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# The Development of Explicit Memory for Basic Perceptual Features

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In three experiments with 164 individuals between 4 and 80 years old, we examined age-related changes in explicit memory for three perceptual features—item identity, color, and location. In Experiments 1–2, feature recognition was assessed in an incidental learning, gamelike task resembling the game *Concentration*. In Experiment 3, feature recognition was assessed using a pencil-and-paper task after intentional learning instructions. The form of the explicit memory function across the life span varied with the particular perceptual feature tested and the type of task. Item recognition was excellent at all ages but was significantly poorer for older adults than children, color recognition peaked in late childhood on the gamelike task, and location recognition peaked in early adulthood on the pencil-and-paper task. These findings indicate that performance on explicit memory tests is not a consistent inverted U-shaped function of age across various features. Explicit memory performance depends on what is measured and how. Because explicit memory typically reflects a composite of different features, age-related changes in explicit memory will not necessarily correspond to the function for any single one. 

*Key Words:* explicit memory; memory development; life span; feature recognition; item recognition; color recognition; location memory; *Concentration*.

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Although they may express these ideas in different ways, current accounts of memory generally distinguish between more perceptually based, automatic, bottom-up processing and more reflectively based, effortful, top-down processing (e.g., Graf & Schacter, 1985; Hasher & Zacks, 1979; Johnson, 1983; Roediger & Blaxton, 1987; Schacter & Moscovitch, 1984; Squire, 1987, 1992; Tulving, 1983). These accounts also generally agree that remembering events, sometimes called episodic (Tulving, 1972) or explicit memory (e.g., Graf & Schacter, 1985), is characterized by the phenomenal experience of specific features (e.g., color, shape, semantic, time, location, and emotion; Brewer, 1988; Johnson, Foley, Suengas, & Raye, 1988) that comprise the event (Johnson & Raye, 1981). Thus, episodic memory depends on encoding multiple features and associations among them. Furthermore, reflective activities (e.g., rehearsal, organization, semantic judgments, and imagery) contribute to establishing such complex event representations.

Many, if not all, of such self-initiated or reflective activities are thought to improve during childhood and decline in normal senescence, yielding an inverted U-shaped function for explicit memory (for review, see Balota, Dolan, & Duchek, 2000). The view that explicit memory is a U-shaped function of age is a reiteration of the Jacksonian principle of the development and dissolution of function (Jackson, 1880, reprinted in Taylor, 1958). This principle states that the last function to develop is the first to disappear after brain damage from injury, disease, or aging, whereas the first function to develop is the last to be affected when an organism undergoes demise. Because explicit memory is widely thought to be late maturing (Naito & Komatsu, 1993; Parkin, 1989; Schacter & Moscovitch, 1984; Tulving & Schacter, 1990), it should also decline in old age (e.g., Light & Lavoie, 1993) if its developmental course is described by the Jacksonian principle.

Ribot (1882) was the first to anticipate the Jacksonian principle in cognitive functioning, citing extensive anecdotal evidence that more recent memories are more vulnerable in disease states and old age. He described one example from a physician in Philadelphia: “Dr. Scandella, an ingenious Italian who visited this country a few years ago, was a master of the Italian, French, and English languages. In the beginning of the yellow fever, which terminated his life . . . he spoke English only; in the middle of the disease, he spoke French only; but, on the day of his death, he spoke only in the language of his native country” (Ribot, 1882, p. 182). A laboratory-based example of the development and dissolution of human cognitive functioning was reported by Ajuriaguerra, Rey-Bellet-Muller, and Tissot (1964), who observed that the sequence in which Piagetian abilities emerge in childhood is reversed as the cognitive abilities of senile adults progressively degenerate. However, these are examples in the domain of semantic knowledge and skills and do not directly address the developmental course of episodic memory.

More recent studies with children have repeatedly found that explicit memory performance on recall and recognition tests improves with age (e.g., Carroll, Byrne, & Kirsner, 1985; DiGiulio, Seidenberg, O'Leary, & Raz, 1994; Greenbaum & Graf, 1989; Kail, 1990; Naito, 1990; Parkin, 1989; Parkin & Streete, 1988; Schneider & Pressley, 1989). Likewise, numerous studies have found that young adults are superior to healthy, older adults on the same tasks (for reviews, see Balota et al., 2000; Graf, 1990; Light & Lavoie, 1993). Considered jointly, these studies appear to support the Jacksonian principle. Most of the studies of memory development with children, however, used verbal materials, raising the possibility that age changes in verbal competence contributed to this result.

Some researchers sidestepped this potential problem by testing children with pictorial stimuli. Mitchell (1993) performed a meta-analysis over nine developmental studies that used pictorial stimuli and that compared at least two age groups of either children or adults on tests of both explicit and implicit memory. All of the studies of explicit memory in his analysis used recognition tests except two, which used cued-recall tests. Mitchell found large age differences in accuracy that were described by an inverted U-shaped function, with older children performing significantly better than younger children (age range = 3–12 years) and older adults performing significantly worse than young adults (age range = 18–71 years). He characterized memory development over the life span in traditional Jacksonian terms: "As the most specialized system, episodic memory is the last to develop fully in childhood. Its unique specialization, however, may also make it the most fragile, and therefore it is the first to go in the course of normal aging" (Mitchell, 1993, p. 173).

The notion that explicit memory improves during childhood, peaks in young adulthood, and declines in late adulthood as a mirror image of its order of appearance has been uncritically accepted for more than a decade (for review, see Rovee-Collier, Hayne, & Colombo, 2001). Mitchell's (1993) meta-analysis, however, was performed over different studies that used different tasks, different stimuli, different metrics, and different instructions. In the present study, we reexamined the validity of the general notion that the pattern of explicit memory over the life span is U-shaped. To this end, we assessed the memory of children, young adults, and healthy, older adults for three, isolated perceptual features of events—item identity, color, and location. Because individuals' memory performance was based on information that they had just studied and because they were explicitly asked to select the item or color that they had just seen or to respond to the location where they had previously seen an object, the memory test met the commonly accepted criteria for a test of explicit memory.

In Experiment 1, we tested 4- and 5-year-olds on a pictorial gamelike incidental learning task. In Experiment 2, we tested groups of 5- to 72-year-olds on an identical, pictorial version of the same task with an expanded set of materials. In Experiment 3, we gave 10-year-olds the same set of materials but used intentional learning instructions and a pencil-and-paper task that had previously been used to study feature recognition with young and healthy, older adults (Chalfonte & Johnson, 1996). In all cases, participants saw colored line drawings of objects located in various cells of an array during study, and then they were tested on their memory for individual features (item, color, or location). Unlike most previous tests with children, the memory tests did not re-present the features that were not being tested (e.g., color information was not present when item information was being tested), and the test did not require that these features had been bound together (e.g., participants did not have to remember that the color "blue" went with the ball).

