Developmental Psychology
1994, Vol. 30, No. 2, 218-228

0012-1649/94/$3.00

Development in the Understanding of Perception: The Decline of Extramission Perception Beliefs

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Ancient philosophers, including Plato, Euclid, and Ptolemy, believed in an extramission theory of visual perception, which held that there are emissions from the eyes during the act of vision. Three studies, comparing college and elementary school students, documented a decrease over age in the belief of emissions from the eye during the act of vision and an increase in the belief that vision involved only incoming information. Questions about hearing and smelling were less difficult than those on vision but yielded analogous age trends. The results have implications for cognitive theories of development, for education, and for understanding the child's concept of mind.

In recent years a surge of research has been dedicated to uncovering children's understanding of various mental processes. One part of this research has examined changes in children's understanding of perception. Various studies have suggested that children are considerably more knowledgeable than one would expect at first glance (see Winer, 1991, for a review). From very early ages, children are aware of gaze and of the fact that the gaze of others might serve the function of pointing (Butterworth & Grover, 1988). Their early vocabulary suggests use of terms relating to the act of vision (Bretherton, McNew, & Beeghly-Smith, 1981). And an impressive amount of research has demonstrated that young children have available a number of facts, such as that the eyes must be open to see and that there must be an unimpeded line of vision (see Lempers, Flavell, & Flavell, 1977), that vision occurs through straight lines (Flavell, Green, Herrera, & Flavell, 1991), and that distance affects vision (Flavell, Flavell, Green, & Wilcox, 1980), to cite just a few. These findings are particularly remarkable because they suggest that many of these types of understanding occur in the preschool years.

Despite impressive evidence of the skills of even very young children, there is reason to suspect that in certain respects their understanding of vision might be severely limited. Consider a statement made by Piaget (1929/1969) that ultimately stimulated the present research. Reporting the observations of G. Stanley Hall and of a friend, Piaget noticed that young children act as if their gazes mix when they meet, as if there were emissions from the eyes (Piaget, 1929/1969, p. 48). Although it is not clear precisely what Piaget or others meant by the mixing of looks, he remarked further that these behaviors were analogous to ancient theories of vision, such as that expressed by Empedocles (Piaget, 1929/1969, p. 49).

The concept that there are emissions from the eye during the act of vision has been termed the *extramission* theory of perception, and it is well described in two texts on the history of theories of visual perception: one by Meyering (1989) and an earlier book by Lindberg (1976). Both authors provide ample evidence that ancient thinkers, including Plato, Euclid, Ptolemy, and the influential Muslim scholar Al Kindi, believed that during the act of vision there were emissions from the eye. So powerful and pervasive was this belief that it persisted even after craftsmen learned how to grind lenses during the 13th century and to correct presbyopia (Meyering, 1989, p. 55). Technological advances that could be used to support a pure *intromission* theory were thus ignored by scholars in favor of contemporary theories that continued to rely on a combination of intromission and extramission beliefs. Indeed, there was even doubt in the mind of Leonardo da Vinci, who subscribed to both an extramission and an intromission theory (Lindberg, 1976, pp. 159-160). This theory was presumably put to rest with advances in the understanding of vision contributed by Kepler and Descartes, who proposed a modern understanding of the theory of the retinal image, including the idea that there was a punctiform relation between the image projected on the retina and the seen object that was transmitted to the passive eye through reflected rays of light (see Lindberg, 1976; Meyering, 1989).

Along with these philosophically oriented extramission views of visual perception, there was another tradition acknowledging that there were emissions from the eyes while explicitly admitting also the co-occurrence of intromissions. This was the ancient-world view of the image of the eye as an arrow-shooter of love. The notion of eyes as transmitters and receivers of arrows, daggers, swords, and fiery beams can be traced back at least as far as Aeschylus. (Donaldson-Evans, 1980, chapter 1, provides an excellent, concise history of this "aggressive eye topos" with literary examples of it from the earliest Greek literature through the French Renaissance.) The motif of eyes as a medium of emissions and intromissions of emotions had been a constant theme in Arabic erotic literature, but it was not until the Provençal troubadour poets of the 12th century came into

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We wish to thank Susan Winer, Philip Clark, and anonymous reviewers for their thoughtful comments. Students in many Ohio school districts, including those in Bexley and in the Hamilton local school district, participated in this research, and we sincerely thank them, as well as their teachers and the administrators of the schools. The second study in this report is based on Jane E. Cottrell's doctoral dissertation.

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contact with Arabic poetry that this view of love began to make its way into European literature. In this tradition, love was portrayed as a painful malady in the form of a substance transmitted from the eyes of the beloved to the victim. The Italian lyric poet, Francesco Petrarch (1304–1374), was responsible for providing a view of love that came to be widely accepted from the 14th through the 16th centuries, namely, that a fine substance of some type enters the eyes of the lover from the eyes of the beloved and travels immediately into the heart, where it causes turbulence (see Lind, 1954, Sonnet 3, p. 186). In short, while philosophers were directly professing extramission theories of vision, poets were at least partially relying on the idea of emissions from the eyes to account for the transmission of emotions. Although it is possible that some of these images have formed the basis for contemporary metaphorical expressions, it is not at all clear from the reading of the aforementioned works that the writers were using metaphors. Indeed, it seems more likely that they reflected current beliefs about vision.

