Available online at www.sciencedirect.com
SCIENCE DIRECT®
J. Experimental Child Psychology 90 (2005) 275–302
Journal of Experimental Child Psychology
www.elsevier.com/locate/jecp

The role of perception, language, and preference in the developmental acquisition of basic color terms

Nicola J. Pitchford [a,*], Kathy T. Mullen [b]

[a] School of Psychology, University of Nottingham, University Park, Nottingham, NG7 2RD, UK
[b] Department of Ophthalmology, McGill University, Montreal, Que., Canada H3A 1A1

Received 17 August 2004; revised 10 December 2004

Abstract

When learning basic color vocabulary, young children show a selective delay in the acquisition of brown and gray relative to other basic color terms. In this study, we first establish the robustness of this finding and then investigate the extent to which perception, language, and color preference may influence color conceptualization. Experimental tasks were designed to measure different aspects of perceptual color processing (discrimination and saliency), color preference and objective counts of color term frequency in preschool-directed language (books and mothers' speech) were used to compare the acquisition of three groups of colors: primary colors, secondary colors (orange, pink, and purple) that appear at the same time as the primary colors, and secondary colors (brown and gray) that appear late. Although our results suggest that perception does not directly shape young children's color term acquisition, we found that children prefer brown and gray significantly less than basic colors and that these color terms appear significantly less often in child-directed speech, suggesting that color preference, linguistic input, and developing color cognition may be linked.

Keywords: Cognition (general); Language acquisition; Visual perception; Color vision

* Corresponding author. Fax: +44 115 951 5324.
E-mail address: nicola.pitchford@nottingham.ac.uk (N.J. Pitchford).

0022-0965/$ - see front matter © 2005 Elsevier Inc. All rights reserved.
doi:10.1016/j.jecp.2004.12.005

Introduction

In this study, we investigated factors that may shape the developmental acquisition of basic color terms. In a seminal study, Berlin and Kay (1969) identified a maximum of 11 basic colors that are believed to be mapped consistently to the corresponding color terms of a given language: black, white, red, yellow, green, blue, brown, orange, purple, pink, and gray. In addition, they proposed a hierarchical order of color term acquisition that was both developmental (occurring within a given language) and evolutionary (occurring across languages) and was believed to be universal, arising from the neurophysiology of the human visual system (e.g., Berlin & Kay, 1969; Kay & Maffi, 2000; Kay & McDaniel, 1978). This hierarchical order of color term acquisition as originally proposed involved progression through seven stages: stage 1 (black and white), stage 2 (red), stages 3 and 4 (yellow and green in either order), stage 5 (blue), stage 6 (brown), and stage 7 (orange, purple, pink, and gray in any order). The first six color terms, acquired during stages 1 to 5 of this order, are the "primary" color terms (black, white, red, yellow, green, and blue), referring to colors that are considered to be perceptually unitary or unique and that cannot be described in terms of any other color combination. The remaining five color terms, acquired during stages 6 and 7, are referred to as "secondary" or "nonprimary" color terms because they can be described using some combination of the six primary color terms. Hence, a simplified version of this proposed developmental order posits an advantage for primary colors, with primary color terms being acquired before the secondary ones.

Although there is considerable evidence in support of the notion of basic color categories (for a comprehensive review, see Hardin & Maffi, 1997), support for Berlin and Kay's (1969) proposed developmental order of color term acquisition has been mixed and appears to be dependent on the nature of the task used to measure color term knowledge and the age at which color term knowledge is assessed (for a detailed review of the literature, see Pitchford & Mullen, 2002). Several developmental studies have failed to find support for a fixed developmental order of basic color term acquisition (e.g., Bornstein, 1985; Heider, 1971; Mervis, Bertrand, & Pani, 1995; Mervis, Catlin, & Rosch, 1975; Pitchford & Mullen, 2002; Shatz, Behrend, Gelman, & Ebeling, 1996), and additional evidence from the development of color terms across languages (e.g., Heider, 1972a, 1972b) has led to the modification of Berlin and Kay's original theory. Even the most recent reformulations of Berlin and Kay's original theory (e.g., Kay, Berlin, Maffi, & Merrifield, 1997; Kay, Berlin, & Merrifield, 1991), however, still predict a temporal advantage for the acquisition of primary color terms over secondary or derived color terms.

We have found, however, only very limited support for a developmental advantage of primary colors over secondary colors (Pitchford & Mullen, 2002). In an extensive study investigating the order in which 2- to 5-year-olds acquire basic color terms, we compared the comprehension and naming of basic colors. Our data showed a significant advantage for primary color terms over secondary color terms only on one condition, namely for children with a language age of 3 years and only on the color-naming task. In all other age groups (2 years and 4–5 years), there was no advantage of primary colors over secondary colors on the naming task. Furthermore, in the tests of comprehension, there was no advantage of the primary colors in any age group. Instead, our results revealed a different order of acquisition in which children acquire an accurate knowledge of the basic color terms in two distinct time frames. First, knowledge of 9 of the 11 basic colors (yellow, blue, black, green, white, pink, orange, red, and purple) is acquired, in any order, between 36 and 40 months of age. Second, knowledge of the remaining 2 basic colors (brown and gray) is achieved, but only after a substantial gap of 6–9 months. Thus, we found evidence for a dichotomous order based only on a selective delay in the acquisition of the 2 secondary color terms, brown and gray, rather than a delayed acquisition of all 5 secondary color terms as predicted by Berlin and Kay (1969).

In the current study, we investigated factors that may influence the developmental acquisition of basic color terms by considering the origins of the tardy conceptualization (as indicated by comprehension and naming) of brown and gray compared with that of the other nine basic color terms. We consider three different possibilities: (a) the role of perception, where we considered whether a differential development in some aspect of the perceptual processing of these two colors relative to the others may limit their conceptualization; (b) the role of linguistic input, where we investigated whether differential use of these two color terms relative to the others within the language directed at preschool children may mould their cognitive acquisition; and (c) the role of color preference, where we considered whether a specific aversion to these two colors may interact with their conceptual development.

With regard to the first hypothesis, we undertook two types of experiments designed to test whether the conceptualization of brown and gray is limited by difficulties in perceptually differentiating these two colors. Previously, we found that preschool children frequently mistook brown for gray and vice versa on tasks of color comprehension and color naming, suggesting that they had difficulty in differentiating these two colors on cognitive tasks (Pitchford & Mullen, 2002, 2003). In the current study, we investigated whether these difficulties arise from an inability to discriminate these two colors perceptually. Substantial psychophysical evidence suggests that within the first few weeks of life, infants can distinguish color differences (e.g., Allen, Banks, & Norcia, 1993; Maurer & Adams, 1987; Morrone, Burr, & Fiorentini, 1993; Teller, 1998; Teller & Bornstein, 1985), and that by 4 months of age, they show categorical perception for the four primary chromatic colors (Bornstein, Kessen, & Weiskopf, 1976; Catherwood, Crassini, & Freilberg, 1989) and some secondary colors (Franklin & Davies, 2004). These studies suggest that when children come to learn basic color terms, their ability to perceive basic colors is well established, even though chromatic discrimination continues to be refined until the teenage years (Knoblauch, Vital-Durand, & Barbur, 2001). However, comparisons of perceptual development across the 11 basic colors have not been made, and differences in the rates of perceptual development of different colors may influence their ease of conceptualization. If the conceptual development of brown and gray is delayed due to an underlying perceptual limitation, a selective deficit in discriminating brown and gray should be exhibited relative to the other 9 basic colors.

A perceptual constraint of a different type, the saliency of brown and gray as colors per se, may also constrain their development. It is well established that at around 3 years of age, color is a salient visual attribute by which children group together objects (e.g., Baldwin, 1989; Brian & Goodenough, 1929; Itskowitz, Strauss, & Gross, 1987; Melkman, Koriat, & Pardo, 1976; Pitchford & Mullen, 2001; Suchman & Trabasso, 1966). In addition, children at this age (and younger) are responsive to novel word use in grouping objects based on kind (noun syntax) versus color (adjectival syntax) (e.g., Waxman & Markow, 1998). Pitchford and Mullen (2001) showed that children with a language age of 3 years will match to sample on the basis of color while ignoring the other key visual attributes of form, size, and motion. Interestingly, this coincides with the age at which they acquire most of the basic color terms and is followed by a shift in perceptual saliency from color to form at around 4 years of age. If children have difficulty in abstracting brown and gray as perceptual features because they are relatively less salient as colors per se than the other nine basic colors, this may hinder their conceptual acquisition.

With regard to the second hypothesis, we consider the role that linguistic input may have in shaping developing color vocabulary. Recent cross-cultural studies of adults have regenerated theories regarding the influence of language on the categorization of basic colors (e.g., Davidoff, Davies, & Roberson, 1999; Saunders & van Brakel, 1997). In addition, previous developmental studies have highlighted linguistic influences on the acquisition of basic color terms. For example, Andrick and Tager-Flusberg (1986) found that maternal input correlated significantly with children's use of specific color words. Furthermore, Zollinger (1988) reported the influence of Western culture on the use of Japanese children's language for secondary colors, although it had little influence on their naming of primary colors. As these studies suggest, language may shape children's developing color terminology. In this study, we investigated the possibility that linguistic input may selectively delay the conceptualization of brown and gray relative to the other basic colors by determining the frequency with which the 11 basic color terms are used in language directed specifically to preschool children. We predicted that if language limits the acquisition of brown and gray, these 2 color terms will occur less frequently than the other basic color terms in two independent and objective measures of basic color term frequency determined from (a) books aimed at 2- to 5-year-olds and (b) mothers' speech while interacting with their children.