Our research questions were threefold. First, is very young children's explicit memory the same for different, basic perceptual features that are common to many events (Experiment 1)? Second, is the pattern of developmental change previously found in studies of explicit memory also found for each of three basic perceptual features when children and adults of different ages are given explicit memory tests for these features—that is, is the same U-shaped function general across different features (Experiment 2)? And third, is the life-span pattern of explicit memory for these basic perceptual features affected by the nature of the task used to measure it (Experiment 3)?

## EXPERIMENT 1: INCIDENTAL EXPLICIT MEMORY PERFORMANCE OF 4- AND 5-YEAR-OLDS

Researchers generally agree that explicit memory performance on recognition, cued-recall, and free-recall tests involves the conscious remembering of a specific, prior study episode (for review, see Rovee-Collier et al., 2001). They also assume that explicit memory improves with age from childhood until young adulthood (Kail, 1990; Mitchell, 1993; Naito, 1990; Naito & Komatsu, 1993; Schneider & Pressley, 1989; Tulving & Schacter, 1990) and declines in old age (for review, see Balota et al., 2000). The inverted U-shaped form of this function over the life span undoubtedly reflects changes in the contribution of many factors, including the speed of processing, attention and its control, strategic skills, motivation, contextual integration, verbal competence, and the neurobiological subsystems that underlie all of these factors.

Because most memory studies with children have used verbal materials, developmental changes in verbal competence may have contributed to the observation that explicit memory improves during the childhood period. As discussed earlier, some developmental researchers have sought to eliminate this problem by using pictorial stimuli in studies with children (for reviews, see Mitchell, 1993; Schneider & Pressley, 1989). Baker-Ward and Ornstein (1988), for example, systematically documented the ability of young children and adults to play the game *Concentration*, which requires that individuals encode and remember multiple items. In this game, identical items appear on two cards in a deck that is shuffled before the cards are placed face down. Participants turn over and then replace each card (e.g., a green vase in location 1), one at a time, until they turn over a card that they recognize as being like one they saw before. If they remember where they saw it, then they retrieve the prior card, striking a match. The object of the game is to strike more matches than the other player. Baker-Ward and Ornstein found that children's memory performance in this game was actually superior to that of adults. This study was the first to challenge the widely held assumption that explicit memory performance improves with age.

In a study that was also motivated by the observation that very young children rarely erred when playing *Concentration,* Schumann-Hengsteler (1992) found that children's memory performance improved with age for the combination of location information and object identity, but it was age-invariant for individual features. In two experiments, Schumann-Hengsteler showed line drawings of organized scenes to 4- to 10-year-olds and later asked them to reconstruct the scenes from a pool of items. Children's responses were scored for correctly identified items irrespective of where they were placed, correctly located items irrespective of what item was placed there, and correctly located items (the conjunction of identity and location information). Although item identity and item location were *scored* separately, in following the task instructions, children were likely attempting to use *bound* identity and location information to reconstruct the pictures, that is, putting a particular item in the place where they remembered seeing it before. Thus, this study may not provide the most sensitive measure of memory for individual feature information.

Unlike Experiment 2 of Schumann-Hengsteler (1992), our first experiment was designed to test the ability of 4- and 5-year-olds to recognize item, location, and color features when each of these three perceptual attributes was tested independent of the other two attributes. To accomplish this, we used a modified version of the *Concentration* game. The stimulus materials were those that had previously been used to study memory and aging (Chalfonte & Johnson, 1996) and amnesia (Chalfonte, Verfaellie, Johnson, & Reiss, 1996), and the procedure was modified to be appropriate for use with young children. As in the *Concentration* game, children actively interacted with the stimulus materials, reaching successively to each location and lifting a card to reveal the particular colored item concealed beneath it. During testing, children similarly selected the correct card from an array (item and color feature tests) or reached to the spot on the board and put a sticker on it (location feature test). Because children frequently see monochromatic line drawings, we expected that children of both ages would be able to recognize black line drawings of colored line drawings of the familiar objects they had just seen, but we had no expectations about whether they would also be able to recognize color and location features when these features were not "attached" to the objects at the time of testing.

## *Method*

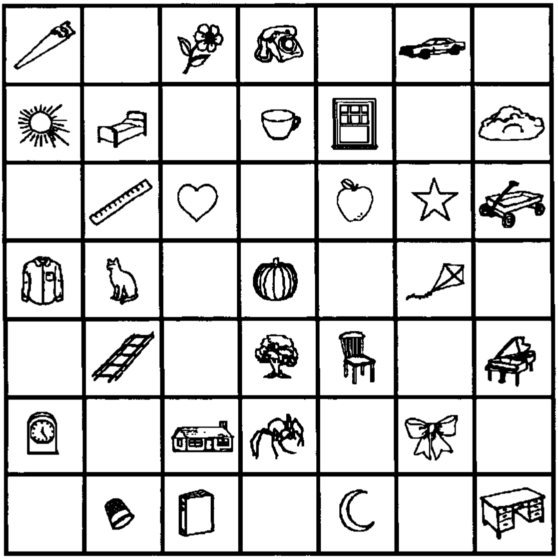
*Participants*. Participants were eighteen 4-year-old children (9 boys, 9 girls) with a mean age of 4.33 years ($SD$ = .27) and eighteen 5-year-old children (9 boys, 9 girls) with a mean age of 5.42 years ($SD$ = .02). Children were recruited from the Rutgers University day-care center and by word-of-mouth and were randomly assigned to one of three feature test groups (a between-subjects design) as they became available for study. They were Caucasian (50.00%), Hispanic (5.55%), Asian (11.11%), and Not Reported (32.21%). Demographic information available from 36% of the sample indicated that their parents' mean educational attainment was 16.00 ($SD = 0.00$), and their mean rank of socioeconomic status (Nakao & Treas, 1992[1]) was 77.03 ($SD = 13.54$).