The present investigation derived from Piaget's (1929/1969) observation, and its main thrust is to determine whether there are developmental trends in extramission versus intromission beliefs about perception, that is, evidence of a belief in extramissions among children and a decline in this belief with development. The theoretical orientation guiding this study is not that of Piaget, however, for Piaget implied that the child's belief in extramissions stemmed from a tendency to confuse internal psychological processes with external events. This proposition has been challenged to some extent by the findings of Wellman and Estes (1986), which suggest that young preschoolers can differentiate between mental and physical events. Instead, the expected changes in extramission perception beliefs are more consonant with Carey's (1985) theory that changes in cognitive functioning during ontogenesis represent changes in expertise that can be likened to paradigm shifts, that is, radical changes in ways of thinking and theorizing about phenomena (Kuhn, 1962). It would certainly appear, for example, that the change in the history of science, from an extramission to an intromission theory of vision, would be a prime example of such a shift. So too would a similar ontogenetic change represent a radical way of reconceptualizing and theorizing about vision. Informal evidence of the nature of such a shift is the fact that many of the professional psychologists we talked to could not conceive of the child having a belief in an extramission theory of perception or of the ancients sharing such a belief. This is the very hallmark of a paradigm shift (see Kuhn, 1962). (For other work on the connection between ontogenesis and the history of scientific thought, see Strauss's, 1988, edited volume on ontogenesis, phylogenesis, and history.)

Evidence supporting the possibility that children believe in extramission is scanty. Guesne (1985), investigating teenagers' understanding of light, asked subjects to respond to a variety of situations involving a light source, including a magnifying glass and the sun; a flashlight, mirror, and sheet of paper; and a glowing stick of incense. She found some statements generally consistent with extramission beliefs. But she stressed that only a small number of children had such thoughts and dismissed the possibility that the "historic [extramission] model" might be of relevance in studying developmental changes in the understanding of light and vision. Other investigators studying the child's understanding of light, however, have found at least some evidence consistent with extramission beliefs. For example, Kärrqvist and Andersson (1983) reported that from 9% to 17% of their sample of 12- to 15-year-olds expressed some notion of extramission when asked to explain how a person sees a book. Anderson and Smith (1986) found 11% of a sample of fifth graders spontaneously drawing arrows outward from the eyes of a figure to a tree, in response to a question about how light from the sun helps a person see a tree (a shining sun was also presented). An additional 10% had lines connecting the person, the tree, and the sun, with no particular direction drawn, a response pattern that might mask some extramission beliefs. However, the majority of their subjects simply drew arrows from the sun to the tree. Finally, Repp, Callanan, Meier, and Miller (1992) asked elementary school children questions such as "How do you see?" and "How do your eyes work?" They also included a drawing version of the task, in which they presented subjects with a picture of a figure looking at an object or another figure—with a sun overhead—and asked the subjects to draw how the light assisted vision. Although their samples were small, some responses were consistent with extramission beliefs. In summary, several studies provide limited evidence of extramission beliefs, but they also show limited evidence of intromission beliefs.

Study 1

Method

Subjects. The subjects were 52 sixth graders (M age = 11 years; SD = 6.3 months) from an upper-middle-class school district and 49 college students (M age = 22 years 9 months, SD = 3.58 years) who were enrolled in a large, advanced undergraduate psychology course in a major state university.

Procedure. All subjects were given a paper-and-pencil questionnaire that was circulated during class time. On this questionnaire was an extramission question asking, "When people look at something or someone, do you think rays or energy or something else goes out of their eyes?" and an intromission question asking "When people look at something or someone, do you think that rays or energy or something else enters their eyes?"

In this study and in Study 2 other questions were presented as well, such as items that asked subjects whether they or other people could feel someone staring at them without seeing the other person's eyes, for instance, "Do you ever feel that someone is staring at you without actually seeing them look at you, for example, in class, on a bus, in a restaurant, etc.?" The position of these feeling questions was systematically varied.

The questionnaire was presented by the instructor or classroom teacher who asked the subjects to participate in a study. No information was given about the nature of the study or questions to be asked.

Results and Discussion

Table 1 presents the frequencies of subjects, by grade level, agreeing or disagreeing with the extramission statement that something like rays or waves or something else goes out of the eyes. The trend is obvious and statistically significant, $\chi^2(1, N = 101) = 25.1$, $p < .001$: More than half of the sixth graders believed in some sort of extramission as compared with only 5 of 49 college students. On the question asking whether the eye receives input, more than half of the sixth graders exhibited a

Table 1
Frequencies of Subjects by Grade Level Agreeing or Disagreeing With the Extramission and Intromission Questions in Study 1

	Extramission		Intromission	
Grade	Agree	Disagree	Agree	Disagree
Grade 6	30	22	31	20
College	5	44	32	17

Note. For the extramission questions, $\chi^2(1, N = 101) = 25.1, p < .001$; for the intromission questions, $\chi^2(1, N = 100) = 0.22, p > .20$. Varying numbers of subjects across questions indicate nonresponses or unscorable responses.

belief in the intromission theory, with a substantial minority (approximately two fifths) denying that anything enters the eyes. On the other hand, a majority (approximately 65%) of college students supported the intromission theory. The grade difference on the intromission question was not significant, $\chi^2(1, N = 100) = 0.22, p > .20$. In short, the results seem to provide evidence that children tend to believe in extramissions and that this belief declines with age.