The third possibility that we considered is whether color preference is linked with the cognitive development of brown and gray. We investigated whether brown and gray are less preferred, or considered to be less attractive, than the other basic colors. Children's preferences for the 11 basic colors may influence their conceptualization in several ways. For example, Zentner (2001) suggested that color preference might serve to focus attention toward or against particular colors within the visual environment and that this, in turn, may make certain colors more or less memorable. Bornstein (1975) suggested that differences in color preference might reflect underlying differences in the biological meaningfulness of particular colors. Moreover, it is frequently assumed that primates' selective acquisition of red, green, and yellow color discrimination was driven by the biological need for food selection and, to a lesser extent, by social signaling (Mollon, 1989).

Of the limited number of studies reported in the literature to date on color preference in preschool children and infants, to our knowledge, none has investigated systematically differences in color preference across the full complement of 11 basic colors. Infant studies of color preference have shown that a preference for chromatic stimuli over achromatic stimuli has been established by at least 3 months of age and that this preference continues into adulthood (Adams, 1987; Bornstein, 1975; Civan, Teller, & Palmer, 2003). In addition, 4- and 5-month-olds prefer focal colors to boundary colors (Bornstein, 1975), and preferences increase with increasing chromatic purity (Civan et al., 2003). Recent work by Teller and colleagues showed that infants possess true intrinsic hue preferences; infant color preferences cannot be attributed to differences in perceived brightness (Teller, Civan, Bronson-Castain, & Pereverzeva, 2003), and preferences persist (although in a reduced form) across different chromatic stimuli even when matched for saturation (Zemach & Teller, 2004).

Within the range of four primary chromatic colors that are typically tested, 4- and 5-month-olds show a preference for red and blue (Adams, 1987; Bornstein, 1975; Zemach & Teller, 2004) over yellow and green, although Adams (1987) found that 3-month-olds preferred yellow over blue. The preference for red appears to continue into early childhood. Zentner (2001) tested color preference in relation to the emotional meaning of colors in a group of Swiss preschool children, ages 30–58 months (mean age 45 months), over 7 of the 11 basic colors. He reported the most preferred color to be red, followed by pink, blue, yellow, green, brown, and black. Thus, Zentner found that 3-year-olds also prefer chromatic colors to achromatic colors and that of the 6 chromatic colors tested, brown was the least preferred. Interestingly, Zentner commented briefly that there was only a partial correspondence between color preference and the developmental order of color term acquisition predicted by Berlin and Kay (1969) but that because support for Berlin and Kay's order of color term acquisition is limited, the relation between color preference and developing color cognition remains unresolved. We predicted that if a relation exists between color preference and the cognitive development of basic colors, children should exhibit a selective aversion to the 2 basic colors (brown and gray) for which they experience particular difficulty in conceptualizing.

In this article, we report a series of six experiments with preschool children (2–5 years of age) designed to test the hypotheses outlined above regarding the different roles that perception, language, and preference may play in the conceptualization of brown and gray relative to the other basic colors. First, we replicated the dichotomous development order of color term acquisition that we previously reported for naming (Experiment 1) and comprehension (Experiment 2) (Pitchford & Mullen, 2002). Second, we investigated the role of perception in the conceptualization of brown and gray in two different tasks: a color discrimination task (Experiment 3) and a color attribute match-to-sample task that assesses brown and gray as a salient object feature (Experiment 4). Third, we investigated the influence of linguistic input on the acquisition of the color terms brown and gray (Experiment 5) over two objective counts of color term frequency generated from (a) written language (preschool texts) and (b) spoken language (mothers' speech while interacting with their children). Fourth, we examined whether children's preference for brown and gray is associated with their delayed conceptual acquisition of these two colors (Experiment 6) by assessing preference and naming of brown and gray in relation to the other nine basic colors.

Experiment 1: Color naming

Method

This task measured children's ability to name the 11 basic colors orally.

Participants

A group of 72 typically developing English-speaking children (32 boys and 40 girls), ages 28–57 months ($M = 42.4$, $SD = 7.7$), participated in the experiment.[1] Children were recruited to the study from two different day care centers in the United Kingdom.

Stimuli

Stimuli were 3×3-cm squares of colored matt paper mounted on 5×5-cm squares of matt light gray paper. The colors were clear examples of each of the 11 basic colors (purple, pink, red, orange, yellow, green, blue, white, gray, brown, and black) based on a range of color chips provided in the *Munsell Book of Color*[2] that corresponded closely to the chips identified by Heider (1972b) as the most "focal" examples of each of the basic color categories (for Munsell chip coordinates, see Appendix A).

Procedure

Each child was tested in a quiet area of the day care center. For each trial, a target color was placed in front of the child and the child was asked, "What's the name of this color?" The experimenter recorded the child's response, and then the next color was presented for oral naming. Each of the 11 basic colors was presented once for oral naming, and the order of target presentation was randomized across children.

Results and discussion

To investigate the status of primary and secondary color names in relation to their developmental appearance, for each child the mean number of correct responses to

[1] Note that all of the children in the six experiments reported in this article had normal or corrected to normal vision and hearing and had experienced normal language acquisition up to the time of testing, as judged by their parents. None of the children had a familial history of color vision deficiencies or was identified with a color vision deficit using the *Colour Vision Test Plates for the Infants* (Matsubara, 1957). Consent was obtained from parents or guardians for participation in the study.

[2] The *Munsell Book of Color* was obtained from the Macbeth division of Kollmorgen Corporation, Baltimore, MD 21218, USA.

the six primary colors (red, green, yellow, blue, black, white) that appear early developmentally (primary–early) was compared with the three secondary colors (orange, pink, and purple) that also appear early (secondary–early) and the two secondary colors (brown and gray) that appear at a later stage of development (secondary–late). The group mean correct responses to primary–early colors was 0.79 ($SD = 0.32$) compared with 0.81 ($SD = 0.36$) for secondary–early colors and 0.58 ($SD = 0.45$) for secondary–late colors. A one-way repeated measures analysis of variance (ANOVA) revealed a significant main effect, $F(2, 142) = 30.884$, $p < .0001$, and post hoc pairwise analyses (using Tukey–Kramer, $p < .05$ at least) revealed that primary–early colors and secondary–early colors were named significantly more accurately than were secondary–late colors, with no significant difference found in the accuracy of naming of primary–early and secondary–early colors. Thus, results show no advantage for primary colors over the five secondary colors and are consistent with the dichotomous developmental order of color term acquisition, reported previously by Pitchford and Mullen (2002), in which the acquisition of the two secondary colors (brown and gray) are selectively delayed.

Further analyses showed that this pattern of color naming was consistent across children of different ages. The group of 72 children was divided into three age groups: 2-year-olds ($n = 15$, mean age = 30.9 months, $SD = 2.1$, range = 28–35), 3-year-olds ($n = 33$, mean age = 41.7 months, $SD = 3.9$, range = 36–47), and 4-year-olds ($n = 24$, mean age = 50.5 months, $SD = 2.6$, range = 48–57). Performance of the age groups on naming primary–early, secondary–early, and secondary–late colors was compared using a 3 (age group) × 3 (color) mixed ANOVA. Consistent with the analyses above, a significant main effect of color was found, $F(2, 138) = 29.5$, $p < .0001$. As expected, the main effect of age group was significant, $F(2, 69) = 18.4$, $p < .0001$, with the 2-year-olds naming significantly fewer colors than the 3- and 4-year-olds and with the 3-year-olds naming significantly fewer colors than the 4-year-olds, as established using post hoc tests (Tukey–Kramer, $p = .05$ at least). More important, however, the interaction between age group and color was not significant, $F(2, 138) = 29.5$, $p = .114$, illustrating a qualitatively similar pattern of naming basic colors in children across the preschool years.

Experiment 2: Color comprehension

Method

This task was designed to measure children's ability to comprehend the 11 basic color terms. In addition, it compared children's ability to comprehend colors and familiar objects so as to control for difficulties in task limiting performance.

Participants

A group of 17 normally developing English-speaking children (5 boys and 12 girls), ages 29–40 months ($M = 34.4$, $SD = 3.2$), participated in the experiment.

Children were recruited from three different day care centers in Montreal, Quebec, Canada. See Footnote 1 for details.

Apparatus and stimuli

Stimuli were computer-generated 8-bit images, generated using custom software developed in the laboratory, and were presented under control of an Apple Macintosh PowerBook G3 computer connected to a Dell CRT color monitor (refresh rate of 67 Hz and resolution of 640×480 pixels). The stimulus arrangement is shown in Fig. 1A and was three circles presented in a triangular format. Each circle was 6.4 cm in diameter, subtending 12 degrees of visual angle at a typical sitting distance of 30 cm. The background of the screen was set to a light gray. The computer-generated color stimuli were adjusted until each matched the Munsell chip exemplars of Heider's (1972b) focal colors, as judged perceptually by the two authors. The Munsell chip coordinates, CIE coordinates, and luminance of each of the 11 color stimuli and background are listed in Appendix A.

