summarized above, Naor-Raz et al. (2003) found that response times for color-naming were significantly longer for incongruently versus congruently colored stimuli.

There is, thus, a precedent for studying Stroop interference in adults using color–object stimuli and a consistent finding of interference in color-naming from incongruently colored objects. What about in children? Cramer (1967) is the only one to have previously investigated this in children. She tested children 4–5 years old (mean age: 4.75 years) using drawings of four familiar objects (apple, sun, water, and tree) and four colors. Children in the color-naming condition received a block of color-only trials first (a patch of one of the four colors on each trial) and then incongruent color–form pairings. Children in the form-naming condition received form-only trials first with each of the four familiar objects and then a block of incongruent color–form pairings. No difference in baseline speed for naming the color (with no form present) or naming the form (no color present) was found. Yet, incongruent color–object pairings caused significantly more interference (increased response times significantly more) for color-naming than for object-naming. Indeed, all children but one were slower at color-naming of incongruent stimuli than for the baseline block of color patches. On the other hand, over half the children in the object-naming condition were as fast, or faster, to name the objects when incongruently colored versus when uncolored.

Given children's well-documented tendency to label things by their object name rather than their color and given previous findings with color–object interference tasks, we predicted that our subjects would have to inhibit their prepotent tendency to identify the object pictured when instructed to name the color in which an object is drawn, and so would be slower to name the color than to name the object, and would be slower to name the color of a nameable object than of an abstract form. Unlike Cramer, we investigated this developmentally, rather than at just one age. Coming decades after Cramer's pioneering work, we were able to improve on her methodology by including congruently and neutrally colored stimuli in addition to incongruently colored ones, counterbalancing order (as order effects might differentially affect color- and object-naming), timing individual trials rather than just trial blocks, and intermixing trial types in mixed-task blocks rather than giving all trials of one condition blocked together in single-task blocks.

3. Methods

3.1. Subjects

Participants were full-term, healthy children 3½–6½ years of age. A total of 168 children were tested: 24 (12 male and 12 female) at each 6-month interval. Most were middle-class and Caucasian of European dissent. The children were recruited from local daycare centers, nursery schools, kindergartens, and by word of mouth. Informed consent was obtained from a parent of each child before testing. At every age (3½, 4, 4½, 5, 5½, 6, and 6½ years) there were equal numbers of boys and girls in each condition (color and form), closely matched on age. The age intervals comprised those children who fell within 3 months in either direction of their age group marker. For example, children from 3 years and 3.1 months through 3 years and 8.9 months were assigned to the 3½-year age group (39.1–44.9 mos). In the color condition, the overall mean age was 59.77 months (4.98 years). In the form condition, the mean age was 59.06 months (4.92 years).

An additional 26 children were tested but could not be used in the analyses. In most cases this was because of insufficient knowledge of the names of colors. Nine 3½-year-olds, five 4-year-olds, four 4½-year-olds, four 5-year-olds, three 5½-year-olds, and one 6-year-old were excluded due to lack of proficiency in color-naming, with the majority confusing brown with black. One subject (age 3½) refused to participate, and 3 subjects were excluded due to experimenter error.

3.2. Materials

The stimuli were line drawings. Each drawing, displayed on a white 20.3 cm × 15.2 cm index card, was presented individually. The testing deck consisted of 46 such cards. The outline of each stimulus was drawn in red, orange, yellow, green, purple, or brown Crayola@ magic marker and oriented horizontally on its index card. The deck consisted of four sets of stimuli. All four sets of stimuli were used in the color identification task. The abstract shapes, comprising Set D, were not used for the object identification task because they were not namable. For both form and color identification, each block of trials contained equal numbers of cards from each set. Set A consisted of drawings of 12 familiar objects strongly associated with a particular color, outlined in their characteristic color (e.g., a red heart). Set B consisted of those same 12 objects, drawn in a different (i.e., non-canonical) color (e.g., a yellow heart). Set C contained drawings of 11 familiar objects not associated with any particular color, each outlined in a color (e.g., a purple scissors). Note that for Set C the color was neither congruent nor incongruent; it was neutral. Set D consisted of 11 abstract shapes, each outlined in one of the six colors used for stimuli in the other sets. Fig. 1 shows examples of the actual test stimuli. Three drawings each are shown of familiar objects having canonical colors, familiar objects with no canonical color, and abstract shapes. Although shown here in black and white, all stimuli were colored.

3.3. Procedure

In this between-subjects design, half the children were asked to say the color in which each object was drawn (the color identification condition) and half were asked to say what

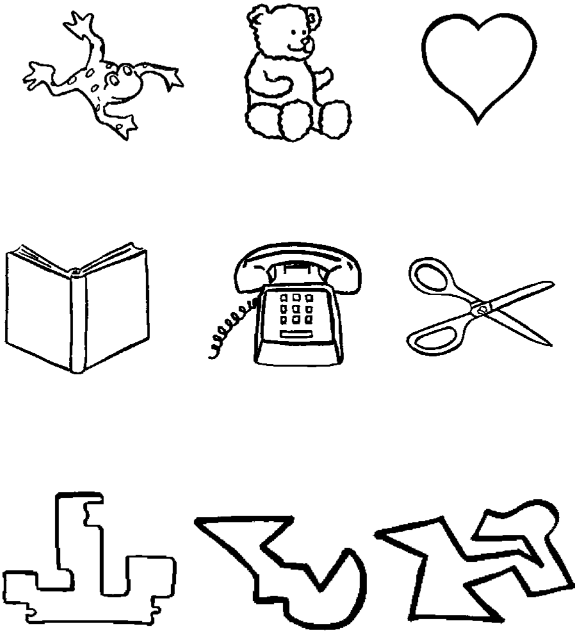

Fig. 1. Examples of Stimuli. On line 1 are examples of drawings of objects that have canonical colors associated with them. On line 2 are examples of drawings of objects that have no particular color associated with them. On line 3 are example of drawings of abstract shapes.

each of the drawn objects was (the object identification condition). All blocks contained all stimulus types (congruent, incongruent, and neutral color–object pairings, plus colored abstract shapes for those assigned to color naming). These stimulus types were randomized within each block of 11–12 trials. The order of trials was constant across children. Because the canonically colored objects were the same as the incongruently colored ones, their order of presentation was counterbalanced so that half the objects were seen in their canonical color first and half were seen in an incongruent color first. There was no break between blocks; we simply use that term to indicate the characteristics of trials 1–12, 13–23, etc.