*Stimuli*. The study and test stimuli were drawn from stimuli used by Chalfonte and Johnson (1996) and Chalfonte et al. (1996). The items used in all experiments are shown in Fig. 1a. During the study phase, stimuli were presented on a large piece of white posterboard (41.5 $cm^2$) that was marked off into 49 squares (5 $cm^2$) in a $7 \times 7$ grid (see Fig. 1a). Twelve line drawings of common objects were randomly assigned to locations. Each item was in a unique color, and no object appeared in its natural color. Two different study arrays were generated in this manner and were counterbalanced within test groups.

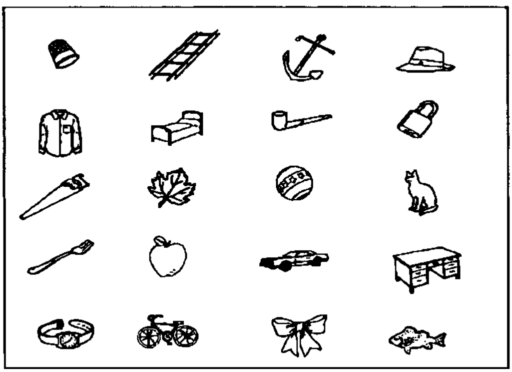
Examples of the three feature test arrays are shown in Fig. 1b–1d. For the *item feature recognition test*, 16 black-and-white line drawings of objects on individual squares of laminated paper were arranged randomly in front of each child. Eight of the items were from the study array, and 8 items were novel. For the *color feature recognition test*, 16 colored laminated cards displaying diagonal stripes in a single color were arranged randomly in front of each child. Eight colors were from the study array, and 8 colors were novel. For both tests, the child was asked to hand the experimenter the cards that showed the objects or colors that he or she had just seen. Testing was discontinued after children had picked 8 items. For the *location feature recognition test*, children were presented with a game board on which 16 locations were blank and the rest were covered with black-and-white laminated cards. Eight of the blank locations had previously displayed a colored object, and eight of the blank locations had also been blank before. The child was given eight identical stickers, each displaying a happy face, and asked to put a sticker in a blank spot on the board where he or she had previously found an object.

*Procedure*. Testing was conducted in the child's home or day-care center during a single session that lasted approximately 10 min. At the beginning of each session, every square on the study array was covered by a black-and-white striped laminated card. The child was asked to remove all of the cards on the board, one at a time, and was told that an object was under some of the cards. When the child removed a card and found an object underneath, he or she was asked to name both the object and its color. This procedure ensured that the objects and their colors were familiar. All children named the objects and their colors without error. As they removed each card, children put it to the side of the board. When all cards had been removed, the experimenter replaced them, and children received a second trial.

[1]The socioeconomic index (SEI), published by Nakao and Treas in 1992, is currently the recommended source for occupational status. Educational attainment, occupational status, and annual income are the major components of socioeconomic status. In the SEI, ranks of occupations range from 1 to 100, with higher paying occupations (e.g., aerospace engineer) being accorded higher ranks. All studies funded by NIMH and NICHHD are required to report information pertaining to racioethnic and socioeconomic status.



(a)



(b)

**FIG. 1.** An example of study and test materials used with 5-, 7-, 10-, 22-, and 72-year-olds in Experiments 2 and 3. A subset of the study and test materials was used with 4- and 5-year-olds in Experiment 1. (a) The study array. (b) Stimuli used for the item feature recognition test.

Children's learning was incidental. That is, they were not told to study either the array or a specific feature, and they also were not told that they would later be asked about the information that they saw. Within 5 min after completing the second trial, children were given a feature recognition test in which they were asked to pick out the items or colors that they had just seen or to put stickers on the squares where they had just seen an object.

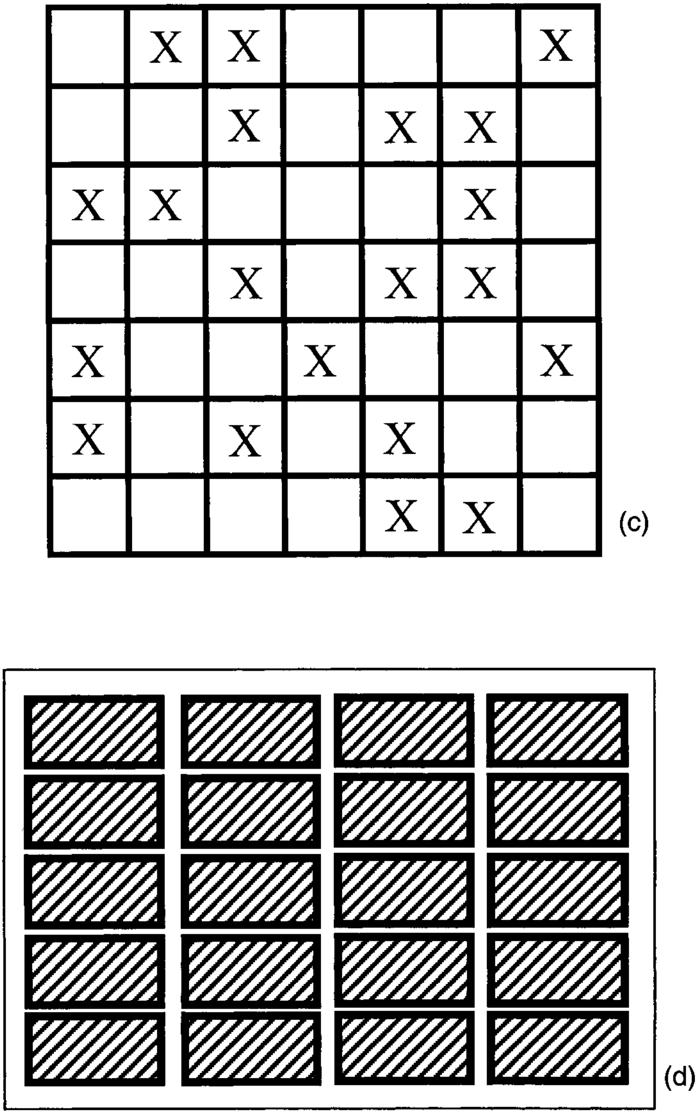



**FIG. 1**—*Continued.* (c) Stimuli used for the location feature recognition test. (d) Array used for the color feature recognition test.