Control task

Before the color comprehension task was administered, each child was given a control task, which was a shorter version of the comprehension task that used computer-presented achromatic outline drawings of a dog, a cat, and a mouse by Snodgrass and Vanderwart (1980) as shown in Fig. 1B. These animals were selected because they are considered to be familiar to children of the age tested. The control task was given prior to the color comprehension task so as to familiarize the child with the nature of the task. For example, a child was considered to understand the requirements of the comprehension task, illustrated in Fig. 1B, if he or she selected the dog over the cat and mouse when asked by the experimenter, "Can you show me the dog?" Each of the three stimuli was presented as a target on three occasions, producing a total number of nine trials per task. Only children who completed the control task successfully were given the color comprehension task. Thus, any deficits in performance on the color comprehension task could not be attributed to task limitations.

Procedure

The child sat on a chair facing the monitor at a distance that enabled the child to touch the screen easily. A target color with two different distracter colors was presented, as illustrated in Fig. 1A. The child was required to point to a color in response to a color term spoken by the experimenter. For example, the child was asked, "Can you show me the blue one?"

The influence of perceptual similarity on color comprehension (Pitchford & Mullen, 2003) was controlled by having the target presented with two distant distracter colors on 50% of the trials (33 trials) and with two adjacent distracter colors on the remaining 50% of the trials (33 trials). (Here, *distant* colors are those that are not neighbors in perceptual color space, such as red and blue, whereas *adjacent* col-

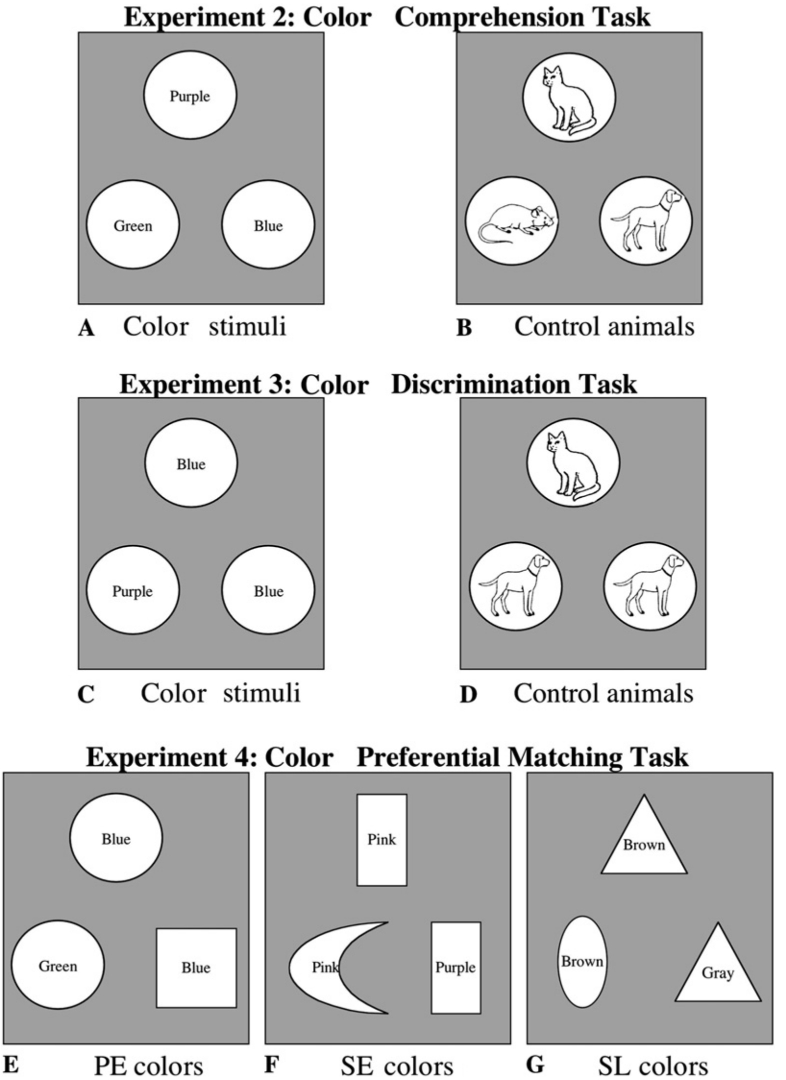

Fig. 1. Schematic illustration of stimulus displays. Experiment 2: (A) experimental color stimuli and (B) control stimuli using familiar animals. Children were asked to point to the color/animal as named by the experimenter. Experiment 3: (C) experimental color stimuli and (D) control stimuli using familiar animals. The experimenter pointed (at random) to one the two identical stimuli, and children were asked to find the other one. Experiment 4: (E) primary–early (PE) color stimuli, (F) secondary–early (SE) color stimuli, and (G) secondary–late (SL) color stimuli. The target stimulus appeared at the top of the screen with the computer voiceover saying, "See this. Can you find another one?" after which the two alternative forced choices were presented at the bottom of the screen. (In the U.K. pilot study using the paper version, the two alternative choices were covered with a piece of gray paper and were revealed after the experimenter had asked the child to choose another one.) In each experiment, stimuli remained on the screen until the child had made his or her response. For all stimulus displays, stimuli are shown not to scale.

ors are those that lie side by side in perceptual color space, such as red and purple.) A total of 66 trials were presented, with each of the 11 color stimuli being presented with the same frequency, both as a target and as a distracter. Thus, each of the 11 basic colors was presented on 6 occasions as a target color and on 12 occasions as a distracter color.

The position of the target stimulus was randomized over trials. Stimuli remained on the screen until the child had responded. After the child had selected one of the circles, the experimenter recorded the child's response in the computer. A short "quack" sounded after the child's response had been entered into the computer to mark the end of each trial, after which the subsequent trial was presented. A trial could be repeated if the child did not make a response; in these rare instances, the position of the target stimulus was again randomized. Blocks of four trials were interspersed with short cartoon movies that played for approximately 30 s to maintain the child's attention. During the cartoon, encouraging comments, such as "keep going" and "yippee," were given. Each child completed the tasks over several sessions lasting approximately 10 min each. Eight practice trials were given before the task was administered.

Results and discussion

The group mean correct responses for comprehending primary–early colors was 5.69 ($SD = 0.47$) compared with 5.75 ($SD = 0.49$) for secondary–early colors and 4.97 ($SD = 0.86$) for secondary–late colors. Because the group means for primary–early and secondary–early colors were close to ceiling, nonparametric statistics were used to analyze the data. A Friedman rank test (corrected for ties) revealed a significant difference between means, $\chi^2(df = 2) = 9.52$, $p = .0086$, and Wilcoxon signed rank tests (corrected for ties) revealed that primary–early colors and secondary–early colors were comprehended significantly more accurately than secondary–late colors (primary–early vs. secondary–late colors: $z = -2.76$, $p = .006$; secondary–early vs. secondary–late colors: $z = -2.64$, $p = .009$), although no significant difference was found in the comprehension of primary–early and secondary–early colors ($z = -0.62$, $p = .535$). Results are shown in Fig. 2A. This pattern of results is consistent with those found in the color naming task in Experiment 1 and supports the dichotomous developmental order of color term acquisition reported by Pitchford and Mullen (2002) across different populations of children and different conceptual tests.

Experiment 3: Color discrimination

Method

This task was given to assess whether a perceptual deficit limits the conceptualization of basic colors and measures color discrimination among the 11 basic colors.

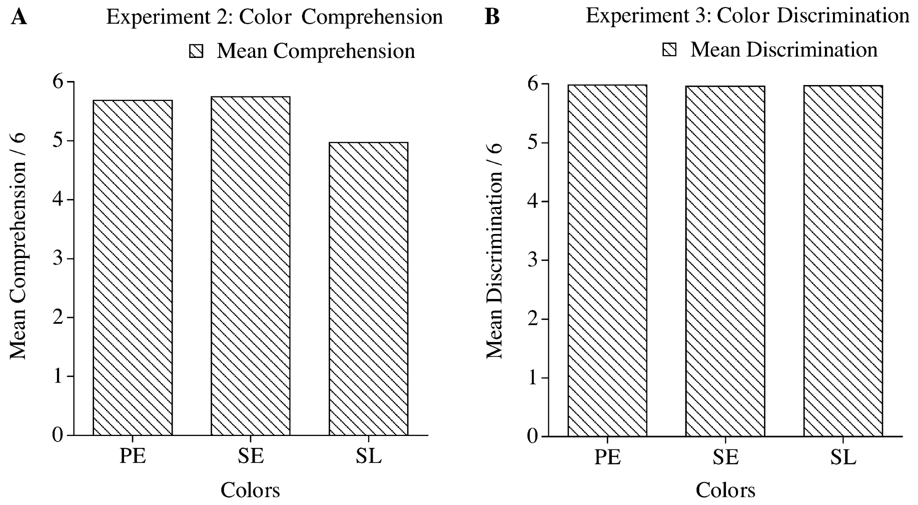

Fig. 2. Mean numbers of correct responses made by the same group of children to primary–early (PE), secondary–early (SE), and secondary–late (SL) colors on the tasks of (A) color comprehension (Experiment 2) and (B) color discrimination (Experiment 3). Results show no selective deficit in perceiving brown and gray relative to the other nine basic colors, even though the children found these two color terms more difficult to comprehend.

Participants, apparatus, and stimuli

The children who participated in the comprehension task of Experiment 2 were given the color discrimination task. Apparatus and stimuli generation were the same as those used in Experiment 2. Experimental stimuli are shown in Fig. 1C, and control stimuli are shown in Fig. 1D.