Additional analyses showed no correlation between responses to the items directly asking about emissions and intromissions and responses to the items on feeling stares. Moreover, there was no effect that was due to order, that is, no transfer from one type of question to the other. Finally, the age trend on the extramission and intromission items was different from the trends we found on the feeling stares items. Thus, in contradistinction to the developmental trend on the intromission and extramission items, results from the *feeling* questions showed that the belief in feeling the stares of others is evident in the children and, if anything, increases with age. It appears, then, that these different questions tapped belief systems that subjects did not spontaneously connect with each other, although it is possible that such systems can intersect. Data from the feeling questions that were used in this investigation and in the remaining studies in this report are presented in Winer, Cottrell, and Smith (1993).

Study 2

Although Study 1 indicated a decline in beliefs about extramission with age, there were possible shortcomings in the study that provided the impetus for Study 2. For one, the tests were given only in a paper-and-pencil format, raising the possibility that the children or adults might have been less than completely attentive in answering the questions. Furthermore, the age range was limited, with only sixth graders and college students being tested. Of particular interest was the question of whether there are substantial changes before the sixth grade. Finally, the questions themselves had limitations as well. For instance, we asked separately about intromission and extramission beliefs but never asked about the possibility of both together, that is, of the co-occurrence of emissions and intromissions. Moreover, the questions were presented to the subjects without any forewarning or practice.

Method

Subjects. Subjects were 41 first graders (*M* age = 7 years 4 months, *SD* = 5.76 months), 40 third graders (*M* age = 9 years 4 months, *SD* = 7.0 months), 49 fifth graders (*M* age = 11 years 6 months, *SD* = 6.6 months), and 58 college students (*M* age = 20 years 5 months, *SD* = 1.8 years). The children were attending school in a working-class, predominantly White, suburban school district; the college students participated in the study for class credit in an introductory psychology class at a major state university.

Questions and procedure. The questions were read to individual subjects and the answers were recorded. The subjects were told they were to be asked some questions about the senses and were then administered an initial set of five warm-up questions that was in part designed to detect and offset a tendency to acquiesce to the main test questions. Included in this introductory set were three straightforward items that asked subjects whether they touched with their fingers, smelled with their nose, and tasted with their tongue. Two other items of the introductory set, however, asked about patently incorrect possibilities of hearing with your eyes or seeing with ears. These were presented as the second and fourth items in the initial set of five questions. Errors on answers to the initial questions were to be corrected orally as part of the procedure. (Because almost all subjects gave perfect responses to these questions, the results on the introductory items will not be presented in this or in the following study, in which they were also used.)

Two sets of questions, with order counterbalanced, were presented next. One set of five items involved feeling the looks or stares of others or of animals. (As was indicated before, responses to these feeling questions are presented in a separate article.) The other set, the items of direct concern in this report, involved the explicit questions on extramissions and intromissions during perception.

The first three intromission–extramission (I-E) questions began with separate items that asked subjects the following: (a) "When people look at something or someone, do rays, energy, mind waves, or something else go out of their eyes?"; (b) "When people look at something or someone, do rays, energy, or something else go into their eyes?"; and (c) "When people look at something or someone, do you think that rays or energy or something else first goes out of their eyes and then comes back in?" The last question in this set represents an extreme statement of an extramission theory, but one, incidentally, that is very much in keeping with ancient theories. Subjects were also asked what they thought it was that entered or exited the eyes.

Three additional I-E questions were presented that forced a choice among three alternatives: whether rays, energy, or something else goes into the eyes, out of the eyes, or both into and out of the eyes. Notice that these items pit a *both* response against a pure intromission and a pure extramission response. The first of these forced-choice questions was purely verbal. The second, however, was a pictorial item, appearing near the end of the test items. It involved a set of three drawings of a unisex person showing arrows going (a) outward from the eyes, (b) inward toward the eyes, or (c) both outward and inward. Each picture was placed on a separate card, and the subject was asked to choose the drawing that best represented what happens when we look at someone or something. The positions of the cards were randomly varied. Finally, the third forced-choice item was a repetition of the initial forced-choice item and was the last question subjects were asked.

There were several other questions interspersed among the main vision items and before the last forced-choice item. One was a question that was based on one interpretation of Piaget's (1929/1969) observation, "When two people look at the same thing at the same time, do you think their looks mix or meet?" Piaget's observation was actually unclear as to whether the children were staring at one another or at the same object. The question we used seemed to measure a pure extramission belief and to omit the possibility that the children were merely staring into each other's eyes, insofar as the experimenter made refer-

ence to the two lookers staring at an area of the wall (toward which the experimenter pointed).

Two questions asked about the possibility of extramissions during the act of hearing ("When people hear something, do you think that invisible rays or energy or maybe something else goes out of their ears or not?") and smelling ("When people smell something, do you think that invisible rays, or energy, or maybe something else goes out of their nose or not?"). We assumed these items might be less difficult than the questions on vision and thus might break a response set that might have been engendered in responding to the direct I-E questions. Two other possible set-breaking questions asked (a) whether people could see well in the dark without any light and (b) whether they could see through thick solid walls. Finally, immediately before the last verbal forced-choice question on vision, subjects were asked some general questions, such as whether they believed people might communicate without using words, or whether they had ever before thought about questions like the ones administered. Responses to the communication questions will not be presented because they did not shed any light on the issues under investigation.