## *Results and Discussion*

Table 1 (*top*) presents the *proportion of hits* (targets selected), *false alarms* (distractors selected), and *corrected recognition scores* (proportion of hits minus false alarms) for the two groups in Experiment 1. A 2 (Age) × 3 (Feature) analy-

TABLE 1
Mean Feature Recognition Performance of Children, Young Adults, and Older Adults in a Gamelike Task with a 12-Object Array (Experiment 1) or a 30-Object Array (Experiment 2)

| Age (Years) | Feature test | Hits | False alarms | Corrected recognition score |
|---|---|---|---|---|
| | | Experiment 1 (12-object array) | | |
| 4 | Item | 0.96 (0.04) | 0.04 (0.04) | 0.92 (0.08) |
| | Location | 0.56 (0.04) | 0.44 (0.04) | 0.13 (0.09) |
| | Color | 0.63 (0.03) | 0.38 (0.03) | 0.25 (0.07) |
| 5 | Item | 1.00 (0.00) | 0.00 (0.00) | 1.00 (0.00) |
| | Location | 0.52 (0.06) | 0.48 (0.06) | 0.21 (0.08) |
| | Color | 0.56 (0.06) | 0.44 (0.06) | 0.21 (0.10) |
| | | Experiment 2 (30-object array) | | |
| 5 | Item | 0.98 (0.02) | 0.02 (0.02) | 0.97 (0.03) |
| | Location | 0.50 (0.04) | 0.50 (0.04) | 0.00 (0.07) |
| | Color | 0.52 (0.06) | 0.48 (0.06) | 0.03 (0.12) |
| 7 | Item | 1.00 (0.00) | 0.00 (0.00) | 1.00 (0.00) |
| | Location | 0.43 (0.05) | 0.57 (0.05) | −0.13 (0.10) |
| | Color | 0.63 (0.02) | 0.37 (0.02) | 0.27 (0.04) |
| 10 | Item | 1.00 (0.00) | 0.00 (0.00) | 1.00 (0.00) |
| | Location | 0.50 (0.03) | 0.50 (0.03) | 0.00 (0.05) |
| | Color | 0.73 (0.04) | 0.27 (0.04) | 0.47 (0.08) |
| 22 | Item | 0.97 (0.02) | 0.03 (0.02) | 0.94 (0.03) |
| | Location | 0.55 (0.06) | 0.45 (0.06) | 0.10 (0.11) |
| | Color | 0.54 (0.04) | 0.46 (0.04) | 0.08 (0.09) |
| 72 | Item | 0.93 (0.02) | 0.07 (0.02) | 0.86 (0.04) |
| | Location | 0.44 (0.04) | 0.56 (0.04) | −0.12 (0.09) |
| | Color | 0.52 (0.04) | 0.48 (0.04) | 0.04 (0.09) |

*Note*. Parentheses contain ±1 SE.

sis of variance (ANOVA) was performed on children's corrected recognition scores. This analysis yielded a significant main effect of Feature, $F(2, 30) = 2.74$, $p < .0001$, but not of Age, $F(1, 30) < 1$. The two-way interaction was also not significant, $F(2, 30) < 1$. Post hoc tests (Duncan's new multiple range test, $p < .05$) indicated that children's item recognition was superior to their recognition of color and location, which did not differ from one another. Thus, both age groups exhibited excellent feature recognition of item information but poor feature recognition of color and location information (see Fig. 2).

Experiment 1 confirmed that the modified gamelike task was appropriate for use with very young children and that they were highly motivated to perform it. The results showed differences in memory for item, color, and location information and that 4- and 5-year-olds performed identically. Children's recognition of item information was nearly perfect, but their recognition of location and color information was poor. Because the study array in Experiment 1 had contained

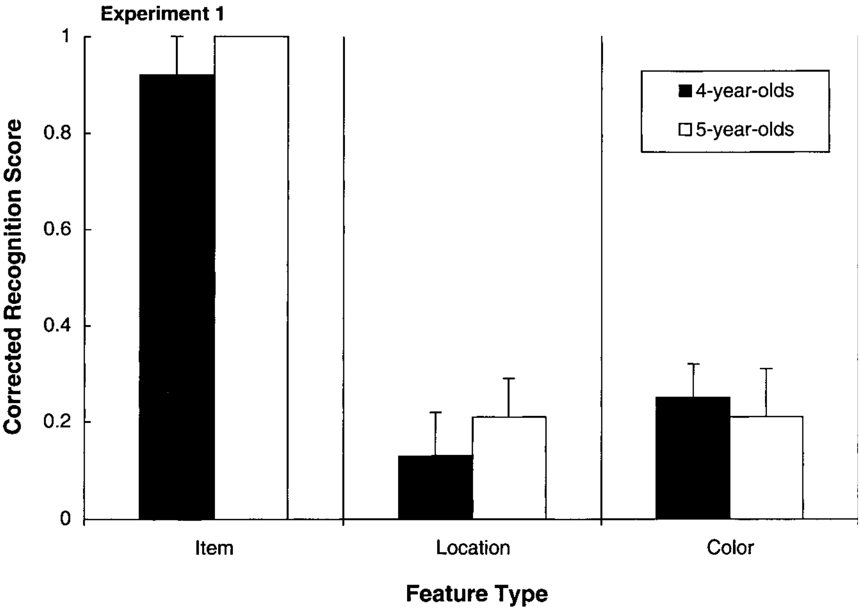



**FIG. 2.** Mean corrected recognition scores on explicit memory tests of each of three features (item, color, and location) for 4- and 5-year-old children who studied a 12-object array (Experiment 1). Vertical bars represent +1 *SE*.

only 12 items, we increased this number in Experiment 2 in order to reduce the possibility of a ceiling effect on item information and to provide an opportunity for memory performance on the item recognition test to improve with age. The study and test arrays in Experiment 2 contained the same items in the same number and colors that Chalfonte and Johnson (1996) had originally used with young and healthy, older adults.

## EXPERIMENT 2: INCIDENTAL EXPLICIT MEMORY PERFORMANCE OF 5-, 7-, 10-, 22-, AND 72-YEAR-OLDS

The widespread assumption that explicit memory is an inverted U-shaped function of age is particularly tenuous because different memory tasks have been used with individuals of different ages. The feature recognition performance of the young children in Experiment 1 strongly suggested that children's explicit memory performance depends on what is measured. In Experiment 2, therefore, we asked if explicit memory for these same three features (item, color, and location) changes in the commonly assumed manner over the life span. To answer this, we administered exactly the same task to children, young adults, and healthy older adults. The children's ages matched the ages of children who had previously received recognition tests with various pictorial materials (e.g., Ceci, Lea, &

Howe, 1980; Fagan & Vasen, 1997; Mitchell, 1993; Russo, Nichelli, Gibertoni, & Cornia, 1995; Schumann-Hengsteler, 1992), and the adults' ages matched those of young and healthy older adults who had previously received recognition tests with the same set of pictorial materials used here (Chalfonte & Johnson, 1996). In contrast to these earlier studies of children, however, here we assessed memory for features presented individually at the time of testing rather than in combination with other features that had been studied, as in Experiment 1 and Chalfonte and Johnson's study of age-related changes in memory.