All children were given a pretest trial to insure they understood the instructions. All children also received a posttest to confirm their ability to name the colors of the stimuli. This was administered after testing to avoid any practice effects. Only those who could name all six colors (red, orange, yellow, green, purple, and brown) without difficulty were included in the analyses. After each correct response during testing, the experimenter gave feedback, saying “right” or “good.” After an incorrect response the experimenter was silent, but showed disapproval by shaking her head. Feedback was provided so that the children would realize when their answers were incorrect and would think back to the task instructions. Accuracy would likely have been lower, and age and condition differences even greater, if feedback had not been provided.

Testing was conducted in a private room in the subjects' school, day care center, or camp, or in our child development laboratory. All sessions were videotaped with a camera equipped with a millisecond timer. Response time was judged from when the stimulus was first visible to the child to when the child first started to utter the response word. Response times were coded from the videotape records by two highly trained coders whose intercoder reliability was verified for 33% of the sessions. The coders were within 100 ms of one another on 85% of the trials, and within 200 ms of one another on 93% of the trials. Each coder was responsible for half of the sessions within each condition × age × gender cell.

3.3.1. Color identification condition

Twelve children at each age were asked to identify the color in which each object was drawn. The cards were presented to the child one at a time, and the child was instructed to respond by indicating the color of each drawing. At the outset of testing each child was told, "You will be shown a series of cards. When you look at a card, I want you to tell me the COLOR that the picture is drawn in as quickly as you can." Each child was given a practice trial with a whale drawn in the color blue. The experimenter showed the practice card and said, "OK, let's try a practice one." If the child was incorrect and said what the object was, the experimenter said, "Not quite, because you are supposed to tell me the color, so for this one it would be 'blue'." The experimenter then repeated the practice trial. No child answered the second practice trial incorrectly.

Children received 46 test trials. The four kinds of forms and six colors were evenly distributed within each of the four blocks of trials. In each of the 2 blocks of 12 trials there were 3 cards from each set. In each of the 2 blocks of 11 trials there were 3 cards from sets A and B, and 2 or 3 from Sets C and D. Thus, each block contained approximately an equal number of trials of each type of stimulus. Similarly, each block contained approximately an equal number of instances of each color.

3.3.2. Object identification condition

A different group of 84 children (12 per age) was shown the stimuli that were identifiable by name (sets A–C). The child's task was to name the objects. The child was told, "You will be shown a series of cards. When you look at a card, I want you to tell me the PICTURE you see as quickly as you can." The session began with the blue whale practice trial. The same procedure was followed for an incorrect response as in the color identification practice, except that the child was reminded to name the picture, and that the right answer was "whale." If a child attached an article to the noun, such as "a frog," the experimenter asked the child to "just say frog." If it happened a second time the experimenter echoed back just the correct word. For children who used an article, the latency of the response was measured to the point at which the child said the article.

As in the color condition, all children received 12 trials of a familiar object drawn in its canonical color, 12 trials of these objects drawn in a non-canonical color, and 11 trials of familiar objects drawn in a neutral color. The 11 abstract-shape trials were omitted for children asked to name the object as the abstract shapes were not nameable. Thus, children in the form condition received a total of 35 test trials. The three kinds of forms (sets A–C) and 6 colors were evenly distributed within each of their 3 blocks of 11–12 trials. All stimuli appeared in the same order as in the color condition, except of course there were no abstract shape stimuli.

3.3.3. Post-test

All children received a post-test to confirm their ability to name the colors. Each child was shown a set of six cards, each containing a swatch of one of the six colors that was used in testing. The child was instructed to identify the color. The experimenter said, “You will be shown a series of cards, and when you look at each one, I want you to tell me the COLOR you see as quickly as you can.” After every correct identification, the experimenter complimented the child by saying, “good” or “right.” If the child hesitated, the experimenter prompted the child once by saying, “What color is this one?” If the child responded correctly and without hesitation to the prompt then the response was counted as correct. A child needed to name all six colors correctly, without a prompt or without hesitation after the prompt, to be included in the analyses.

3.4. Statistical methods

Results were analyzed with mixed-model analysis of variance for repeated measures (McLean, Sanders, & Stroup, 1991) using PROC MIXED in the SAS statistical software package (Littell, Milliken, Stroup, & Wolfinger; SAS Institute Inc., 1990; Singer, 1998). Pairwise comparisons were performed using the Tukey–Kramer test and Tukey’s honestly significant difference (HSD) test (Snedecor & Cochran, 1989; Westfall & Young, 1993) to compensate for the additive risk of Type I error due to multiple comparisons. To look at between-subject differences in children’s performance in the color-identification and object-identification conditions, an analysis was run omitting abstract-shape trials, as those were not administered in the object-identification condition. To look at between- and within-subject differences within condition, analyses were run separately for the two conditions. Here, the between-subject variables were gender and age; all within-subject variables, except trial number, were repeated (stimulus type, object identity, color, and whether the congruent or incongruent version of a stimulus was presented first or second).