All but one of the aforementioned questions on vision were presented without prompts or cues. The one exception was the last forced-choice, purely verbal I-E item that asked the subjects to select from among *in, out,* or *both* choices. Before this item, subjects who had given potentially inconsistent responses to the different types of questions were confronted with possible contradictions between their responses to the prior I-E questions and other items. For example, subjects who claimed their looks mixed but who had given only intromission responses to the direct I-E questions were asked to account for the discrepancies between their answers, for example, "How come looks meet if nothing goes out of the eyes?" Note that this type of prompt could lead the subject to change either response.

Results

A 2 (order: main I-E items before vs. after feeling questions) × 2 (sex) × 4 (grade) analysis of variance (ANOVA) was initially used to analyze responses to the eyes question. In this analysis we combined responses to the first four verbal eyes questions: one asking about intromissions, one asking about extramissions, one asking about whether rays first go out and then in, and the first of the three forced-choice items asking about *in, out,* or *both.* (Responses to the last two of these were not included in the initial analysis because these two questions, one involving pictures and the other occurring after a potential prompt, might have yielded responses different from those given to the first four verbal items. However, an additional analysis on combined responses to all six questions produced the same effects as those that occurred in the original analysis.) For this analysis a subject received a score of 1 on each item if the response to the item was correct (intromission) and a 0 if incorrect (any other response). The results of the analysis revealed a significant effect only for grade, $F(3, 167) = 22.87$, $p < .001$. Analysis of the means with the Newman-Keuls procedure revealed a significant difference between college students (M = 2.91 of 4, SD = 1.2) and all other grades: first grade (M = 1.75, SD = 0.91); third grade (M = 1.41, SD = 0.84), and fifth grade (M = 1.51, SD = 0.83). Note that first graders had slightly (but not significantly) higher scores than the older children, a finding that will sometimes appear in other analyses and that might be caused by sample differences or by the possibility that the first graders were more likely than others to respond by chance. Different t tests comparing the obtained mean against what would be expected according to chance (a mean of 2) revealed, in fact, that the first graders' responses were indistinguishable from chance, whereas responses of subjects in each of the other scholastic levels exceeded chance ($ps < .001$). The analysis of frequency data, to which we now turn, also shows a pattern resembling chance responding by first graders on various items.

Responses to the individual questions on eyes are presented in Tables 2 and 3. Table 2 presents the frequencies and percentages of subjects responding correctly or incorrectly to the first three items—the first item asking about extramissions, the second item asking about intromissions, and the third item asking about whether something first goes out and then comes back in. Note the increase in correct answers to all three questions in the comparisons of college students' and the children's responses. However, the college students were far from perfect. For example, approximately 33% of these students believed in extramissions, 12% explicitly denied intromissions, and 24% agreed with the notion that rays and so on first go out from and then return to the eyes! Finally, on the questions asking about rays leaving and entering, first graders appeared to be responding virtually according to chance, as did the fifth graders on the single item asking about emissions.

Table 3 shows frequencies and percentages of subjects giving various responses to each of the three questions that forced the subject to select among the responses of *in, out,* or *both:* the two verbal questions, (the first given without a prompt and the second after the prompt) and the single pictorial item. Several findings are of interest. On the two verbal questions forcing the choice among *in, out,* and *both,* many elementary school children selected the *both* response, whereas many college students selected the correct intromission response. This finding suggests that the developmental trend on the initial items, those asking separately about intromissions and extramissions—as well as responses to analogous questions in Study 1—might be caused by changes over age in a belief that *both* occur. However, there is also an apparent difference between the two verbal questions and the single pictorial question, in that the children gave considerably more pure extramission responses to the pictorial question (range = 44%–61% across grades) than to the two verbal items (range = 12.5%–35% across grades). A more careful comparison of the first and last verbal questions also showed a slight decline in the number of correct responses, which was statistically significant and due to an increase in *both* responses over the trials. This decline possibly reflected the impact of the prior conflict trial, on which an analysis showed that the changes that were due to conflict were in the direction of endorsing emissions! Finally, visual inspection of this table indicates that there is very little evidence of subjects at any age responding according to chance.

Analyses of answers to the questions of what the subjects thought it was that left or entered the eyes provided some interesting information, which we summarize. The preponderance of answers to the question asking what left the eye made reference to energy or mind waves at every grade level (although it should be noted that many subjects at every grade level did not provide us with adequate answers but indicated instead that they did not know, or responded that it was "something else"). Nine of 15 college students who gave an explanation, 8 of 12 fifth graders, 15 of 23 third graders, and 10 of 16 first graders,

Table 2
Frequency (Freq.) and Percentage of Correct and Incorrect Responses to the Three Initial Individual Intromission–Extramission Questions of Study 2

	Rays go out from eyes		Rays enter eyes		Rays go out from then back into eyes	
Grade	Correct	Incorrect	Correct	Incorrect	Correct	Incorrect
Grade 1						
Freq.	21	20	22	19	24	17
%	51	49	54	46	59	41
Grade 3						
Freq.	12	28	24	16	15	25
%	30	70	60	40	38	62
Grade 5						
Freq.	24	25	15	34	31	18
%	49	51	31	69	63	37
College						
Freq.	39	19	51	7	44	14
%	67	33	88	12	76	24

Note. Varying numbers of subjects across questions indicate nonresponses or unscorable responses.

said energy or mind waves were emitted from the eyes. The answers to the "rays in" questions, in which mind waves were not part of the question, revealed that 27 of 40 responding college students referred to light or rays, whereas very few children (1 of 11 responding fifth graders, 1 of 20 third graders, and 2 of 13 first graders) mentioned light, and very few per grade (3 responding fifth graders, 6 third graders, and 5 first graders) mentioned rays. These results support the possibility that children and adults hold different concepts of intromission and extramission perception.