### *Method*

*Participants*. Fifty-four children, 30 young adults, and 30 healthy older adults were participants. All were recruited through published news releases and by word-of-mouth and were randomly assigned to one of the three feature test groups (a between-subjects design) as they became available for study. The children ranged in age from 5 to 10 years and included 9 boys and 9 girls with a mean age of 5.25 years ($SD = .32$), 9 boys and 9 girls with a mean age of 7.25 years ($SD = .25$), and 7 boys and 11 girls with a mean age of 10.42 years ($SD = .37$). They were Caucasian (44.44%), Asian (3.70%), African American (9.25%), Hispanic (1.85%), and Not Reported (40.74%). The children's parents had a mean educational attainment of 15.56 years ($SD = 0.95$), and their mean rank of socioeconomic status (Nakao & Treas, 1992) was 66.33 ($SD = 21.22$).

The young adults were upper-level college students and included 13 males and 17 females with a mean age of 22.83 years ($SD = 1.17$). They were Caucasian (83%) and Asian (27%). The older adults were recruited from the local community and included 12 males and 18 females with a mean age of 72.1 years ($SD = 5.21$). Their mean level of educational attainment was 11.5 years ($SD = 3.6$) and mean rank of socioeconomic status (Nakao & Treas, 1992) was 47.38 ($SD = 25.74$). All were Caucasian.

*Stimuli and procedure*. The study and test materials and the procedure were the same as in Experiment 1 except that the number of items in the study array was increased from 12 to 30 (see Fig. 1a and the Appendix), and the number of test items was increased from 16 to 20 (10 old items and 10 new items). Also in Experiment 2, participants were not asked to name the objects or colors, and testing was stopped when an individual had picked 10 items.

### *Results and Discussion*

Initially, we asked if the number of items in the study array affected the youngest children's explicit memory performance. To answer this, we compared the memory performance of 5-year-olds who studied the 30-item array in Experiment 2 with that of 5-year-olds who had studied the 12-item array in Experiment 1. More than doubling the number of items in the study array affected neither 5-year-olds' recognition of feature identity nor their pattern of feature recognition (see Table 1, rows 2 and 3). A 2 (Array Size) × 3 (Feature) ANOVA on the corrected recognition scores from the three feature recognition tests of 5-year-olds in each experiment yielded no effect of Array Size, $F(1, 30) < 1$, and no interaction, $F(2, 30) < 1$. As before, however, the effect of Feature was highly significant, $F(2, 30) = 88.88$, $p < .0001$. A Duncan's new multiple-range test ($p < .05$) indicated that 5-year-olds' feature recognition of item identity was again superior to their feature recognition of color and location, which did not differ. As in Experiment 1, 5-year-olds' recognition of color and location information was poor.

A 5 (Age) × 3 (Feature) ANOVA was conducted on the corrected recognition scores from Experiment 2 (see Table 1, *bottom*) to assess potential differences in test performance. This analysis yielded significant main effects of Age, $F(4, 99) = 3.29$, $p < .02$, and Feature, $F(2, 99) = 203.60$, $p < .01$, and a marginally significant interaction, $F(8, 99) = 1.99$, $p < .056$. The interaction was clarified by separate one-way ANOVAs for each feature. Not only did the pattern of recognition differ for the three features as it had in Experiment 1, but also the pattern of recognition changed differently across age. First, the ages differed significantly on the item feature recognition test, $F(4, 33) = 3.26$, $p < .03$. Post hoc tests (Duncan's new multiple range test, $p < .05$) indicated that 5-, 7-, and 10-year-olds recognized significantly more items than 72-year-olds, while the mean item recognition score of 22-year-olds was intermediate between the mean item recognition scores of the children and older adults. On the color feature recognition test, the ages also differed significantly, $F(4, 33) = 3.74$, $p < .05$, with 10-year-olds outperforming 72-year-olds, 22-year-olds, and 5-year-olds; their performance on the color feature recognition test, however, did not significantly differ from that of 7-year-olds. Although performance on the location feature recognition test was best for 22-year-olds, performance was relatively poor at all ages, $F(4, 33) = 1.10$, *ns*.

The recognition performance of 5-, 7-, and 10-year-olds on the item feature test was near or at ceiling; therefore, these age groups might have differed had the test array been larger. Nevertheless, the findings did *not* suggest that the children and older adults performed more poorly than young adults. More critical to evaluating the Jacksonian hypothesis was the *superior* performance of 10-year-olds relative to that of 22- and 72-year-olds on the color feature recognition test. Finally, these results reveal that performance on the color memory task was not simply a function of verbal skills because young and older adults undoubtedly possessed better verbal labels than 10-year-olds for the 30 studied colors (see the Appendix).

## EXPERIMENT 3: INTENTIONAL EXPLICIT MEMORY PERFORMANCE OF 10-, 19-, AND 70-YEAR-OLDS ON THE PENCIL-AND-PAPER TEST

In Experiment 2, we used a gamelike task with children, young adults, and healthy older adults to compare their incidental explicit memory for three perceptual features. The general pattern of results favored the children—not the young adults, as would be predicted by the Jacksonian hypothesis. We wondered, however, if the pattern of results would be the same under intentional learning conditions using the pencil-and-paper task that Chalfonte and Johnson (1996) had previously used with young and healthy older adults. Experiment 3 was designed to answer this question.

Because the pencil-and-paper task is inappropriate for use with younger children, we administered it only to a new group of 10-year-olds and compared their memory performance in this task with their memory performance in the gamelike task in Experiment 2. In addition, we compared the memory performance of young and older adults in the gamelike task from Experiment 2 with the memory performance previously obtained by Chalfonte and Johnson (1996) from young and older adults in the pencil-and-paper task.

### *Method*

*Participants*. Thirty 10-year-old children (9 boys and 21 girls) with a mean age of 10.25 years (*SD* = .33) were recruited by word of mouth and newspaper advertisements and were randomly assigned to one of three tests as they became available for study. They were Caucasian (73.33%), African American (3.33%), Asian (10.00%), Hispanic (10.00%), and Other (3.33%). Their parents' mean educational attainment was 15.33 years (*SD* = 1.24), and their mean rank of socioeconomic status (Nakao & Treas, 1992) was 71.04 (*SD* = 15.19).