All analyses were performed once for accuracy (percentage of correct responses) and once for speed (response latency on correct trials). Compliance of residuals to a normal distribution was evaluated by Kolmogorov–Smirnov goodness of fit tests (Siegel, 1956) and graphically by inspection of histograms of residuals. The accuracy data did not differ significantly from a normal distribution, but for analyses of response speed, the natural logs of response times were used, as those complied better with normality, as determined from histograms and the Kolmogorov–Smirnov test. Any response faster than 300 ms was considered too fast to have been in response to the stimulus and was not counted; there were almost no such trials. If a child gave no response on a trial, that was counted as an error. Since we allowed children to take as long as they needed (the longest response latency was 8 s, which occurred on 4 out of the 6804 trials), there were extremely few no-response trials. Self-corrections were not uncommon, where a child first gave one response and then immediately tried to correct it. In those cases, the first answer given was the one counted.

4. Results

Not surprisingly, as age increased from 3½ to 6½ years, reaction time (RT) progressively decreased ($F[6,239] = 5.85$, $p < .0001$). Overall accuracy did not change significantly over age, however. Girls responded faster, though no more or less accurately, than boys (RT: $F[1,237] = 20.19$, $p < .0001$). Response speed was fastest on the first several trials and declined over the course of testing, as did accuracy (RT: $F[2,4548] = 27.07$, $p < .0001$; %correct: $F[2,4748] = 4.96$, $p < .01$; trials ≥#36 were administered only for the color condition and so were not included here [performance across the full range of trials administered in the color condition is reported below]). Children were slower to name the stimulus or its color when the stimulus was a recognizable animate object (Big Bird or Barney) than when it was not ($F[1,4547] = 99.05$, $p < .0001$). Condition (color- or object-naming) did not interact significantly with whether the stimulus was an identifiable creature or not, but congruency did (RT: $F[1,3325] = 6.27$, $p = .01$). The difference in performance on congruent versus incongruent trials was smaller when the stimulus was Big Bird or Barney, as RT tended to be long on those trials even when congruently colored. Neither age nor gender interacted with each other, with how early or late during the session a trial occurred, stimulus type, or condition (object-naming versus color-naming). There was no significant effect of stimulus color (red, orange, yellow, green, purple, or brown) and no interaction between color and condition.

4.1. Results for color-naming versus object-naming

Children's prepotent tendency was to give the object name. They were faster, and more accurate, at naming the object pictured than at saying the color in which it was drawn (for RT: $F[1,155] = 43.30$, $p < .0001$; %correct: $F[1,147] = 18.94$, $p < .0001$; see Fig. 2). It is unlikely that the difference in performance in color-identification versus object-identification was due to lack of familiarity with color names or to baseline group differences between the children assigned to the color and object conditions: Children assigned to the color condition were as fast and accurate at saying the color of abstract shapes as were the children assigned to the form condition at naming the familiar objects (see Fig. 3).

The markedly better performance in object-naming versus color-naming appears to be due to interference in the color condition from the presence of a nameable object. The presence of color seemed to create little or no interference in the object-naming condition. Children's prepotent tendency when shown a colored familiar object (whether congruently colored or not) appeared to be to say what the object was. There were only *two instances* in the object-naming condition of a child saying a color when the correct answer was an object label (one of those children was 4½ and the other was 5½ years old). However, there were *62 instances* in the color-naming condition of a child naming the object kind when the correct answer was a color. This is striking because (a) children in the color condition were *never* asked to identify or name the object (their *only* task was color naming) and (b) feedback was given on every trial. As you can see from Table 1, over half of these 62 instances occurred among 4-year-olds and over a third were made by the same subject. At 4 years of age, one child in the color condition named the object on 6 trials and another on a whopping 21 trials. The first child never did this on more than two consecutive trials and