Procedure

The procedure outlined in Experiment 2 was followed for the color discrimination task. Two identical target colors were presented with one distracter color, as shown in Fig. 1C. The experimenter pointed, at random, to one of the two identical target colors and said to the child, "See this? Can you show me the other one?" Fig. 1C illustrates an example experimental trial in which two blue circles and a purple circle were presented. The experimenter pointed to one of the two blue circles, and the child was asked to select the other blue circle by pointing.

As in Experiment 2, the effect of perceptual similarity on the children's ability to discriminate the 11 basic colors was controlled by presenting target colors with a distant distracter color on 50% of the trials (33 trials) and with an adjacent distracter on the remaining 50% of the trials (33 trials). Each of the 11 basic colors was presented as a target on six occasions and as a distracter for the same number of times, producing 66 experimental trials in total. The distant distracter color was blue for brown and was yellow for gray. In addition, brown acted as a distracter color for purple, and gray acted as a distracter color for yellow. Black was the adjacent color for brown, and brown was the adjacent color for gray.

In addition to the 66 experimental trials, each child was given 12 extra trials in which the target color was matched to the distracter color in luminance. Of these 12 trials, 6 required pink to be discriminated from green and 6 required red to be discriminated from gray. Because these trials eliminated any brightness cue, the child could succeed only if he or she discriminated the colors purely on the basis of hue. The 12 luminance trials were presented in a random order with the 66 experimental trials, producing a total number of 78 trials over the entire task.

Control task

As in Experiment 2, each child was given a control task using outline drawings of a cat, a mouse, and a dog prior to the color discrimination task so as to familiarize the child with the task demands. For example, a child was considered to be able to perform the discrimination task, shown in Fig. 1D, if he or she selected the dog instead of the cat after the experimenter had pointed to one of the dogs. Any child who was unsuccessful on the control task was not given the color discrimination task.

Results and discussion

The group mean correct performance on the color discrimination task was at ceiling for primary–early colors ($M = 5.98$, $SD = 0.08$), secondary–early colors ($M = 5.96$, $SD = 0.16$), and secondary–late colors ($M = 5.97$, $SD = 0.12$), indicating that preschool children have no selective difficulty in discriminating brown and gray relative to the other nine basic colors. These results, illustrated in Fig. 2, show that the difficulty the children experienced in conceptualizing brown and gray (Fig. 2A) does not arise from a deficiency in discriminating these two basic colors (Fig. 2B), indicating that these perceptual categories are in place prior to the conceptual development of brown and gray. Results suggest that any difficulties children experience in conceptualizing the 11 basic colors (Experiment 2) are not limited by a deficit in color perception (Experiment 3). In addition, children could discriminate targets and distracters that were matched on the basis of luminance given that the mean correct performance for the 12 luminance trials was 11.94 ($SD = 0.24$, range = 11–12). Thus, children's perceptual discrimination of basic color categories was accurate.

Experiment 4: Color attribute match-to-sample

Method

This task was designed to establish children's ability to group together objects on the basis of the overall saliency of pairs of primary–early, secondary–early, and secondary–late colors. A match-to-sample task, in which children matched one of two stimuli to a target stimulus, was used. Children could match on the basis of either stimulus color or shape. The effect of primary–early, secondary–early, and secondary–late colors was systematically manipulated to investigate whether the number of color matches (as opposed to shape matches) depends on the colors presented. We predicted that any overall differences in perceptual saliency of primary–early, secondary–early, and secondary–late colors as colors per se would affect the relative numbers of color matches made.

Participants

A group of 18 typically developing English-speaking preschool children (10 girls and 8 boys) with a mean age of 37.7 months ($SD = 8.2$, range $= 25$–50), attending a day care center in Montreal, participated in the experiment.

Apparatus and stimuli

Stimuli were computer-generated 8-bit images, generated using custom-developed software, and were presented under control of a portable computer connected to a color monitor (refresh rate of 67 Hz and resolution of 1024×768 pixels). Stimuli consisted of six basic colors presented as three pairs: one pair of primary–early colors (blue and green), one pair of secondary–early colors (pink and purple), and one pair of secondary–late colors (brown and gray) (Figs. 1E–G). Within each of the three color pairs, the colors selected lay adjacent to each other (i.e., neighboring colors) in Munsell color space so as to control for any effect of perceptual similarity on performance (Pitchford & Mullen, 2003). The shape stimuli consisted of six basic shapes—three with straight edges (square, rectangle, and triangle) and three with curved edges (circle, oval, and eclipse)—presented as three pairs, each containing one straight-edged shape and one curved-edge shape. The shape stimuli combine to produce nine different pairings, each of which was presented in each of the three color pairings, thereby producing 27 different shape–color combinations. Each child was given 1 of the 27 possible shape–color combinations so as to control for particular color/shape biases that may occur across individual children. For each child, stimuli were presented in three blocks of 12 trials, with 12 trials of primary–early colors given in one block, 12 trials of secondary–early colors given in another block, and 12 trials of secondary–late colors given in another block. The order of block presentation was systematically counterbalanced across children so as to control against color order effects that may influence the nature of the matches children made.

Each shape was approximately 2.5 cm square, subtending 4.8 degrees of visual angle at a typical sitting distance of 30 cm. The computer-generated color stimuli were created by adjusting the red, green, and blue guns (of the monitor) to match the Munsell coordinates of the colors given in Appendix A. Stimuli were presented against a gray background (Appendix A). The luminances of the brown and gray stimuli were adjusted to match each other so as to avoid luminance differences as a cue for preference matching.

Procedure

A version of this task was used previously (Pitchford & Mullen, 2001). The task required the child to match a target stimulus to one of two choices by pointing. The target stimulus was a colored shape that was consistent with each of the two possible matches in only one attribute. For example, Fig. 1E illustrates an example of the primary–early color stimuli in which the target stimulus was a blue circle, the corresponding color match was a blue square, and the corresponding shape match was a green circle.

The child sat on a chair facing the monitor at a distance that enabled the child to touch the screen easily. The experimenter explained to the child that he or she was going to play a game on the computer. The task started with some lively music and the appearance of a cartoon monkey called "Charlie." Task instructions, spoken by a female, were recorded and presented via Charlie. After the music, Charlie introduced the game by saying, "Hi. My name's Charlie and we're gonna play a game. Are you ready?" after which the first trial was presented. Each trial started with the appearance of a target stimulus at the center top of the screen, and the child was asked via computer voiceover, "See this. Can you find another one?" The target stimulus was presented for 5 s, after which the two choices appeared simultaneously below the target. The position of the two alternative forced choices was randomized across trials so as to control for position biases in responding. All of the stimuli remained on the screen until the child indicated his or her preference match by pointing to one of the two choices. A short "quack" sounded after the child's response had been entered into the computer and marked the end of each trial, after which the subsequent trial was presented. Each trial was interspersed with a short cartoon movie that played for approximately 30 s to maintain the child's attention. During the movie, encouraging comments, such as "keep going" and "yippee," were given. The end of the game was indicated by the music that played at the start and the appearance of Charlie saying, "Thanks for playing my game. You were very good." Each child completed three blocks of 12 trials on different sessions, with each lasting approximately 10 min.[3]

Results and discussion

Results are shown in Fig. 3. Overall, the mean number of color matches made was 17.5 ($SD = 12.35$) and the mean number of shape matches was 18.5 ($SD = 12.35$). The

[3] This task was first piloted on a group of 27 children (14 girls and 13 boys) with a mean age of 44 months ($SD = 6.6$) attending a day care center in the United Kingdom. The same procedure as outlined in Experiment 4 was followed, but stimuli were presented on matt colored paper instead of on a computer screen. The different stimuli were mounted on sheets of gray paper, and in each trial the two alternative forced choices were covered while the target stimulus was shown and the experimenter said, "See this. Can you find another one?" The experimenter then uncovered the two stimulus choices, and the child selected his or her preference match, after which the next trial was presented. Results showed that the pilot data were consistent with the pattern of results found in Experiment 4 using the computer presentation. No significant difference was found in the number of color matches children made across the three color conditions, $F(2, 52) = 1.186$, $p = .314$, primary–early colors: $M = 4.19$, $SD = 4.03$; secondary–early colors: $M = 3.89$, $SD = 4.42$; secondary–late colors: $M = 4.48$, $SD = 4.54$.

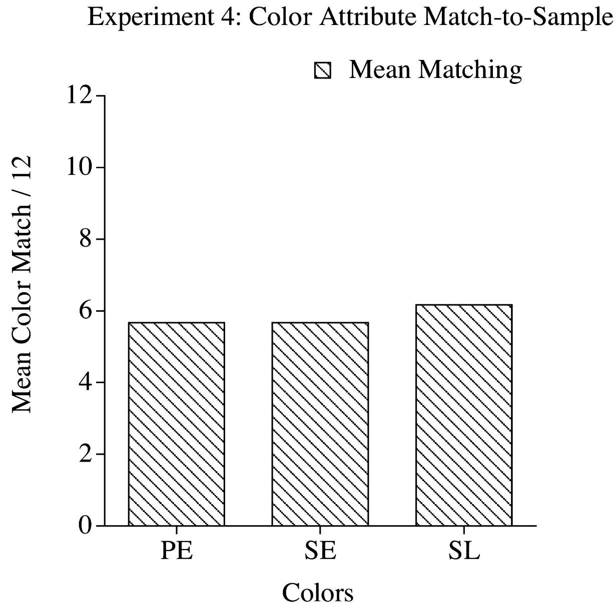

Fig. 3. Mean numbers of color matches made to primary–early (PE), secondary–early (SE), and secondary–late (SL) colors in Experiment 4. Results show no significant differences in the saliency of PE, SE, and SL colors for grouping objects on the basis of color.

similar proportion of shape matches to color matches made is typical for 3-year-olds (Pitchford & Mullen, 2001). Because this experiment was designed to investigate the relative saliency of primary–early, secondary–early, and secondary–late colors, only the mean number of matches made on the basis of color was analyzed. As a group, children made a mean of 5.67 color matches to primary–early colors ($SD = 4.22$) compared with 5.67 color matches to secondary–early colors ($SD = 4.26$) and 6.17 color matches to secondary–late colors ($SD = 4.30$). A one-way repeated measures ANOVA revealed no significant effect of color, $F(2,34) = 0.845$, $p = .438$, indicating that children's preference behavior was not significantly affected by the nature of the color stimuli. These results suggest that children can use the colors brown and gray to group objects, even when their conceptualization of these two colors is not yet complete.