Mixing. Analyses of responses to the question on mixing supported our inference based on Piaget's (1929/1969) report that looks meet or mix when two people gaze at the same objects. Sixty-three percent of first graders, 72% of third graders, 51% of fifth graders, and 40% of the college students claimed that their looks mix. A chi-square comparing subjects believing versus those not believing in mixing across grades indicated a significant effect. What is perhaps most surprising about the data from this question was the large number of college students affirming that their looks mix. Subjects of different ages may have interpreted this question differently, although experimenters took care in explaining the question so as to clarify that it meant looks meeting at a point external to the questioner and subject (an area on a wall) that two people were looking at simultaneously and did not mean two people looking into each other's eyes. Informal observations indicated that the youngest children had no hesitation and little difficulty with this question in comparison with college students, who often evinced puzzlement. In other words, the mixing question appeared to have made more intuitive sense to the young children. Measuring latencies of responses to such questions might be a productive avenue for future research.

Table 3
Frequency (Freq.) and Percentage of Subjects Giving Various Responses to the Three-Choice Questions of Study 2

	Verbal				Pictorial			Repeat verbal			
Grade	In	Out	Both	None	In	Out	Both	In	Out	Both	None
Grade 1											
Freq.	6	7	24	4	6	23	12	3	7	31	0
%	15	17	59	10	15	56	29	7	17	75	
Grade 3											
Freq.	6	5	27	2	2	17	20	2	6	32	0
%	15	12.5	67.5	5	5	44	51	5	15	80	
Grade 5											
Freq.	2	11	25	10	3	30	16	0	17	30	2
%	4	23	52	21	6	61	33	0	35	61	4
College											
Freq.	35	2	17	3	34	7	17	26	4	28	0
%	61	3.5	30	5	59	12	29	45	7	48	

Note. Varying numbers of subjects across questions indicate nonresponses or unscorable responses.

Table 4
Frequency (Freq.) and Percentage of Correct and Incorrect Responses to the Hearing and Smelling Questions of Study 2

Grade	Invisible rays/waves go out of our ears when we hear something		Invisible rays/energy go out of our nose when we smell something	
	Correct answer	Incorrect answer	Correct answer	Incorrect answer
Grade 1				
Freq.	24	17	27	13
%	59	41	67.5	32.5
Grade 3				
Freq.	17	23	24	16
%	42.5	57.5	60	40
Grade 5				
Freq.	38	11	38	11
%	78	22	78	22
College				
Freq.	49	8	52	6
%	86	14	90	10

Note. For the hearing questions, $\chi^2(3, N = 187) = 24.31, p < .001$; for the smelling questions, $\chi^2(3, N = 187) = 12.94, p < .005$. Varying numbers of subjects across questions indicate nonresponses or unscorable responses.

Ears and nose versus eyes. In an initial ANOVA we combined responses to the questions on nose and ears and conducted a 4 (grade) × 2 (sex) ANOVA. The ANOVA revealed a significant effect for grade, $F(3, 178) = 10.8\ p < .001$, and a subsequent Newman-Keuls test showed higher scores for children in the fifth grade ($M = 1.55$ out of 2, $SD = 0.58$) and for college students ($M = 1.75$, $SD = 0.58$) than for children in Grades 1 ($M = 1.28$, $SD = 0.75$) and 3 ($M = 1.03$, $SD = 0.77$).

Frequencies of subjects responding correctly and incorrectly to the individual ears and nose items appear in Table 4. The table reveals the superiority of the older subjects over the younger children.

Data presented in Tables 5 and 6 indicate, for questions on emissions, the frequencies of subjects finding the ears (Table 5) or nose (Table 6) questions more or less difficult than the item on eyes, as well as the number of subjects who pass or fail both items. These tables clearly reveal that the question on eyes was more difficult than those on ears and the nose. (Separate chi-square analyses combining responses across grades and comparing the numbers of subjects finding eyes versus nose items easier and eyes versus ears questions easier were highly significant.)

In summary, the results suggest that (a) the extramission question on vision was more difficult than similar items asking about olfaction and audition and (b) there was evidence of a decline in extramission beliefs regarding smelling and hearing, across age.

Seeing well in the dark and through thick solid walls. As might be expected, there were relatively high numbers of correct responses to questions asking whether one could see well in the dark or through thick walls, both of which were intended as set breakers. Thus on the question about seeing in the dark, there were from 75% (third graders) to approximately 95% (college students) correct answers, and on the question regarding seeing through walls, the range was from approximately 88%

Table 5
Comparisons of Difficulty Levels in Eyes and Ears Extramission Question in Frequencies of Subjects in Study 2

Grade	Response patterns			
	Eyes easier	Ears easier	Fail both	Pass both
Grade 1	3	6	14	18
Grade 3	3	8	19	9
Grade 5	4	18	7	20
College	1	12	7	37

Note. $\chi^2(1, N = 55) = 19.8, p < .01$ (pooling grades and comparing first two columns against chance).