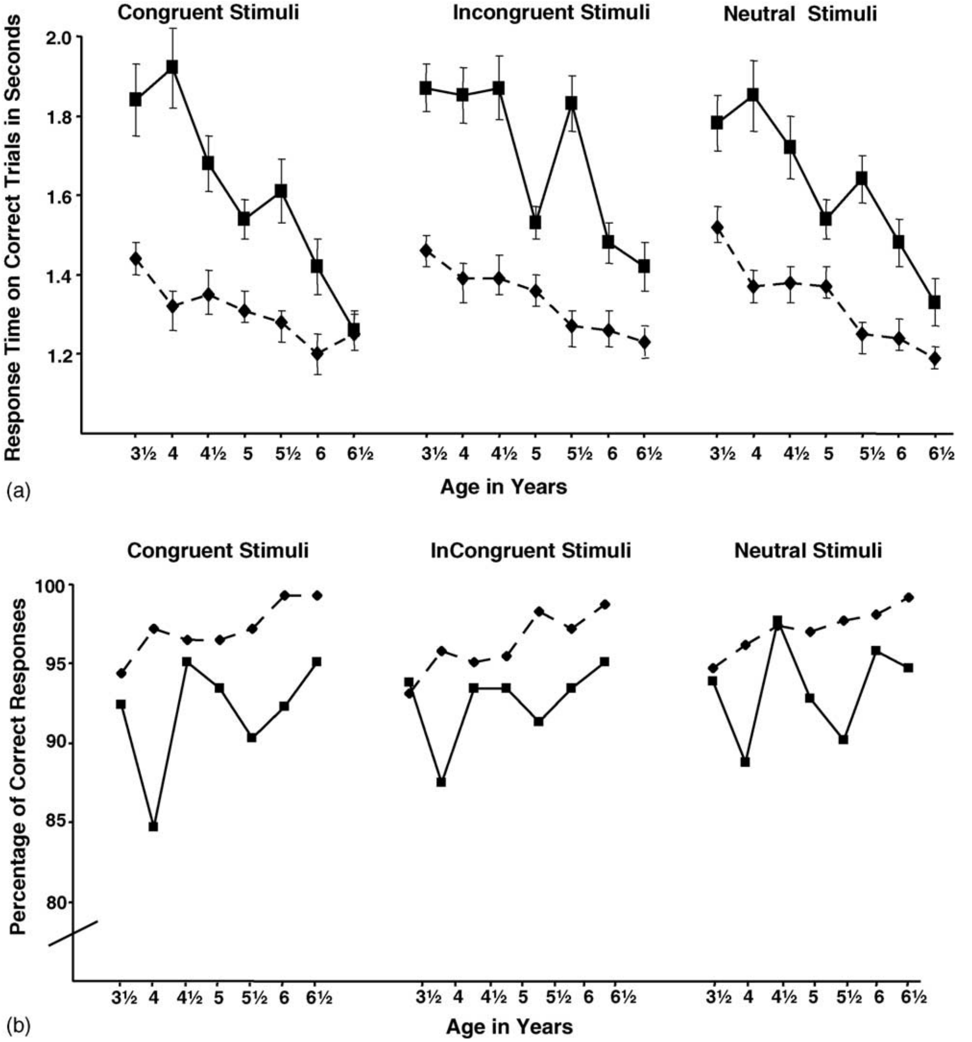

Fig. 2. Comparison of object-naming and color-naming performance by stimulus type and age. (a) Response latency for object-naming vs. color-naming by stimulus type and age. (b) Accuracy for object-naming vs. color-naming by stimulus type and age. Dashed line: object-naming. Solid line: color-naming.

the second child on never more than three consecutive trials (the first occurrence was Trial 9 and the last was Trial 46).

The faster and more accurate performance in object-naming than color-naming was true for both boys and girls (especially boys), for each stimulus type (congruently, incongruently, and neutrally colored familiar objects), and for each one-third of trials (early, middle, or later in the session). Nor was there any age × condition interaction for either dependent measure. The difference in performance by condition did not vary by stimulus: The difference in

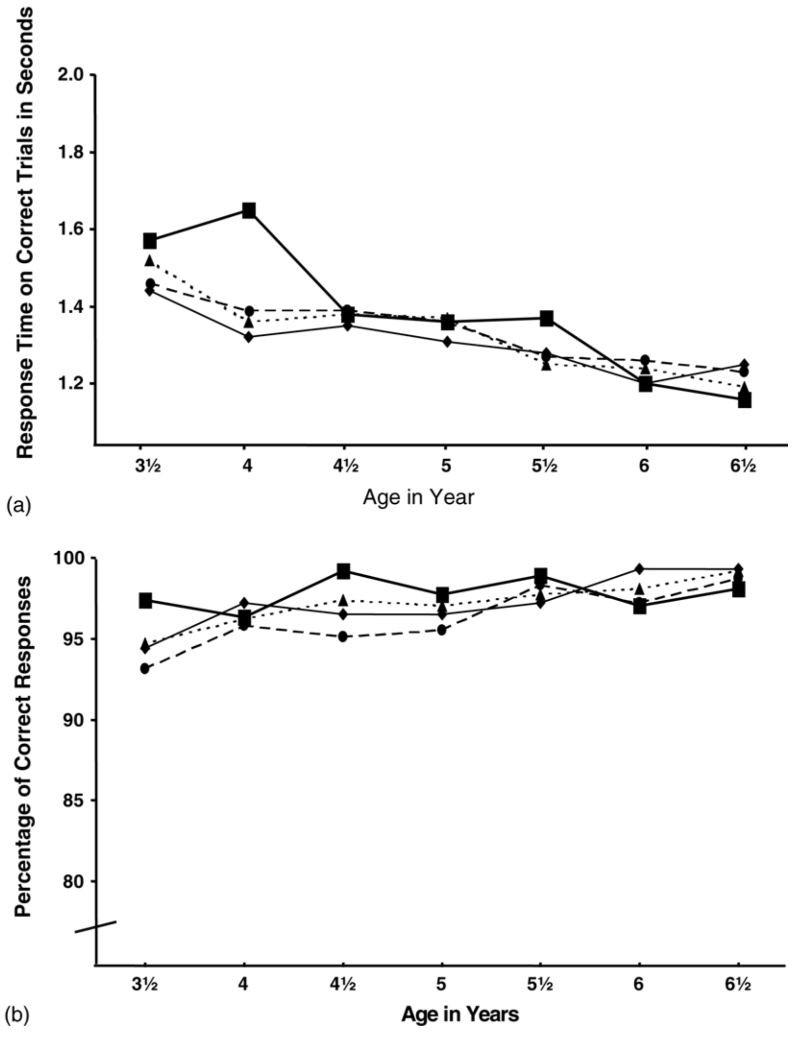

Fig. 3. Comparison of performance when asked to name objects with performance when asked to name the color of abstract shapes. (a) Speed of identifying familiar objects and of identifying the colors of abstract shapes. (b) Accuracy in identifying familiar objects and of identifying the colors of abstract shapes. ( ) Objects drawn in their canonical color (congruent stimuli). ( ) Objects drawn in a non-canonical color (incongruent stimuli). ( ) Objects having no canonical color (neutral stimuli). ( ) Abstract, unnameable shapes.

percentage of correct responses was between 3 and 5% for all three stimulus types presented in both conditions. Similarly, the difference in RT was between 250 and 300 ms for each of the three stimulus types. Always, the better performance occurred in object-naming than color-naming.