Forty-eight young adults (*M* age = 19.17 years, *SD* = 1.42) and 48 healthy older adults (*M* age = 70.50 years, *SD* = 4.58) were tested by Chalfonte and Johnson (1996). The young adults were predominately college freshmen (*M* educational attainment = 13.9 years, *SD* = 1.2), and the older adults were recruited from local retirement communities. Their mean educational attainment was 15.1 years (*SD* = 2.3). Data pertaining to sex and socioeconomic status were not reported.

*Study stimuli*. The study and test stimuli were identical to those used by Chalfonte and Johnson (1996). The study array, a 7 × 7 grid (19 $cm^2$), was presented on a single 8 $^1/_2$ × 11-in. sheet of paper. Line drawings of common objects were displayed in 30 of the 49 possible locations on the grid (see Fig. 1a). All study objects were computer-drawn in unique colors, no more than five objects were located in any given row or column, and none of the objects was in its natural color. Two study arrays were generated in this manner and were counterbalanced within test conditions.

*Test stimuli*. The pencil-and-paper test was also identical to that used by Chalfonte and Johnson (1996). As before, the item recognition test consisted of 10 studied items and 10 novel items. This time, however, the test objects appeared as black-and-white line drawings arranged in five rows of four items each on an 8 $^1/_2$ × 11-in. sheet of paper (see Fig. 1b). For the item feature recognition test, children were asked to circle with a pencil the objects that they had seen in the study array. For the location feature recognition test, children were presented with a 7 × 7 array marked off on an 8 $^1/_2$ × 11-in. sheet of paper. A black "X" appeared in each of 10 studied locations and in the 10 novel locations (see Fig. 1c). Children were asked to circle those locations that were marked by an "X" where an object had previously appeared in the study array. For the color feature recognition test, 10 studied colors and 10 novel colors were arranged in five rows of four blocks each on an 8 $^1/_2 \times$ 11-in. sheet of paper. Each block displayed a rectangle with 12 stripes in a single color (see Fig. 1d). Children were asked to circle the colors that they had seen in the study array.

*Procedure*. A single session lasting approximately 5 min was conducted in the child's home. Unlike Experiments 1 and 2, at the beginning of the session in Experiment 3, participants were explicitly instructed to study a particular feature (item, location, or color) for 90 s and were told that they would then be tested on this information. They received one of the three feature recognition tests 5 min later.

### *Results and Discussion*

A 2 (Test) $\times$ 3 (Feature) ANOVA was performed on 10-year-olds' corrected recognition scores for the two test procedures (the posterboard game from Experiment 2 and the pencil-and-paper task from Experiment 3) and the three feature tests (item, color, and location). This analysis yielded a significant main effect of Test, $F(1, 42) = 5.39$, $p < .03$, and Feature, $F(2, 42) = 78.51$, $p < .0001$, but the two-way interaction was not significant, $F(2, 42) = 1.58$, *ns*. A Duncan's new multiple-range test ($p < .05$) indicated that the 10-year-olds' corrected recognition scores on the pencil-and-paper test in Experiment 3 (see Table 2) were significantly lower overall than their scores on the modified *Concentration* game in Experiment 2 (see Table 1). As before, 10-year-olds' performance on the item feature recognition test in Experiment 2 was significantly better than their performance on both the color feature and the location feature recognition tests.

TABLE 2
Mean Feature Recognition Performance of Children, Young Adults, and Older Adults in a Pencil-and-Paper Task with a 30-Object Array

| Age (Years) | Feature test | Hits | False alarms | Corrected recognition score |
|---|---|---|---|---|
| | | Children (Experiment 3) | | |
| 10 | Item | 0.94 (0.03) | 0.06 (0.03) | 0.88 (0.06) |
| | Location | 0.50 (0.05) | 0.50 (0.05) | −0.01 (0.10) |
| | Color | 0.61 (0.04) | 0.37 (0.03) | 0.20 (0.06) |
| | | Young and older adults (Chalfonte & Johnson, 1996) | | |
| 19 | Item | 0.93 (0.03) | 0.02 (0.01) | 0.91 (0.03) |
| | Location | 0.58 (0.06) | 0.24 (0.03) | 0.34 (0.07) |
| | Color | 0.65 (0.05) | 0.41 (0.04) | 0.24 (0.05) |
| 70 | Item | 0.95 (0.02) | 0.06 (0.02) | 0.89 (0.04) |
| | Location | 0.56 (0.05) | 0.49 (0.04) | 0.07 (0.05) |
| | Color | 0.71 (0.05) | 0.50 (0.05) | 0.21 (0.04) |

*Note*. Parentheses contain ±1 SE.

Planned comparisons using Student's unpaired $t$ tests indicated that the type of test did not affect either item feature recognition, $t(14) = 1.50$, *ns*, or location feature recognition, $t(14) < 1$; however, 10-year-olds' color feature recognition was significantly better on the gamelike task, $t(14) = 2.57$, $p < .03$. Their poorer performance on the color feature recognition test undoubtedly contributed to their poorer overall performance on the pencil-and-paper test.

Next, we compared the memory performance of the 10-year-olds in Experiment 3 with that previously obtained from 19- and 70-year-olds on an identical pencil-and-paper version of the same feature recognition tests with identical materials and instructions (Chalfonte & Johnson, 1996). Student's unpaired $t$ tests on the corrected recognition scores revealed that the 10-year-olds did not differ from the 19-year-olds on the item feature and color feature recognition tests, both $t$s$(24) < 1$. The same results were obtained when 10-year-olds' performance on the item feature and color feature recognition tests was compared with that of 70-year-olds, $t(24) = 1.29$, *ns*, and $t(24) < 1$, respectively. On the location feature recognition test, however, 10-year-olds performed significantly worse than 19-year-olds, $t(24) = 2.92$, $p < .005$, but not differently from 70-year-olds, $t(24) < 1$. Thus, although 10-year-old children recognized color feature and item feature information as well as young and older adults on the pencil-and-paper test, their location feature recognition was poorer than that of the young adults but equivalent to that of older adults.