Experiment 5: Color linguistic frequency

Method

This experiment was designed to measure the frequency with which each of the 11 basic colors occurs within the English language to which preschoolers are typically exposed. Two separate measures of basic color term frequency were generated from (a) written language and (b) spoken language directed to preschool children.

Written color term counts

Studies of adult cognitive processing typically use measures of word frequency derived from written texts (e.g., Kucera & Francis, 1967). No such measures are currently available for texts dedicated to preschool children, yet "reading" books with caregivers is a familiar activity for most preschool children, either at home or in day care, where joint attention is drawn between the preliterate child and the caregiver orally reading the book. As such, books provide a useful source of the range of words commonly used in child-directed language from which frequency counts can be constructed.

To generate frequency counts for each of the 11 basic colors, a sample of 374 different books aimed toward preschool children, ages 2–5 years, was used. Books were selected at random from libraries, day care centers, and bookstores in the United Kingdom and, thus, represented the range of written material available to preschoolers. Of the 374 books sampled, 17 (4.5%) were aimed specifically at teaching colors. Each book was read by at least one of three experimenters, and the number of times each of the 11 basic color terms was written in text was recorded. Of the 374 different books used, 15 were rated by at least two of the experimenters. The mean interrater reliability was 94.3%, indicating considerable consistency in the counts recorded by each of the three experimenters.

Spoken color term counts

To obtain an objective measure of the frequency with which mothers use basic color terms when interacting with their preschool children, data from the Manchester corpus (Theakston, Lieven, Pine, & Rowland, 2001) of the CHILDES database (MacWhinney, 2000) were analyzed. The Manchester corpus consists of all child-directed speech generated by 12 mothers during play interactions with their first-born children (6 boys and 6 girls) measured systematically over a 1-year period. For the duration of the study, the children ranged in age from 2 to 3 years, which is the age when children begin to learn basic color terms (Pitchford & Mullen, 2002). For each of the 12 mothers, 34 h of continuous speech was available for analysis, and the number of occasions each of the 12 mothers used each of the 11 basic color terms was calculated from this. The mean numbers of times primary–early, secondary–early, and secondary–late color terms were used by the 12 mothers were then determined.

Results and discussion

For both measures of basic color term frequency in child-directed speech, the mean number of occasions primary–early colors appeared was calculated and compared with the mean number of times secondary–early and secondary–late colors appeared. Results are shown in Figs. 4A and B.

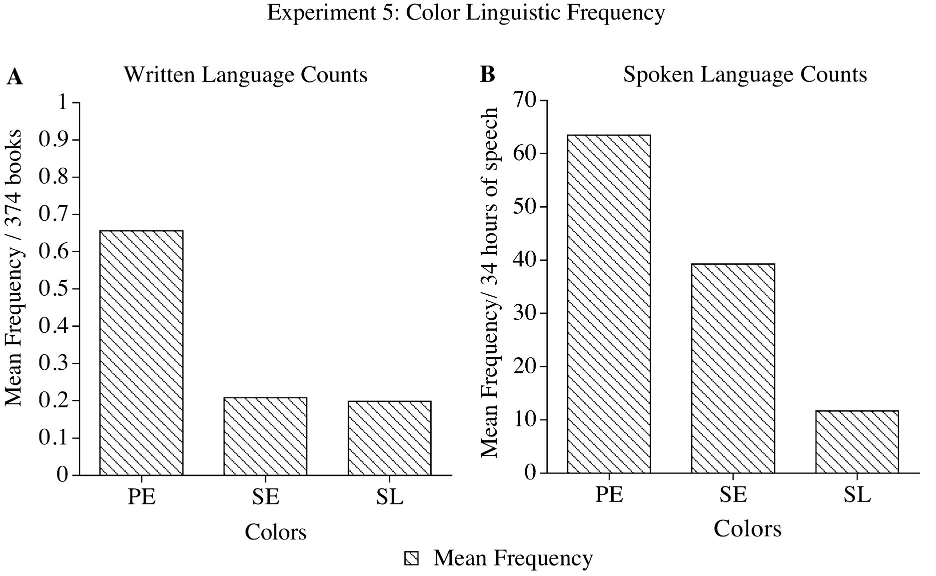

Fig. 4. Results from Experiment 5: Counts derived from (A) written language and (B) spoken language. Mean numbers of occasions primary–early (PE), secondary–early (SE), and secondary–late (SL) color terms appeared in (A) 374 preschool texts and (B) speech of 12 mothers while interacting with their children. A significant advantage for primary color terms is shown.

Written color term counts

The mean number of occasions primary–early color terms appeared in preschool texts (i.e., sum frequency/374 books) was 0.66 ($SD = 0.96$) compared with 0.21 ($SD = 0.46$) for secondary–early color terms and 0.20 ($SD = 0.54$) for secondary–late color terms. A one-way repeated measures ANOVA revealed a significant main effect, $F(2, 746) = 96.296, p < .0001$. Post hoc analyses (using Tukey–Kramer, $p < .05$ at least) revealed that primary–early color terms appeared significantly more often in preschool texts than did secondary–early and secondary–late color terms, but there was no significant difference in the frequencies with which secondary–early and secondary–late color terms were used (Fig. 4A).

Spoken color term counts

The mean number of occasions mothers used terms referring to primary–early colors was 63.47 ($SD = 21.48$) compared with 39.25 ($SD = 13.6$) for secondary–early colors and 11.63 ($SD = 11.16$) for secondary–late colors. A significant main effect was found using a one-way repeated measures ANOVA, $F(2, 22) = 37.932, p < .0001$, and post hoc analyses (using Tukey–Kramer, $p < .05$ at least) revealed that primary–early colors were used significantly more by mothers when interacting with their preschool children than were secondary–early and secondary–late colors but that mothers also used the secondary–early color terms (orange, pink, and purple) significantly more often than they used brown and gray, the two basic color terms that are typically acquired last.

A significant positive correlation was found between the basic color term counts derived from written language and those derived from spoken language, $r = .69$ ($N = 11$), $p = .016$, illustrating a strong degree of concordance between these two measures. Interestingly, both measures of basic color term use in child-directed language consistently support an advantage for primary color terms over secondary color terms. This is in line with the prediction made by Berlin and Kay (1969), although our data show that primary color terms appear at the same time as the secondary color terms orange, pink, and purple (Experiments 1 and 2) (Pitchford & Mullen, 2002). Linguistic frequency may, however, contribute to the late acquisition of brown and gray by preschool children to some extent given that these two color terms are consistently less frequent across both measures of linguistic frequency (written and spoken counts). Appendix B reports the written and spoken word frequency counts for each of the 11 basic colors. Interestingly, spoken (but not written) word frequency counts correlated significantly with naming performance across each of the 11 basic colors by the preschool children in Experiment 1, $r = .76$ ($N = 11$), $p = .004$, two-tailed. This suggests that the order in which preschool children acquire basic color terms may be influenced, to some extent, by the frequency with which mothers use color terms when interacting with their children (Andrick & Tager-Flusberg, 1986). In addition, mothers' speech appears to be a better measure of linguistic input than does books for this age group.

Experiment 6: Color preference

Method

This task was designed to measure children's preference for the 11 basic colors in relation to their basic color naming.

Participants and stimuli

A group of 52 typically developing English-speaking children (25 boys and 27 girls), ages 24–64 months ($M = 45.4$, $SD = 9.9$), participated in this experiment. All of the children were drawn from three day care centers in Montreal. Stimuli were identical to those used in Experiment 1.

Procedure

Each child was given two tasks. A color preference task was given first, followed by a task of basic color naming.

Color preference task

The child sat facing a teddy bear in front of an open box. The child was told that he or she was going to play a game in which the child was to place his or her favorite color in the teddy bear's box. The experimenter placed the 11 basic colors in a random order in front of the child and asked, "See these colors. Which of these colors do you like best? Point to the color you like best." After the child had responded, that color sample was removed from the array and was placed in the teddy bear's box, out of the sight of the child. The child was then asked, "Now show me the color you like best. Which of these colors do you like best?" This continued until all of the 11 basic colors had been removed. The resultant order in which the colors were removed from the array indicated the child's rank preference of the 11 basic colors, with the first one removed being the most preferred and the last one removed being the least preferred.

Control trials

To assess the child's understanding of the preference task, three control trials, using pictures of familiar animals (a dog, a cat, and a mouse), were given prior to the color stimuli. The child was asked, "See these animals? Which of these do you like best? Point to the animal you like best." After the child had responded, the experimenter placed the picture in the teddy bear's box and repeated the procedure until all of the animals had been removed. To test whether or not the child was responding consistently in accordance with the question asked, the experimenter said, "Let's do it again," and the entire procedure was repeated. Children who responded in the same order of preference on the control trials were given the color stimuli.