The difference in speed and accuracy increased linearly across trials. Over the first block of 12 trials, the average response latency for color was 1.48 and 1.26 s for form (a

Table 1
Instances of a naming an object when the correct response was to name the color

Age in years	Number of children	Total number of trials	Number of instances per child
3.5	5	10	1, 1, 2, 2, 4
4	5	32	1, 2, 2, 6, 21
4.5	2	2	1, 1
5	3	5	1, 2, 2
5.5	3	8	2, 3, 3
6	2	4	1, 3
6.5	2	2	1, 1
Total	22	62	

difference of 220 ms; all comparisons here include only the stimuli used in both conditions [abstract-shape trials omitted]). Over the third block of trials (the last block administered in the object-naming condition), the response latencies for color and shape, respectively, were 1.68 and 1.37 s (a difference of 310 ms). Similarly, the average percentage of correct responses for the first 12 trials was 95.5% for color and 97.8% for shape (a difference of 2.3%). By the third block of trials, the mean accuracy for color and shape were 92.2 and 96.9%, respectively (a difference of 4.7%). The increasing difference in performance on color versus form is due to the sharper drop-off in performance in the more demanding condition (color-naming). There, the average speed declined by 200 ms (14%) and the average accuracy dipped by 2.3%. In the shape condition, on the other hand, speed declined only 110 s (8%) over the course of a session and mean accuracy changed by less than 1%.

4.2. Results within the color-naming condition

Children were faster and more accurate at identifying the color of a stimulus when it could not be named (abstract shape) than when it was a recognizable object. This was true regardless of whether the stimulus appeared in its correct color, wrong color, or a neutral color (see Fig. 4). Thus, the main effect of stimulus type in the color condition was significant for RT ($F[3,3463] = 40.56$, $p < .0001$) and accuracy ($F[3,210] = 14.33$, $p < .0001$). For both speed and accuracy, the results of all pairwise comparisons of performance with abstract shapes versus each of the other three stimulus types were significant at $p < .001$, even with the stringent Tukey–Kramer adjustment for multiple comparisons.

Children were slower to name the color of an incongruently colored object than they were to name the color of a congruent, neutral, or abstract stimulus. The difference in speed of responding to incongruent stimuli versus congruently colored ones or abstract shapes was significant at $p < .0001$; the difference in speed on incongruent versus neutral trials was significant at $p < .03$. Children were not less accurate on incongruent trials, however, than they were on congruent or neutral ones. There were no significant differences in accuracy among congruent, incongruent, and neutral trials. Nor was there a significant difference in response speed on congruent and neutral trials. Indeed, RTs on congruent and neutral trials were remarkably similar (mean RT was 1.69 ms for both congruent and neutral trials for boys, and the two mean RTs were 1.51 and 1.54 ms, respectively, for girls).

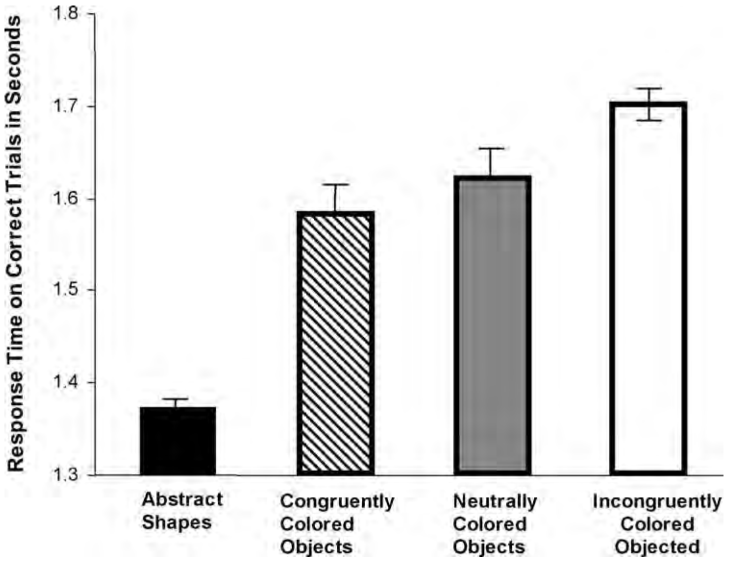

Fig. 4. Response latency for color naming by stimulus type. Children were significantly faster to name the colors of abstract shapes than the colors of any real objects, and they were significantly slower to name the colors of incongruently-colored objects than of any other type of stimulus.

If performance with abstract shapes is taken as the baseline, children appeared to experience interference (as indicated by longer response times and poorer accuracy) whenever a namable object was present, whether it was congruently, incongruently, or neutrally colored. On the other hand, if performance with neutrally colored objects is taken as the baseline, then interference appears to have been evident only in the incongruent condition and only in response speed. Indeed, though children were slower at naming both congruent and incongruent stimuli than abstract shapes, the difference in speed between incongruent and abstract stimuli was significantly greater than was the speed differential between congruent and abstract stimuli. Thus, the presence of any nameable object interfered with color-naming, slowing down response time and predisposing children to more errors, and the presence of an anomalously colored familiar object was disproportionately interfering. There was no evidence of facilitation (better performance with congruent stimuli) in either speed or accuracy using either neutral or abstract stimuli as the baseline (but see results for the first half of the trials per testing session that follows).

Response time increased linearly over trials in the color condition. On trials 1–12, the mean RT was 1.42 s. On trials 13–23, it was 1.54 s. RT was 1.63 and 1.71 s for trials 24–35 and trials 36–46, respectively (main effect for RT over trials grouped into quarters: $F[3,3464] = 44.74$, $p < .0001$). Children in the color condition responded significantly faster on the first 25% of the trials than on the second, third or fourth 25% (each pairwise difference significant at $p < .0001$; same results among girls only and among boys only). Children were significantly faster on the second quartile of trials (trials 13–23) than on the third ($p < .01$)

or the fourth quartile ($p < .0001$).[1] The difference in speed on the third and fourth quartile of trials was not significant. At every age, except 4½ years, response speed decreased continuously over trials, the mean RT on each successive quartile of trials being longer than on the previous. At 4½ years, this was true through the third quartile, but then RT declined slightly for the last quartile of trials. As speed decreased over the course of the testing session, the number of errors tended to increase ($F[3,176] = 2.28$, $p = .07$), but that change was not as marked as the slowdown in speed. The decrease in accuracy was primarily after the first quartile of trials.