Identical analyses were used to compare the corrected recognition scores of the young and older adults on the gamelike task (Experiment 2) and the pencil-and-paper task (Chalfonte & Johnson, 1996). These analyses indicated that young adults performed equivalently on the two versions of the item feature recognition test, $t(24) = 1.37$, *ns*, as did the older adults, $t(24) < 1$. Young adults also performed equivalently on the two versions of the color feature recognition test, $t(24) = 1.89$, *ns*, as did the older adults, $t(24) = 1.40$, *ns*. However, both young adults, $t(24) = 3.50$, $p < .01$, and older adults, $t(24) = 2.38$, $p < .05$, performed significantly better on the pencil-and-paper version of the location feature recognition test, suggesting that they were able to improve their memory for location information under intentional learning conditions. Thus it appears that, relative to the incidental gamelike task, the intentional paper-and-pencil test situation reduced children's memory for color and increased adults' memory for location.

## GENERAL DISCUSSION

Cognitive psychologists and cognitive neuroscientists often treat episodic memory as a single entity (Nelson, 1995; Squire, 1987, 1992; Tulving & Schacter, 1990), or as reflecting one of two states (e.g., "remember" vs "know;" Gardiner & Java, 1993; Tulving, 1985), rather than as the final, expressed outcome of a number of different types of information and processing factors (Johnson, 1983, 1992; Johnson & Hirst, 1993; Johnson & Raye, 1981). This assumption and the Jacksonian (first-in, last-out) principle have led to the widely held but oversimplified conclusion that explicit memory improves during childhood, peaks in adulthood, and declines in old age.

The present findings raise questions about this conception of the development of explicit memory. First, the explicit memory function for three different perceptual features over the life span was not universally described by the Jacksonian principle—a first-in, last-out principle. Figure 3 shows that insofar as there was an age trend for the recognition of item information, children performed the best and older adults performed the worst. Figure 3 also shows that incidental recognition memory for color information peaked at 10 years of age on the gamelike task. Finally, Chalfonte and Johnson (1996) previously found that young adults' recognition of location information on a pencil-and-paper test was superior to that of healthy, older adults after intentional learning instructions. At present, we found that 10-year-olds' recognition of location information under the same conditions did not differ from that of Chalfonte and Johnson's older adults but was significantly worse than that of their young adults (see Fig. 4). Thus, the only indication from the present studies of a finding consistent with the Jacksonian hypothesis and resembling the U-shaped function typically used to describe changes in explicit memory over the life span (e.g., Mitchell, 1993, p. 172) was

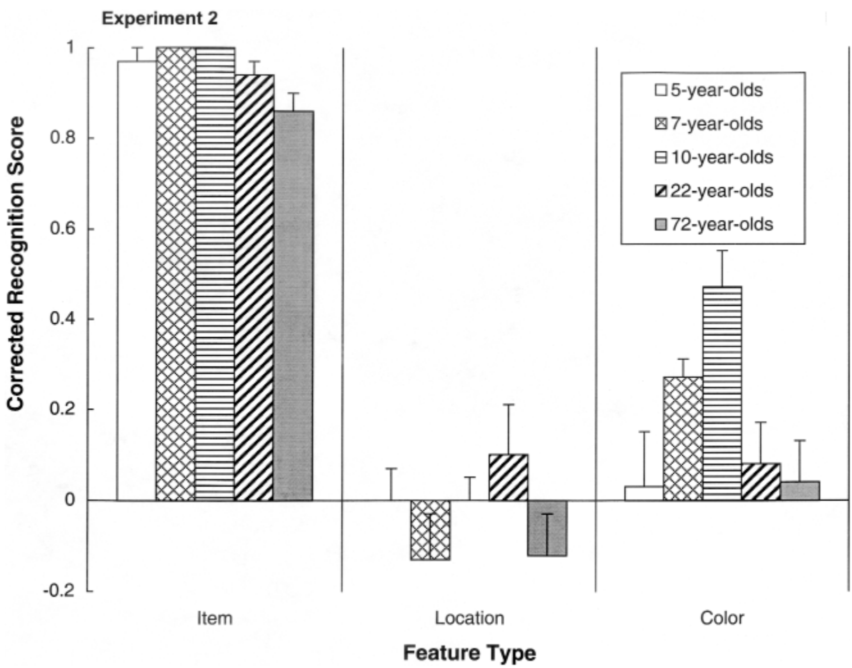



**FIG. 3.** Mean corrected recognition scores on explicit memory tests of each of three features (item, color, and location) for 5-, 7-, 10-, 22-, and 72-year-olds who studied a 30-object array in a game-like task (Experiment 2). Vertical bars represent +1 *SE*.

for the recognition of location feature information as measured on the pencil-and-paper test, which peaked at 19 years under intentional learning instructions.

Taken together with previous findings, these results suggest several points and directions for further research. First, the fact that children's color memory was better than that of adults suggests that the availability of verbal categories does not necessarily help memory under all circumstances (see Schooler, Fiore, & Brandimonte, 1997, for examples in which verbal processing may reduce, rather than help, memory for hard-to-describe experiences). The finding that children's color memory was actually hurt by intentional learning instructions (Experiment 3 vs Experiment 2), which may invoke inappropriate encoding strategies or strategies that are as yet poorly developed, is consistent with this notion. If so, then there may be other features of experience about which children's incidental memory is actually better than that of adults. Alternatively, children may have better color perception—findings by Kovacs and colleagues (Kovacs, 2000, personal communication, January 2001; Kovacs, Kozma, Feher, & Benedek, 1999) suggest that the perception of color peaks at 14 years of age, or color may be more salient to children than to adults (i.e., receive more processing).

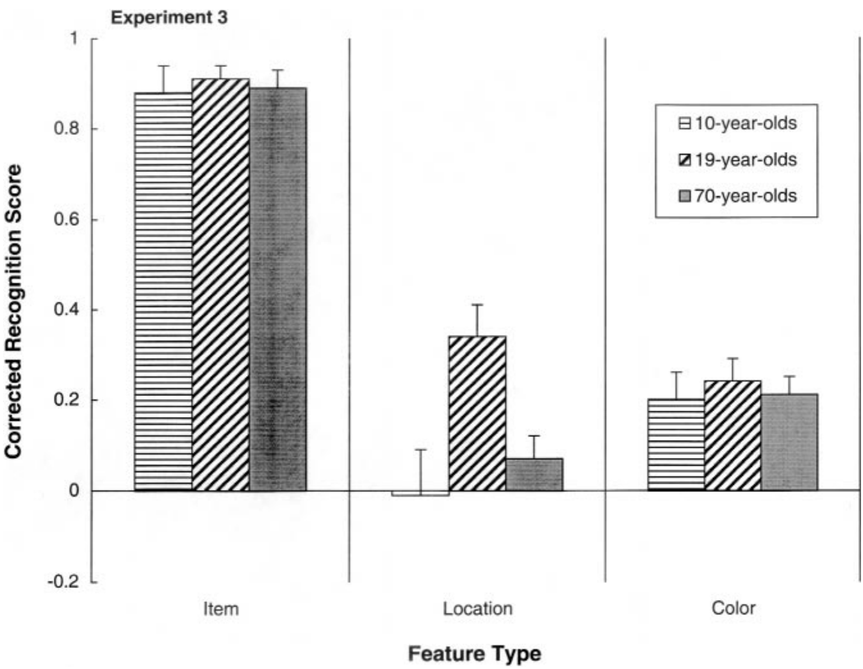



**FIG. 4.** Mean corrected recognition scores on explicit memory tests of each of three features (item, color, and location) for 10-year olds (Experiment 3) and 19- and 70-year-olds (Chalfonte & Johnson, 1996) who studied a 30-object array under intentional learning instructions. Vertical bars represent $+1$ *SE*.