Table 6
Comparisons of Difficulty Levels in Eyes and Nose Extramission Question in Frequencies of Subjects in Study 2

Grades	Response patterns			
	Eyes easier	Nose easier	Fail both	Pass both
Grade 1	5	11	8	16
Grade 3	4	16	11	8
Grade 5	9	23	2	15
College	2	15	4	37

Note. $\chi^2(1, N = 85) = 23.82, p < .01$ (pooling grades and comparing first two columns against chance).

(first graders) to 100% (third graders and college students) responding correctly.

Discussion

The results of Study 2 yielded several findings. First, they confirmed the findings of Study 1, revealing, moreover, that more children than college students believe in extramission processes. Second, they confirmed the hypothesis that was based directly on Piaget's report, that with development there is a decline in the belief that looks mix. Third, there was evidence of an analogous decline in extramission beliefs on audition and olfaction. Fourth, they revealed a tendency for college students to endorse pure intromission beliefs, although a greater number than expected subscribed to a combination of intromission and extramission beliefs. Also there was some evidence that confronting subjects with a conflict between intromission and extramission responses led to an increase in erroneous responses to a question asking about the possibility of intromissions, emissions, or both occurring. It is conceivable that subjects felt obliged to resolve the discrepancy between what were described as competing answers and changed the answer of the one of which they were less certain.

Finally, there were indications that the frequency of extramission responses depended on the question asked. For example, the verbal items that pitted the extramission response against a *both* and an *in* choice provided less evidence for pure extramission beliefs than the questions asking separately about intromissions and extramissions. This difference might be partially a result of a statistical effect, because there were three choices in one type of question versus two in the other. Or it might be because some subjects who answered the single extramission question positively really believed all along that extramissions co-occur with intromissions.

There was also more evidence among children for pure extramission beliefs on the pictorial question as compared with the similarly structured verbal items. It is possible that the very concreteness of the pictorial representation was responsible for the increase in extramission responses. Thus the effect might be explained by assuming that the pictures resemble common graphic renditions of vision (or sighting), even those that occur in comics or movies.

Variations in responses across questions can also be seen in comparing the data from Studies 1 and 2. For example, in Study 1 approximately 10% of the college students agreed to extramission (see Table 1), whereas 33% agreed to the same question in Study 2. There are no simple explanations for this difference. It is possible that sample differences (Study 1 subjects were in advanced, as opposed to introductory, psychology classes) or that differences between the brief written test of Study 1 and the oral test of Study 2 contributed to the greater incidence of extramission responses in the older subjects of Study 2. For instance, college students given the paper-and-pencil test in Study 1 might not have given the questions much thought and responded with negative responses, denying both intro- and extramissions. Reference to mind waves in one question of Study 2 (included because it corresponds to the Augustinian notion of vision) did not apparently influence the outcome, because some recently collected data suggest that many college students err on verbally administered questions that make no mention of mind waves. For example, one study (Chronister, 1993) found that 24% of a college sample ($n = 68$) and 54% of a fifth-grade sample ($n = 52$) affirmed a belief in extramission. None of the questions in the remaining study, incidentally, made reference to mind waves.

Study 3

A major purpose of Study 3 was to investigate and compare responses to questions on different types of perception: seeing, hearing, and smelling. Although there were questions on hearing and smelling in Study 2, the questions were limited in several respects. For example, they only asked about emissions, and they were embedded among the questions on vision. If the findings on the nonvisual modalities reported in Study 2 were valid, then we should find evidence for a decrease in extramission in these areas, across age, even when such questions are not embedded among those on vision.

We were also interested in the effects of varying the order of question presentation. For example, what is the effect of the prior appearance of the presumably less difficult, nonvisual (hearing and smelling) questions on the subsequent performance on the vision questions, and vice versa? A related goal was to examine the consequences of altering the position of the single pictorial question on vision, so that it appeared before or after the questions on looking, hearing, and smelling.

Two hypotheses can be made regarding varying the order of the nonvision (hearing and smelling) and vision questions. On the basis of simple learning and transfer effects, we would assume that the prior appearance of the presumably less difficult questions on ears and nose would facilitate performance on the more difficult items on the eyes. This assumes of course that subjects do not completely differentiate questions on vision from those on hearing and smelling, for example, they see some similarities in the processes involved. In the same manner, if we assume simple transfer effects or generalization, then the initial appearance of the more difficult question on eyes should depress performance on the later appearing items on ears and nose. On the other hand, if we assume that subjects treat vision as qualitatively distinct from the other modalities, we would expect an independence of responses to the eyes versus ears and nose questions. In this case, there should be no transfer.

Expectations for the effects of manipulating the order of the single pictorial question, vis-à-vis the others, parallel the aforementioned expectations on changing order of the eyes items. The initial appearance of the single pictorial question on vision—which we presumed, on the basis of the findings of Study 2, to be the most difficult item on eyes—should cause a decrement in performance on later appearing verbal questions, especially those regarding vision, unless, again, the beliefs tapped by the different questions are cognitively distinct.

Notice that any order effects among the various types of eye items would reveal the stability or lability in one's tendency to give an extramission response. For instance, if we could show that extramission responses to the verbal questions increased because of the prior appearance of the pictorial item, we would have evidence that intromission beliefs are not particularly strong.