There was a significant interaction of stimulus type with quartiles of trials for response speed in the color condition ($F[9,3363] = 2.03$, $p < .03$). Children grew significantly slower on trials with congruent and neutral stimuli over the course of a session (for each of those types of stimuli, RT for the first quartile of trials was significantly shorter than for either the third or fourth quartile, all p's $\leq .05$; 28% increase in RT from 1st to 4th quartile for congruent stimuli, 21% increase for neutral stimuli). On the other hand, the relatively long RTs for incongruent stimuli and the relatively quick RTs for abstract shapes stayed more stable over trials, showing more modest increases in RT from the 1st to 4th quartiles of 13 and 15%, respectively, with no significant differences between speeds earlier and later in the testing session. In both quartiles of trials in the first half of the testing sessions, speed on incongruent trials was consistently slower than on neutral trials and speed on congruent trials was consistently faster (showing interference and facilitation, respectively). For both quartiles in the second half of the testing sessions, speed was slower on both congruent and incongruent trials than on neutral ones (thus showing interference only). There was no interaction of stimuli $\times$ quartiles of trials for percentage of correct responses.

Girls were faster to name the colors of the stimuli than were boys ($F[1,69] = 5.85$, $p < .02$; mean RTs of 1.49 s versus 1.65 s). There were no significant interactions of gender with any other variable. That is, girls were faster than boys on each stimulus type, and not disproportionately faster on any particular stimulus type or during any particular period during a testing session. Girls also made slightly fewer errors than boys, but that difference was not significant (94.5% versus 93.3%). For accuracy, there was a significant three-way interaction of stimulus type $\times$ age $\times$ gender ($F[18,210] = 1.65$, $p = .05$). Four-year-old boys were disproportionately pulled to name the object rather than its color when stimuli were congruently colored (72% correct versus an average of 89% for the other three stimulus types and versus 4-year-old girls' performance with congruently colored stimuli [89% correct]). Among 6½-year-olds, it was the girls who were disproportionately distracted when stimuli were congruently colored (86% correct versus an average of 96% for the three other stimulus types) and the boys who performed perfectly when the stimuli were congruently colored (100% correct).

Older children named the colors of the stimuli significantly faster than younger children ($F[6,93] = 5.51$, $p < .0001$). Even within each quartile of trials, RTs continuously decreased across age groups, except for an elevation in RT for quartiles 2–4 among 5½-year-olds. Accuracy changed less over age, with only a tendency for older children to make fewer errors

[1] Children received 11 more trials in the color-naming condition than the object-naming condition because of the inclusion of abstract-shape trials for color-naming. Hence, each 11–12 trials makes up one-third of a session of object-naming but one-quarter of a session of color-naming.

than younger children ($F[6,70] = 2.06$, $p < .07$). There was no interaction of age with stimulus type for either dependent measure, nor did the difference in performance on incongruent versus neutral trials or incongruent versus abstract-shape trials change significantly over age.

Children responded faster in the color condition on both the congruent *and* incongruent versions of stimuli if the congruent version was presented first ($F[2,1607] = 3.67$, $p < .03$). Thus, while RT benefited on congruent trials if the stimulus had not been previously presented, RT was slower on incongruent trials if the stimulus had not been presented before. Indeed, during the second half of the testing session, children were faster on incongruent trials when the stimulus had previously been presented congruently colored than they were on congruent trials if the stimulus had previously been presented incongruently colored. During the first half of the session, RTs were faster on congruent than incongruent trials regardless. This interaction of order (first or second presentation of a stimulus) × stimulus type (canonically or anomalously colored) × when in the testing session (1st, 2nd, 3rd, or 4th quartile) was significant ($F[6,1606] = 3.54$, $p < .001$).

4.3. Results within the object-naming condition

Children were as fast and accurate to identify the pictured object when it was incongruently colored as when it was colored in a congruent or neutral color (see Fig. 3). Performance on shape was affected little by the color in which the stimulus appeared. There were also no gender differences in either dependent measure as main effects or interactions.

As in the color-naming condition, older children were faster and more accurate than younger children in naming the objects (RT: $F[6,74] = 4.19$, $p < .001$ and %correct: $F[6,70] = 2.85$, $p < .01$). The difference over age in each dependent measure was linear. Also as in the color condition, children grew slower as the testing session progressed (RT: $F[2,2690] = 34.25$, $p < .0001$; mean RT was 1.26 s on trials 1–12 and 1.38 s on the last 12 trials). There was also a significant interaction of age × when-in-the-testing-session for RT ($F[12,2690] = 2.27$, $p < .01$). Children ≥4½ years of age took progressively longer as the testing session proceeded, but children of 3½ and 4 years were slowest in the middle of the session and then sped up again toward the end. Children performed so well in the object-identification condition that although the accuracy results followed the speed results (e.g., worsening accuracy as the testing session progressed), the differences in accuracy were not significant. All differences (whether across ages or across trials) were smaller in the object condition than in the color condition.