Color naming task

After the color preference task, a task of basic color naming was given. The procedure was identical to that in Experiment 1.

Results and discussion

Color preference task

For each child, each of the 11 basic colors was assigned a ranking from 1 to 11 according to the order in which the child selected his or her favorite colors. A rank of 1 indicated the most preferred color, whereas a rank of 11 indicated the least preferred color. It is not possible to analyze these data by comparing directly the mean ranks for primary–early, secondary–early, and secondary–late colors because the range of possible mean ranks differs from 3.5 to 8.5 for the 6 primary–early colors, from 2 to 10 for the 3 secondary–early colors, and from 1.5 to 10.5 for the 2 secondary–late colors. Thus, to compare color preference across the three color groups, for each child, preference ranks were adjusted for guessing by subtracting the sum rank for primary–early, secondary–early, and secondary–late colors from the expected sum rank for the 6 primary–early colors (36), 3 secondary–early colors (18), and 2 secondary–late colors (12) on the basis that each of the 11 basic colors had an equal opportunity of being selected at each of the 11 possible rankings. This enabled adjusted mean preference ranks to be determined for primary–early, secondary–early, and secondary–late colors for the group of children.

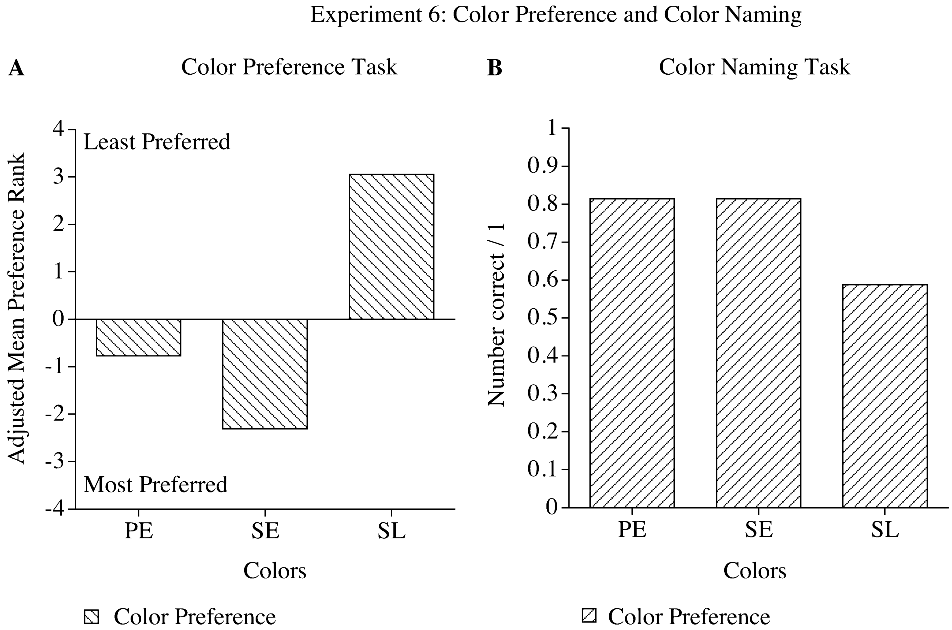

Fig. 5. Results from Experiment 6: Adjusted mean difference ranks for primary–early (PE), secondary–early (SE), and secondary–late (SL) colors. Results show that SL colors were preferred significantly less than PE and SE colors when corrected for chance.

Results are shown in Fig. 5A. A negative adjusted mean preference rank indicates colors that children prefer more than would be expected on the basis of chance, whereas a positive adjusted mean preference rank indicates colors that children prefer less than would be expected on the basis of chance. As shown in Fig. 5A, as a group, children preferred primary–early colors (adjusted mean preference rank $= -0.77$, $SD = 6.1$) and secondary–early colors (adjusted mean preference rank $= -2.30$, $SD = 6.39$) more than would be expected by chance, whereas they preferred secondary–late colors (adjusted mean preference rank $= 3.06$, $SD = 3.72$) less than would be expected by chance. A one-way repeated measures ANOVA revealed a significant main effect, $F(2, 102) = 8.65$, $p = .0003$, and post hoc analyses (using Tukey–Kramer, $p < .05$ at least) revealed that children preferred primary–early and secondary–early colors significantly more than secondary–late colors, but no significant difference was found between children's preference for primary–early colors and their preference for secondary–early colors.

Color naming task

As a group, children correctly named primary–early colors with a mean of 0.81 ($SD = 2.90$) compared with a mean of 0.81 ($SD = 0.31$) for secondary–early colors and 0.59 ($SD = 0.45$) for secondary–late colors. A one-way repeated measures

ANOVA revealed a significant main effect, $F(2, 102) = 22.27$, $p < .0001$, and post hoc analyses (using Tukey–Kramer, $p < .05$ at least) revealed that secondary–late colors were named significantly less accurately than primary–early and secondary–early colors. Furthermore, a significant positive correlation was found between the naming performance across each of the 11 basic colors for the 52 Canadian children who participated in this experiment and that for the 72 U.K. children who participated in Experiment 1, $r = .89$ ($N = 11$), $p < .0001$, two-tailed, indicating a strong degree of concordance across different groups of preschool children on the basic color naming task.

These results replicate and extend those found in Experiment 1 and show that preschool children name brown and gray significantly less accurately than the other basic colors and that they also prefer brown and gray significantly less than the other 9 basic colors. Thus, we found that, of the 11 basic colors, the 2 colors that children least prefer are the ones that appear selectively late in conceptual development, raising the possibility that color preference and color cognition may be linked.

Furthermore, children showed the same preference pattern irrespective of whether or not they could name brown and gray accurately. In a further analysis, the group of 52 children were divided into three groups on the basis of their ability to name brown and gray, where Group 1 ($n = 17$) named brown and gray inaccurately, Group 2 ($n = 9$) named either brown or gray accurately, and Group 3 ($n = 26$) named both brown and gray correctly. Their mean preferences across primary–early, secondary–early, and secondary–late colors were compared using a 3 (naming group) $\times$ 3 (colors) mixed ANOVA. Consistent with the findings reported previously, results showed a significant main effect of color, $F(2, 98) = 5.80$, $p = .004$; however, neither the main effect of naming group, $F(2, 49) = 0.49$, $p = .62$, nor the interaction between naming group and color, $F(4, 98) = 1.02$, $p = .40$, was significant. This analysis shows that children's preference for brown and gray remains stable throughout the period in which they are acquiring these two color terms.

The association between color preference and color naming in this group of 52 children was confirmed by a significant negative correlation between their color preference and color naming scores, $r = -.765$ ($N = 11$), $p = .004$, indicating that children were more likely to correctly name the colors they most preferred.[4] Of particular interest, however, was the association between color preference (Experiment 6) and maternal spoken word frequency (Experiment 5) given that a significant negative correlation was found between preschoolers' color preferences across each of the 11 basic colors and the frequency with which mothers use basic color terms in child-directed language, $r = -.61$ ($N = 11$), $p = .04$, two-tailed (Appendix B). These results suggest that linguistic input, color preference, and color term acquisition are developmentally linked.

[4] Color preferences for the 52 Canadian children who participated in Experiment 6 also correlated significantly with naming of each of the 11 basic colors by the 72 U.K. children in Experiment 1, $r = -.813$ ($N = 11$), $p = .001$. This is indicative of the generalizability of the association between color preferences and color naming found in Experiment 6.

General discussion

In this study, we investigated the role of perception, language, and preference in the conceptualization of basic colors. In a previous study based on more than 14,000 trials obtained from a group of 43 children, we showed that the cognitive development (combined comprehension and naming) of brown and gray was selectively delayed relative to the other nine basic color terms (Pitchford & Mullen, 2002). This dichotomous developmental order of color term acquisition differs from that predicted by Berlin and Kay (1969) in that there is no overall difference in the order of acquisition between primary colors and secondary colors, in support of recent results (Shatz et al., 1996). In the current study, we sought to investigate factors that may contribute to this selective delay.

In the first two experiments, we aimed to confirm our original result that brown and gray are late to develop conceptually compared with the other nine basic color terms using both a color naming task (Experiment 1) and a color comprehension task (Experiment 2). Results from both experiments showed no advantage of primary colors over secondary colors, a finding that is inconsistent with the prediction of Berlin and Kay (1969). We found that the conceptualizations of the primary colors and the three secondary colors (pink, purple, and orange) are developmentally similar, supporting our previous results (Pitchford & Mullen, 2002). Furthermore, brown and gray were named and comprehended less accurately than the other nine basic colors, consistent with our previous study and illustrating the delayed developmental appearance of brown and gray relative to the other basic colors (Pitchford & Mullen, 2002). This clearly demonstrates that a dichotomous developmental order of color term acquisition is robust across different conceptual tasks, different populations of children, and different media of presentation.[5]

In the remaining four experiments of the study, we investigated the different possible constraints on the developmental acquisition of brown and gray relative to the other basic colors. In Experiment 3, we considered the possibility of a perceptual limitation that might inhibit the conceptual differentiation of these two colors. We found that children could accurately discriminate brown and gray, even though they might not comprehend the linguistic terms. Although relative differences may exist in discriminating primary–early, secondary–early, and secondary–late colors on more sensitive tasks, such as a threshold discrimination task (Petzold & Sharpe, 1998), our data show that the late appearance of brown and gray shown in our experiments does not reflect a simple perceptual limitation brought about by immaturity in the development of perceptual mechanisms at the time of color term acquisition.