Method

Subjects. The subjects were 67 sixth graders (M age = 11 years 7 months, SD = 6 months) from an upper-middle-class, mostly White, suburban community and 98 college students (M age = 21 years 9 months, SD = 2.6 years) who volunteered to fill out the questionnaire in class. We used only older children and adults in this study, because it is most likely that such subjects would demonstrate a gain from having a prior exposure to the less difficult items on the ears and nose.

Procedure. Each subject was presented with a paper-and-pencil test containing (a) a set of five warm-up questions that was identical to the set given verbally in Study 2; (b) a total of nine main questions, three each on hearing, smelling, and looking; and (c) a single, pictorial vision question identical to that in Study 2 that required the subject to select one of a set of three pictures depicting arrows pointing in, out, and both in and out of the eyes, respectively.

The sets of three verbal questions on the eyes, nose, and ears were similar in structure. The first question of each set was an extramission item: "When people look at (hear, smell) something, do you think waves or rays (for smelling, "invisible particles") or anything else goes out of their eyes (ears, nose)?" The second item of each set was an intromission item: "into their eyes (ears, nose)?" And the last item of each set asked about the possibility of both intromissions and extramissions: "both into and out of their eyes (ears, nose)?"

The single pictorial question on the eyes showed subjects the three pictures of the unisex person used in Study 2. Under each picture was a statement: "This shows waves or rays going into the eyes (out of the eyes, or both into and out of the eyes)." Printed instructions located at the top of the pictures asked subjects to look at the drawings and to write an X in the space under the one that best describes what happens when a person looks at something or someone.

With the exception of the pictorial item, questions about each sensory modality were presented in blocks, for example, all the eyes questions were presented together. One of the two main independent variables consisted of the order of the block of the three verbal eyes questions. Thus, in one condition the verbal questions on eyes preceded the two blocks of items on ears and nose, and in the second order the six questions on ears and nose preceded the three verbal questions on the eyes.

The other independent variable was the order of the single pictorial question, which was varied so that in one condition it preceded the entire set of nine questions on eyes, ears, and nose and in a second condition it followed these questions and was the last item to appear.

Results

A 2 (picture position: first vs. last test question) × 2 (verbal eyes questions position: before vs. after questions on ears and nose) × 2 (grade) × 3 (sensory modalities referred to in the questions: eyes vs. nose vs. ears) repeated measures ANOVA was conducted on the number of correct responses to the nine questions (three each) on eyes, nose, and ears. In this analysis the repeated measures were on the questions asking about the three sensory modalities. Notice that in this ANOVA, responses to the single picture condition were not considered part of the dependent variable; instead the position of the pictorial question served as an independent variable. The ANOVA that is reported involved all subjects, although when we restricted the analysis to those subjects who passed the initial five warm-up items, the same effects occurred.

The analysis revealed a significant effect for grade, $F(1, 155) = 54.7$, $p < .0001$; a significant effect for picture position, $F(1, 155) = 25.4$, $p < .0001$; a significant effect for sensory modality referred to in the questions, $F(2, 305) = 39.69$, $p < .0001$; and a significant Sensory Modality × Grade interaction, $F(2, 305) = 3.04$, $p < .05$. No other main effects or interactions were significant.

Analysis of the means showed that college students had higher scores ($M = 2.49$, $SD = 0.82$ out of 3) than sixth graders ($M = 2.04$, $SD = 0.97$), whereas post hoc analysis of the effect due to sensory modalities within questions showed that the eyes questions were significantly more difficult ($M = 1.93$, $SD = 0.98$) than the ears ($M = 2.48$, $SD = 0.84$) and nose ($M = 2.52$, $SD = 0.78$) items. The interaction between sensory modality referred to in the questions and grade revealed that the sixth graders answering the eyes questions had significantly lower scores than subjects in any other combination of grade and question type condition. The interaction did not explain the effect due to sensory modality referred to in the question, as the questions on eyes were significantly more difficult than those on nose or ears for each age studied, nor did it explain the grade effect, as there were significant improvements across grades in response to questions of each modality, eyes, nose, and ears. The effect for picture position revealed that there were fewer correct responses when the picture appeared first ($M = 2.14$, $SD = 0.97$) as compared with last ($M = 2.47$, $SD = 0.81$). Specific chi-square analyses comparing grades and passing versus failing each specific verbal eyes, ears, and nose question were conducted. That is, a separate analysis on grades was conducted for the specific item asking about whether rays went out of the eyes; a second analysis was conducted on whether rays went into the eyes, and so on. We summarize the results of these analyses by presenting the percentages of correct responses, although the analyses were conducted on frequencies.

On the eyes questions, there were significant ($p < .05$) improvements across grades on the questions asking about emissions (43% of sixth graders vs. 68% of college students correct, where a correct response indicated denying emissions) and intromissions (53% of sixth graders vs. 89% of college students correct), but there was no significant grade difference on the item asking about both (55% of sixth graders and 64% college students correct).

On the two ears questions asking separately about intromissions and extramissions, there were relatively high percentages of subjects showing success at each grade level (more than 80%), with no improvement across grades. But there was a significant improvement across grades on the ears question asking about both (change from 61% to 83% correct across grades). Finally, for the nose items, there was a significant improvement across grades on the extramission question (78% vs. 92% correct), no change across grades, but high levels of correct response on the intromission question (85% vs. 92% correct), and a significant improvement across grades on the item asking about both (69% vs. 83%).