Children in the object-naming condition were quickest to label the stimulus when it was congruently colored and they were seeing it for the second time (having previously seen it incongruently colored) and were slowest to label stimuli that were congruently colored and were being presented for the first time (RTs were intermediate for incongruently colored stimuli; $F[3,1777] = 4.31$, $p < .001$, for the interaction of stimulus type × order of presentation). Having seen the object, regardless of the color in which it was drawn, facilitated subsequent naming of the same object on its second presentation; not only were RTs fastest for congruent stimuli previously presented incongruently colored, but the next fastest RTs were for incongruent stimuli previously presented congruently colored. There was also a significant three-way interaction for stimulus type × order of presentation ×

when in the testing session ($F[6,1777] = 6.97$, $p < .0005$). At the outset of testing, children were fastest to name incongruently colored stimuli not previously seen before; by the last 12 trials, it was those stimuli on which children were slowest.

5. Discussion

Interference in the classic Stroop task occurs because experienced readers are strongly predisposed to attend to the meaning of a word and to pay less attention to surface features such as the color of the font. On color-naming trials, Stroop-task participants are to inhibit their tendency to say what the word is, and instead name the color in which the word is printed. Similarly, children and adults have a well-documented predisposition to take the "meaning" of a stimulus to be its shape or object classification, and tend to direct their attention to (and respond on the basis of) shape or object kind rather than color (e.g., Biederman & Ju, 1988; Colby & Robertson, 1942; Cramer, 1967; Gelman & Markman, 1987; Glaser & Glaser, 1993; Kendler, 1961; Landau et al., 1988; Menard-Buteau & Cavanagh, 1984; Suchman & Trabasso, 1966). In the color condition of our color–object Stroop task, participants were to inhibit their tendency to name the object presented (to say what it is) and instead name the color in which it was drawn.

Our results appear to nicely parallel those obtained for the classic color–word Stroop task (MacLeod, 1991): (1) Children were faster and more accurate at naming the object presented than at naming its color, just as adults are faster on the classic Stroop task at naming the word presented than in naming its color. (2) Naming the ink color in the classic Stroop task is significantly slower for incongruent stimuli than for congruent or neutral ones. Similarly we found that naming the color of our incongruent stimuli was significantly slower than naming the color of our congruent or neutral stimuli. (3) In the classic Stroop task, naming the word is almost unaffected by an incongruent ink color, whereas naming the ink color is severely slowed by the incongruent word. Similarly, we found that children were as fast to name an object whether it was congruently, incongruently, or neutrally colored, but their color naming was significantly slower for incongruent object–color pairings than for congruent or neutral pairings. That is, as in the classic Stroop task, we found an asymmetric effect—the meaning of the object interfered with naming the color in which it was drawn (lengthening response latencies), but the color in which the object was drawn had little effect on children's ability to quickly name the object. (4) Indeed, even the general lack of a facilitation effect for congruent stimuli on our task is in accord with most studies of Stroop-like interference. Facilitation for congruent stimuli (faster RTs than in the baseline or neutral condition) usually requires distractor pre-exposure of $\geq$200 ms for adults and is only marginal when distractor and target are presented synchronously, as we have done (Glaser & Glaser, 1993). Even so, we found evidence of facilitation from congruent stimuli during the first half of the testing sessions, though that did not last.

Our results also nicely parallel those of Cramer (1967) despite the methodological differences noted in Section 1. The bottomline that emerges from Cramer's study and ours is the same—children experience greater interference when they have to inhibit responding on the basis of object kind in order to name a color than they do when required to name the object, not its color.

The markedly better performance we found in object-naming versus color-naming seems to be due to interference in the color condition from the presence of a nameable object. Although interference was greatest for incongruent stimuli, the presence of *any* nameable object apparently interfered with color-naming. Response times were significantly slower even for congruently or neutrally colored familiar objects than for neutrally colored abstract shapes. While there were only two instances of a child saying a color when the correct answer was an object label, there were 62 instances of a child naming the object when the correct answer was a color. It is unlikely that these errors were due to the children forgetting which task they were supposed to be performing because (a) children in the color condition were *never* asked to identify or name the object (their *only* task was color naming), (b) feedback was given on every trial, and (c) these errors did not occur in long perseverative strings (naming the object rather than the color never occurred consecutively on more than three trials in any session). We think the children's problem was in inhibiting the dominant response to name the object. Exercising such inhibitory control is demanding, and the toll it took can be seen in the disproportionate lengthening of response times and decrease in accuracy over time during the course of a testing session for color-naming versus object-naming.

5.1. Limitations and areas for future exploration

While we had a baseline color-naming condition in the absence of familiar objects (the abstract-shape trials), we did not include a baseline object-naming condition where color was absent (familiar objects outlined in black). Thus, we do not know if baseline speeds for color- and object-naming would have been comparable for our participants, though that is likely since both Cramer (1967) and Glaser & Glaser (1993), who included baseline trials for form as well color, report comparable baseline RTs for color- and object-naming in children (Cramer) and adults (Glaser & Glaser). In the absence of baseline object-naming trials we also cannot know if object-naming might be slowed by the presence of color, whether it is a congruent, incongruent, or neutral color (though there is no evidence to suggest that object-naming would be slowed). We can assert with surety, however, that object-naming was *not* disproportionately slowed when the object–color pairings were incongruent (in contrast to color-naming) and that for each type of stimulus (congruent, incongruent, or neutral) children in the object condition were faster and more accurate to name the object than were children in the color condition to name the color in which it was drawn. There is other evidence, too, from our study that color–object congruity affected color-naming more than object-naming. Having seen a stimulus before facilitated subsequent naming of that stimulus, whether its earlier or current color–object pairing was congruent or incongruent. On the other hand, seeing a stimulus congruently colored on its first presentation facilitated naming the color of that stimulus. Children were faster to name the color of both the congruent *and* incongruent versions of stimuli *if* the congruent version was presented first. Indeed, while children were faster to name the colors of congruent than incongruent stimuli during the first half of the testing session regardless of which version of a stimulus was shown first, during the later half of the testing session children were actually faster to the name the color of incongruent stimuli that had previously been presented congruently colored than they were to the name the color of congruent stimuli previously presented incongruently colored.