In Experiment 4, we explored another possible perceptual constraint, namely a reduced saliency of brown and gray relative to the other basic colors. Children performed as well when they were asked to group objects on the basis of brown and gray

[5] Naming results are also consistent with those found by a group of Canadian children in Experiment 6. A significant positive correlation was found across the naming performance of children in Experiments 1 and 6, indicating that the tardy naming of brown and gray is consistent across these cultures.

as when they grouped objects that were pink and purple or blue and green. That is, brown and gray are as salient as the other basic colors in this task, and children can readily use brown and gray to make perceptual judgments regarding object similarity.

We also investigated, in Experiment 5, whether linguistic input shapes the developmental acquisition of basic color terms, as implied by recent studies that have illustrated the influence of language on color naming in adults (e.g., Davidoff et al., 1999; Saunders & van Brakel, 1997). Analyses of two independent counts of basic color term frequency showed that of the 11 basic color terms, brown and gray appeared significantly less often in both preschool texts and mothers' speech. In addition, spoken (but not written) word frequency counts correlated significantly with color naming (Experiment 1) across the 11 basic colors, suggesting that linguistic input contributes to the tardy conceptualization of brown and gray.

Finally, in Experiment 6, we considered the relation between color preference and the conceptualization of basic colors. Results showed that preschool children exhibit clear color preferences. As a group, no significant difference was found between children's preference for the 3 secondary colors (pink, purple, and orange) that appear early conceptually and the 6 primary colors that are also conceptualized early. However, children liked brown and gray significantly less than the other 9 basic colors, indicating a selective aversion to these 2 colors. These results are interesting because they show that the two colors that preschool children least prefer are also those that are the latest to develop conceptually, raising the possibility of an association between color preference and cognitive development. This association was confirmed within the same group of children in that a significant correlation was found between children's preference and naming of the 11 basic colors, indicating that within the same children, the colors that are least likely to be named accurately are those that are least preferred.

It is difficult to determine the direction of causality of this association between color preference and developing color cognition. For example, children may like the colors they know, suggesting that color language drives the establishment of color preferences. Alternatively, children may begin to name the colors they like, suggesting that preferences shape developing color cognition. However, in a further analysis of our data, we divided children into three groups on the basis of their ability to name brown and gray, and we found that color preferences remain stable over the period in which preschool children acquire the terms for brown and gray. This suggests that color preferences exist before accurate color naming.

To address a possible causal link between color preference and color term acquisition directly, however, color preference across the 11 basic colors needs to be established during early infancy, well before the onset of color term acquisition for which preferential looking methodology is required. Studies on color preferences in 3-month-olds have reported a preference order of the four chromatic primary colors (red, blue, yellow, and green) (Adams, 1987; Bornstein, 1975; Zemach & Teller, 2004) that corresponds closely to the order of color preference for these four colors shown by the children in our study. For example, Zemach and Teller (2004) found that red and blue were preferred more than yellow and green, a finding that is consistent with our data. The nature of color preferences during infancy appears to be related to chromatic purity (Pereverzeva & Teller, in press), determined by hue and/or saturation rather than by brightness (Teller, Civan, & Bronson-Castain, in press). It is possible that the preferences of preschool children are also mediated by chromatic purity given that brown and gray are relatively desaturated colors that fall in the interior of perceptual color space compared with the other basic colors. Thus, we speculate that the relative positions of colors within perceptual color space, whether more or less saturated, may influence both color preferences and emerging color cognition during early childhood, although this remains to be determined experimentally.

The order of color preference shown by the children in our study (Experiment 6) corresponds very closely with that found by Zentner (2001), who measured color preference for 7 of the 11 basic colors in Swiss preschoolers. The correlation between the preference order found by Zentner and that found in the current study was remarkably high, Spearman's rho = .893 ($N = 7$), $p = .029$, two-tailed, indicating that the color preference of preschoolers appears to be consistent across different cultures. Although there is considerable consistency concerning the color preferences of infants and preschoolers, the preferences do not reflect those of adults (Zentner, 2001), whose preferences show little consistency across cultures (Saito, 1996).

Cultural factors may also influence color preferences and color cognition during childhood. Our data showed that spoken word frequency counts (Experiment 5) correlated significantly with color preference and color naming (Experiment 6), suggesting that children are more likely to prefer and name the colors that mothers use when interacting with their children. Maternal input could influence color preference by referring to specific objects within children's environment (e.g., "Look at your lovely pink dress"). As such, cultural influences may shape color preferences and emerging color cognition during early childhood by reflecting the extent to which children are exposed to particular colors in their environment. Perceptual exposure per se, however, is unlikely to be related to linguistic input and color preference given that brown and gray are ubiquitous in our everyday environment but are used by mothers and preferred by children significantly less than the other basic colors. Rather, if perceptual exposure helps to shape color preferences and developing color cognition through maternal input, we suggest that it is through children's direct interactions with, for example, the colors of toys in their immediate perceptual environment rather than the broader visual environment in which they exist.

Zentner (2001) suggested that color preference could influence color term acquisition by drawing attention to particular colors that might, in turn, make them more memorable, although this possibility has yet to be tested explicitly. In addition, colors that are more salient may be named more frequently by caregivers than colors that children find to be less attention grabbing, thereby proving the existence of a possible link among color preference, linguistic input, and emerging cognition. It is worth noting, however, that color preference is different from color saliency given that a color may be salient but disliked nonetheless. Indeed, in

Experiment 4, we showed that brown and gray were perceptually salient to preschool children as colors per se, given that the children used these two colors as readily as other basic colors to match objects on the basis of perceptual similarity, even though brown and gray are conceptualized later and children least prefer these two colors (Experiment 6). This shows that even when children cannot comprehend or name brown and gray, they can abstract each of these colors as a salient object feature and use it as a basis for informing judgments concerning perceptual similarity. However, it is conceivable that children may find brown and gray to be relatively less salient than the other basic colors in a task that directly compares brown or gray against other basic colors. Thus, relative perceptual saliency among the 11 basic colors, rather than absolute perceptual saliency as colors (as measured in Experiment 4), may help to mould developing color cognition. This would be consistent with studies showing that differences in relative color saliency influence adult color cognition (for a detailed review of the literature, see Jameson & Alvarado, 2003).

In summary, the current study is important in that it demonstrates, for the first time, a developmental linkage among maternal input, color preference, and developing color cognition. Although in this study we find little support for a direct perceptual influence on the conceptualization of basic colors, this does not imply that perception is unimportant; rather, it implies that perception may interact with color preferences to influence the order in which young children acquire basic color terms. This would account for the consistency with which we find brown and gray to be conceptualized late relative to the other basic colors, and it would also allow for the individual variation in color term acquisition that is also observed (Pitchford & Mullen, 2002). However, our results clearly suggest that linguistic input, color preference, and emerging color cognition are developmentally linked, although the underlying nature of this association has yet to be determined. We suggest that a third mediating factor, pertaining to the perceptual organization of color space, may form the basis of this association.

Acknowledgments

We are particularly grateful to the children, staff members, and directors (including Ellen Unkrig-Staton, Carole Monpetit, and Maria Ottoni) of the day care centers that kindly participated in this research. We also thank Tim Ledgeway for the development of the software used in Experiments 2, 3, and 4; Caroline Bellman, Joanna Bennett, Lauren Kemple, Chloe Yates, and Adam Vickers for assisting with the data collection; and Julian Pine for the analysis of speech extracts from the CHILDES database. This research was supported, in part, by a University of Nottingham Research Committee Grant (A2RBF7), a Universitas 21 Travel Grant to Nicola Pitchford, and a Canadian Institute of Health Research Project Grant (MT-10819) to Kathy Mullen.

Appendix A

Color	Munsell chip coordinate	Chromaticity coordinates ($x, y; u', v'$)	Luminance (% difference from background)
White		0.273, 0.289; 0.185, 0.439	+78.6
Black			
Red	7.5R 5/16	0.634, 0.328; 0.447, 0.521	−57.5
Green	2.5G 7/10	0.302, 0.552; 0.134, 0.551	−6.1
Yellow	5YR 8.5/10	0.441, 0.489; 0.221, 0.551	+30.6
Blue	5PB 4.5/12	0.148, 0.069; 0.167, 0.177	−69.4
Brown	5YR 3/6	0.570, 0.328; 0.393, 0.510	−93.1
Purple	3.75P 5/10	0.214, 0.106; 0.223, 0.247	−70.2
Pink	2.5RP 8/6	0.321, 0.267; 0.230, 0.432	−6.1
Orange	5YR 7/14	0.522, 0.422; 0.297, 0.541	−28.6
Gray	N5.5/1	0.268, 0.281; 0.184, 0.434	−59.2
Background	N8/1	0.277, 0.297; 0.185, 0.444	0

Note. Munsell chip coordinates are shown in the second column. CIE 2° x, y and u', v' chromaticity coordinates and brightness for the 11 basic color stimuli and background were measured with a Photo Research PR-645 SpectralCal Colorimeter. Luminance is reported as the percentage difference (plus or minus) from the background (49 cd/m^2).