Incidental memory for location was too poor in all age groups to provide a good assessment of potential changes in memory for location across the life span. However, the fact that both children and older adults were less accurate in intentional location memory than young adults (see Fig. 4) suggests that intentional encoding of location information profits from the types of reflective processing, perhaps including verbal coding (e.g., “a saw is in the upper left corner”) or relational processing (e.g., “a saw is above the sun”) of items, that presumably develop into young adulthood and become less effective in older adults.

Finally, we should note that these studies investigated the encoding of feature information as a first step toward clarifying age-related changes in explicit memory. Understanding how features become bound together into complex episodic memories is also critical (e.g., Johnson, 1992; Johnson & Chalfonte, 1994; Mitchell, Johnson, Raye, & D’Esposito, 2000; Mitchell, Johnson, Raye, Mather, & D’Esposito, 2000; Reinitz & Alexander, 1996). These two aspects of episodic memory—memory for features and memories for what features go together (source memory; Johnson, Hashtroudi, & Lindsay, 1993)—often are not clearly separated in the developmental literature. The present findings suggest that (a) a variety of features may have to be systematically investigated before it is possible to make general conclusions about developmental trends in feature memory, and (b) a range of possible combinations of features may have to be systematically investigated before general conclusions can be drawn about developmental trends in memory for bound features. For example, although children’s location memory was poor when it was tested independently of item and/or color information, their location memory is quite good under some circumstances, as when they were cued with item and/or color information in the game *Concentration* (Baker-Ward & Ornstein, 1988). That is, there may indeed be many situations in which children’s memory might be worse than that of adults, but there may also be situations in which it might be no worse, or even better.

Why are some stimuli easier to remember than others? Superior memory for different features or feature combinations is found even in studies of young infants. Adler and Rovee-Collier (1994), for example, found that 3-month-olds remembered the combination of two line segments in the shape of L or T equally long but not as long as when the segments were combined in the shape of a +. Evidently, the crossing in the + makes it especially memorable (Julesz, 1981). Of course, memory for some features and feature combinations that is based on acquired world knowledge should be easy (e.g., Bransford & Johnson, 1973). Such results, along with the present findings, indicate that studies that systematically investigate various features and combinations of features across a wide range of ages would be useful in clarifying the development of explicit memory. Further questions need to be answered as well: Are the features combined during encoding and consolidation and reactivated as a unit? Or are they reassembled during remembering? Are different features and feature combinations forgotten at different rates? And, if so, what are the determinants?

There is considerable neuropsychological, human neuroimaging, and animal lesion work implicating both the hippocampal system and frontal regions in explicit memory (Schacter & Tulving, 1994; Squire, 1987). There is also evidence that older adults' source memory is disrupted more than their memory for individual features (Chalfonte & Johnson, 1996) and that this is at least partly a consequence of disrupted feature-binding processes at encoding (Mitchell, Johnson, Raye, Mather, & D'Esposito, 2000) that are mediated by a frontal-hippocampal circuit (Mitchell, Johnson, Raye, & D'Esposito, 2000). Because the development of the hippocampus and frontal regions continues through childhood (cf. Diamond, 1990) and these regions show an increasing chance of neuropathology with age (Raz, 2000), it seems reasonable to expect explicit memory to assume a Jacksonian, U-shaped function. Nevertheless, even should children turn out to be poorer than young adults at some types of feature binding, the present studies reveal that their memory for some types of individual features is not poorer. Eventually, how features and processing components interact with each other and with the requirements of the task at hand (cf. Johnson & Chalfonte, 1994) should determine the shape of the age-related, explicit memory function in different situations.

## APPENDIX

A List of RGB Values That Describe the Colors Used in the Stimuli of Experiments 1, 2, and 3.

| | Colors | | |
|---|---|---|---|
| Stimulus | R | G | B |
| 1 | 0 | 44564 | 0 |
| 2 | 0 | 57146 | 51903 |
| 3 | 0 | 65535 | 0 |
| 4 | 1951 | 39640 | 55154 |
| 5 | 13107 | 25952 | 64486 |
| 6 | 16253 | 0 | 2884 |
| 7 | 17301 | 36437 | 0 |
| 8 | 19660 | 11796 | 0 |
| 9 | 20185 | 20447 | 0 |
| 10 | 20709 | 0 | 37748 |
| 11 | 24903 | 36699 | 65010 |
| 12 | 28311 | 0 | 17301 |
| 13 | 29097 | 17563 | 0 |
| 14 | 35127 | 262 | 62389 |
| 15 | 35913 | 62651 | 60030 |
| 16 | 41680 | 49544 | 65273 |
| 17 | 41680 | 65535 | 41942 |
| 18 | 44268 | 180 | 7167 |
| 19 | 45874 | 47447 | 0 |
| 20 | 46399 | 0 | 27000 |
| 21 | 46923 | 24641 | 63962 |
| 22 | 54525 | 40894 | 65535 |
| 23 | 56098 | 65535 | 47185 |
| 24 | 58719 | 16515 | 23855 |

## APPENDIX—*Continued*

| | Colors | | |
|---|---|---|---|
| Stimulus | R | G | B |
| 25 | 61340 | 37224 | 0 |
| 26 | 63962 | 23068 | 46923 |
| 27 | 64748 | 262 | 10486 |
| 28 | 65535 | 20709 | 2097 |
| 29 | 65535 | 41680 | 31981 |
| 30 | 65535 | 50593 | 53214 |

*Note*. We used color laser prints of the stimuli that were colored on a Macintosh IIci in the graphics environment of PowerPoint (version 2.01; Microsoft).

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