If stimuli are geometric shapes (such as a triangle) rather than everyday objects, the tendency to focus on their form rather than their color is greatly reduced. Conversely, when familiar, meaningful stimuli are used (especially if they are animals or humans) the degree of form dominance, at least in children, increases (Descoudres, 1941; Tobie, 1926). A few of our stimuli were drawings of animate creatures, such as a frog, Big Bird, and Barney. Children responded more slowly on the Big-Bird and Barney trials, but that was true for both color- and object-naming and for congruent and incongruent trials. The difference in performance on congruent versus incongruent trials was smaller when the stimulus was Big Bird or Barney, as RTs were long on those trials even when congruently colored. In the future, researchers might find greater congruency/incongruency effects if identifiable animate creatures are not used.

If three-dimensional stimuli are used rather than two-dimensional drawings (and/or if subjects can handle the stimuli), a stronger tendency to name the object and a greater interference effect for color-naming might be found (Vokvelt, 1926). Color could probably be made more salient by coloring the stimuli in, rather than just outlining them in color, perhaps making the tendencies to focus on color or shape more equal. Certainly, saturated colors produce a higher incidence of choices by color rather than by form than do grays or paler shades (Vokvelt, 1926). However, Hale and Green (1976) report that using bright fluorescent colors did not help at all to draw children's attention to color versus shape compared with shapes in standard primary colors.

Research indicates that a shape bias is most pronounced when the task is verbal, or involves extending a verbal label to other exemplars, and is much reduced or absent when the task is nonverbal or involves finding which model a stimulus "goes with" (Davidoff & Mitchell, 1993; Diesendruck & Bloom, 2003; Glaser & Glaser, 1993; Jones, Smith, & Landau, 1991; Landau et al., 1988). For example, Landau et al. (1988) report that the shape bias is much stronger for word extension than for non-word classification tasks. The response on our color–object task was verbal; if future studies use a key-press or pointing response, less of a tendency to name the stimuli and less interference in color-naming might be found. Indeed, on the classic color–word Stroop task, a reversed Stroop effect is often found if a nonverbal response, such as a key-press, is used (Durgin, 2003; Glaser & Glaser, 1993; Treisman & Fearnley, 1969). For example, Simon and Sudalaimuthu (1979) found that the RT difference on incongruent versus congruent trials for color-naming was 86 ms with verbal responding but only 39 ms with key pressing, whereas for word-reading the RT difference was only 11 ms with verbal responding but a relatively whopping 68 ms with key-pressing. Such results have potentially important implications not only for future studies with our paradigm, but for all fMRI studies of the classic Stroop task, most of which use a key-press response.

As discussed in Section 1, a bias to attend to shape appears to increase during development. From 3 to 3½ years onward there is a steady progression from preferentially attending to color to preferentially attending to form (e.g., Brian & Goodenough, 1929; Colby & Robertson, 1942; Suchman & Trabasso, 1966) with a shape bias of adult-like strength appearing by age 9 (Colby & Robertson, 1942). Such results raise the possibility that a stronger tendency toward object-naming, and greater interference for color-naming, might be found for older subjects than those tested here, and in particular that elderly adults might show a much stronger interference effect than did our young children. It is also possible that if 3-year-olds are tested they might show a weaker tendency toward object-naming and weaker interference for color-naming, although our interference effects were at least as strong at 3½ years as they were at later ages.

Our study used a mixed-block design in that congruent, incongruent, neutral, and abstract-shape trials were intermixed. It might be interesting to see what is found if this task is administered in single-task blocks. Mixed-block designs can minimize differences in performance by trial type, as subjects often slow-down across the board for mixed blocks, responding more slowly even on easy trials when they are intermixed with difficult ones (Cohen, Bixenman, Meiran, & Diamond, 2001; Diamond & Kirkham, 2005; Fagot, Lacreuse, & Vauclair et al., 1994; Los, 1996, 1999; Kray & Lindenberger, 2000; Mayr & Liebscher, 2001). On the other hand, when single-task blocks are used (e.g., a block of incongruent stimuli on all trials), subjects can get used to responding a certain way (e.g., ignoring the irrelevant dimension) and can show a weaker cost than when trial types are intermixed (e.g., Davidson, Cruess, Diamond, O'Craven, & Savoy, 1999; Wylie & Allport, 2000).

Our study used a between-subject design for the color-naming and object-naming conditions. It would be interesting to see what would be found with a within-subject design. In particular, when within-subject designs are used for the classic Stroop task, where blocks of color-naming and blocks of word-reading are presented, a striking asymmetric switch cost is found (Allport & Wylie, 2000). That is, because word-reading is the dominant response and that has to be inhibited for color-naming, RTs are significantly slowed for word-reading trials immediately preceded by a block of color-naming because the inhibition imposed during color-naming cannot be immediately reversed. Color-naming is slower than word-reading, but it is no slower if it immediately follows a block of word-reading or not. It would be very interesting to see if such asymmetric switch costs were found with our color–object task.

Finally, our use of feedback almost certainly minimized our effects. Future studies that do not provide feedback and/or that require faster responding, will likely find even stronger interference effects than reported here.

We hope our color–object Stroop task may be of use with young children and with non-readers of all ages. This paper represents a first step in using the task to investigate the existence and characteristics of color–object interference among preschoolers and young school-age children and of the development of the executive attentional control needed to overcome that interference. As we have indicated, there are many questions yet to be explored for which this task might prove useful.

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