Appendix B

Mean measures for each of the 11 basic colors

Basic color	Experiment 5		Experiment 6		Experiment 1
	Written counts	Spoken counts	Preference rank	Naming	Naming
Black	0.62	21.80	0.37	0.81	0.74
White	0.57	36.00	0.96	0.67	0.71
Red	0.98	90.60	−1.33	0.85	0.83
Green	0.69	81.60	0.58	0.88	0.82
Yellow	0.45	68.30	−0.44	0.83	0.81
Blue	0.61	82.60	−0.90	0.85	0.86
Orange	0.16	53.00	−0.62	0.85	0.89
Pink	0.29	33.40	−1.17	0.77	0.81
Purple	0.17	31.30	−0.52	0.83	0.74
Brown	0.26	13.50	1.44	0.60	0.64
Gray	0.62	21.80	0.37	0.81	0.74

Note. Experiment 5: written frequency (per preschool text) and spoken frequency (per 34 h of mothers' speech). Experiment 6: preference rank adjusted for chance (note possible range from –4 (most preferred) to +4 (least preferred) and naming (per single presentation)). Experiment 1: naming (per single presentation).

References

Adams, R. J. (1987). An evaluation of color preference in infancy. *Infant Behavior and Development, 10*, 143–159.

Allen, D., Banks, M. S., & Norcia, A. M. (1993). Does chromatic sensitivity develop more slowly than luminance sensitivity. *Vision Research, 33*, 2553–2562.

Andrick, G., & Tager-Flusberg, H. (1986). The acquisition of colour terms. *Journal of Child Language, 13*, 119–134.

Baldwin, D. (1989). Priorities in children's expectations about object label reference: Form over color. *Child Development, 60*, 1291–1306.

Berlin, B., & Kay, P. (1969). *Basic color terms*. Berkeley: University of California Press.

Bornstein, M. H. (1975). Qualities of color vision in infancy. *Journal of Experimental Child Psychology, 19*, 401–419.

Bornstein, M. H. (1985). On the development of color naming in young children: Data and theory. *Brain and Language, 26*, 72–93.

Bornstein, M. H., Kessen, W., & Weiskopf, S. (1976). Color vision and hue categorization in young human infants. *Journal of Experimental Psychology: Human Perception and Performance, 2*, 115–129.

Brian, C. R., & Goodenough, F. L. (1929). The relative potency of color and form perception at various ages. *Journal of Experimental Psychology, 12*, 197–213.

Catherwood, D., Crassini, B., & Freilberg, K. (1989). Infant response to stimuli of similar hue and dissimilar shape: Tracing the origins of the categorization of objects by hue. *Child Development, 60*, 752–762.

Civan, A., Teller, D. Y., & Palmer, J. (2003). Spontaneous preferences versus novelty effects as indicators of chromatic discrimination among suprathreshold stimuli. *Journal of Vision, 9*, 712a.

Davidoff, J. B., Davies, I., & Roberson, D. (1999). Colour categories in a stone-age tribe. *Nature, 398*, 203–204.

Franklin, A., & Davies, I. R. L. (2004). New evidence for infant colour categories. *British Journal of Developmental Psychology, 22*, 349–377.

Hardin, C. L., & Maffi, L. (1997). *Colour categories in thought and language*. Cambridge UK: Cambridge University Press.

Heider, E. R. (1971). "Focal" color areas and the development of color names. *Developmental Psychology, 4*, 447–455.

Heider, E. R. (1972a). Probabilities, sampling, and ethnographic method: The case of Dani color names. *Man, 7*, 448–466.

Heider, E. R. (1972b). Universals in color naming and memory. *Journal of Experimental Psychology, 93*, 10–20.

Itskowitz, R., Strauss, H., & Gross, Y. (1987). Differential use of dimensions in similarity and preference judgements among 4- to 6-year-olds. *Perceptual and Motor Skills, 65*, 147–156.

Jameson, K. A., & Alvarado, N. (2003). Differences in color naming and color salience in Vietnamese and English. *COLOR Research and Application, 28*, 113–138.

Kay, P., Berlin, B., Maffi, L., & Merrifield, W. (1997). Color naming across languages. In C. L. Hardin & L. Maffi (Eds.), *Color categories in thought and language*. Cambridge UK: Cambridge University Press.

Kay, P., Berlin, B., & Merrifield, W. R. (1991). Biocultural implications of systems of color naming. *Journal of Linguistic Anthropology, 1*, 12–25.

Kay, P., & Maffi, L. (2000). Color appearance and the emergence and evolution of basic color lexicons. *American Anthropologist, 10*, 743–760.

Kay, P., & McDaniel, C. K. (1978). The linguistic significance of the meaning of basic color terms. *Language, 54*, 610–646.

Knoblauch, K., Vital-Durand, F., & Barbur, J. L. (2001). Variation of chromatic sensitivity across the life span. *Vision Research, 41*, 23–36.

Kucera, H., & Francis, W. N. (1967). *Computational analysis of present-day American English*. Providence RI: Brown University Press.

MacWhinney, B. (2000). *The CHILDES Project: Tools for analyzing talk, Vol. 2: The database* (3rd ed.). Mahwah NJ: Lawrence Erlbaum.

Matsubara, H. (1957). *Colour vision test plates for the infants*. Tokyo: Handaya Company Ltd.

Maurer, D., & Adams, R. J. (1987). Emergence of the ability to discriminate blue from gray at one month of age. *Journal of Experimental Child Psychology, 44*, 147–156.

Melkman, R., Koriat, A., & Pardo, K. (1976). Preference for color and form in preschoolers as related to color and form differentiation. *Child Development, 47*, 1045–1050.

Mervis, C. B., Bertrand, J., & Pani, J. R. (1995). Transaction of cognitive–linguistic abilities and adult input: A case-study of the acquisition of colour terms and colour-based subordinate object categories. *British Journal of Developmental Psychology, 13*, 285–302.

Mervis, C. B., Catlin, J., & Rosch, E. (1975). Development of the structure of color categories. *Developmental Psychology, 11*, 54–60.

Mollon, J. D. (1989). "Tho' she kneel'd in that place where they grew …": The uses and origins of primate colour vision. *Journal of Experimental Biology, 146*, 21–38.

Morrone, M. C., Burr, D. C., & Fiorentini, A. (1993). Development of infant contrast sensitivity to chromatic stimuli. *Vision Research, 33*, 2535–2552.

Pereverzeva, M., & Teller, D. Y. (in press). Infant colour vision: Influence of surround chromaticity on spontaneous looking preferences. *Visual Neuroscience*, 21.

Petzold, A., & Sharpe, L. T. (1998). Hue memory and discrimination in young children. *Vision Research, 38*, 3759–3772.

Pitchford, N. J., & Mullen, K. T. (2001). Conceptualization of perceptual attributes: A special case for color? *Journal of Experimental Child Psychology, 80*, 289–314.

Pitchford, N. J., & Mullen, K. T. (2002). Is the development of basic colour terms in young children constrained? *Perception, 31*, 1349–1370.

Pitchford, N. J., & Mullen, K. T. (2003). The development of conceptual colour categories in pre-school children: Influence of perceptual categorisation. *Visual Cognition, 10*, 51–77.

Saito, M. (1996). Comparative studies on color preference in Japan and other Asian regions, with special emphasis on the preference for white. *Color Research & Application, 21*, 35–49.

Saunders, B. A. C., & van Brakel, J. (1997). Are there nontrivial constraints on colour categorization? *Behavioural and Brain Sciences, 20*, 167–228.

Shatz, M., Behrend, D., Gelman, S. A., & Ebeling, K. S. (1996). Color term knowledge in two-year-olds: Evidence for early competence. *Journal of Child Language, 23*, 177–199.

Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology, 6*, 174–215.

Suchman, R. G., & Trabasso, T. (1966). Color and form preference in young children. *Journal of Experimental Child Psychology, 3*, 177–187.

Teller, D. Y. (1998). Spatial and temporal aspects of color vision. *Vision Research, 38*, 3275–3282.

Teller, D. Y., & Bornstein, M. H. (1985). Color vision and color perception in infancy. In L. B. Cohen & P. Salapatek (Eds.), *Handbook of infant perception*. New York: Academic Press.

Teller, D. Y., Civan, A., & Bronson-Castain, K. (in press). Infants' spontaneous color preferences are not due to adult-like brightness variations. *Visual Neuroscience*, 21.

Teller, D. Y., Civan, A. L., Bronson-Castain, K., & Pereverzeva, M. (2003). Infants' spontaneous hue preferences are not due solely to variations in perceived brightness. *Journal of Vision, 3*, 142a.

Theakston, A. L., Lieven, E. V. M., Pine, J. M., & Rowland, C. F. (2001). The role of performance limitations in the acquisition of verb–argument structure: An alternative account. *Journal of Child Language, 28*, 127–152.

Waxman, S. R., & Markow, D. B. (1998). Object properties and object kind: Twenty-one-month-old infants' extension of novel adjectives. *Child Development, 69*, 1313–1329.

Zemach, I. K., & Teller, D. Y. (2004). *Infants' spontaneous hue preferences are not due solely to variations in perceived saturation.* Poster presented at the meeting of the Vision Sciences Society, Sarasota, FL.

Zentner, M. R. (2001). Preferences for colours and colour–emotion combinations in early childhood. *Developmental Science, 4*, 389–398.

Zollinger, H. (1988). Categorical color perception: Influence of cultural factors on the differentiation of primary and derived basic color terms in color naming by Japanese children. *Vision Research, 28*, 1379–1382.