A series of analyses was conducted on responses to the single pictorial question. This is an important item because it is the only one in the set of questions that forces a choice among all three possibilities: *in, out,* or *both.* The results appear in Table 7.

As shown, the majority of college students believed that rays go into the eyes, but there was a substantial proportion of college students who believed in *both,* that is, that rays go into and out of the eyes. Very few (approximately 4%) believed only in emis-

Table 7
Frequencies of Subjects Selecting the Three Response Choices on the Single Pictorial Item of Study 3

Grade	Response		
	In	Out	Both
Grade 6	8	18	39
College	58	4	32

sions. Analyses of the effect of order on college students' responses revealed an identical number of *both* and *in* responses when the picture question appeared first, whereas there was about a 3 to 1 ratio of *in* to *both* responses when the picture item was last. In other words, prior appearance of the less difficult verbal items increased the number of pure intromission responses on the later appearing pictorial test.

In contrast to college students, the majority of children endorsed both extramissions and intromissions (i.e., *both*), and a considerable number (almost 28%) endorsed pure emissions. Analyses of the effect of order on responses to the pictorial question showed no effect for sixth graders.

A final series of analyses was conducted to examine the effect of the picture position on responses to each of the nine questions on the various modalities. These analyses were conducted because we had expected that the initial placement of the picture question would selectively influence subsequent responses to specific items. For instance, one would expect that picture order would affect responses to the verbal questions asking about *both,* given that the pictorial item allowed for a response of *both.* Moreover, despite the nonsignificant interaction between sensory modality and picture position in the ANOVA, we expected the picture condition, which asked about eyes, to affect responses to the purely verbal items on eyes more strongly than items asking about nose and ears. That is, we expected most transfer to occur between questions asking about similar modalities. The results of these analyses were generally consistent with the expectations and are summarized. For sixth graders there was only one significant effect out of nine analyses. Initial presence of the picture item created more errors on the verbal question on eyes that asked whether both emissions and intromissions occur. For the college students, however, five out of nine analyses were significant. Initial placement of the picture question created more errors on all three of the *both* questions (those involving eyes, ears, and nose) and on the *out* questions for ears and eyes.

Discussion

The results confirmed the findings of the previous study on the relative ease of the questions on ears and nose compared with those on eyes, and they confirmed, moreover, a developmental effect for each type of item. That is, as grade level increased, there was a tendency for fewer subjects to believe in emissions or the possibility of both emissions and intromissions. However, the developmental trend was strongest for questions on the eyes, because there were more incorrect responses from the children on these items.

What was rather perplexing, however, was an unpredicted combination of an order effect for the placement of the single pictorial question and the absence of an order effect when the position of the verbal eyes questions was varied, the latter outcome suggesting a differentiation between understanding the modalities. Why, in other words, should we expect an order effect for one type of question but not another?

The obvious answer to this question must be based on the likelihood that the pictorial question is so much more convincing to the subjects than the remaining items. This might be because of the graphic quality of the item or it might be because it requires subjects to choose among the three alternatives of *in, out,* and *both.* Notice that there were more *both* responses and fewer *in* responses to the pictorial question when it appeared first, rather than last, among college students. The act of initially giving *both* responses might have induced subjects subsequently to select more extramission responses than would otherwise occur, if for no other reason than to be cognitively consistent.

General Discussion

The results of this study show that, in the transition from childhood to adulthood, there is a decline in extramission beliefs and an increased belief in intromissions when perception is considered. This developmental change is more marked for vision than for other sensory modalities.

There is also considerable evidence that the degree of extramission depends on the type of question asked. For example, verbal questions asking subjects to select from *in, out,* and *both* indicate that younger subjects are more inclined to believe in both processes, and they reveal considerably less evidence for pure extramission than if subjects are merely asked about the possibility of extramission occurring. These variations might be caused by a number of factors already described. For instance, subjects who believe in the occurrence of both intromission and extramission would be likely to give an extramission response when asked about only emissions and to give an intromission response when asked only about intromissions, but they would respond *both* when given that option. There are other possibilities. For example, the choice of *both* might be selected because subjects are conservative and want to select the option that optimizes the opportunity for them to be correct. Or some subjects might also choose *both* because it requires less of a discriminative effort in a situation of uncertainty.

The extent to which there was a belief in extramissions also depended on the presence or absence of the pictorial item. In particular, the children in Study 2 were much more inclined to give pure extramission responses to the pictorial item compared with the similarly structured verbal items. We attribute the greater degree of difficulty of the picture item to the fact that it presents a graphic representation that perhaps resembles other renditions of vision that children and adults commonly experience. That is, representations of vision commonly involve showing arrows projected outward from the eye.

Finally, there was evidence of differences when we compared the results on the extramission questions of Study 1 and 2. There are many possible explanations for the difference, including the fact that the questions were worded slightly differently and the samples were different across the two studies. Another

intriguing possibility, though, is that social context of the second study permitted more thoughtful responses on the part of subjects, that is, less of a tendency simply to give automatic negative responses to all I-E questions. Recall that in Study 2, not only were the main questions presented orally, but they were preceded by questions designed to break sets to respond positively or negatively.

The findings certainly provide more evidence for extramission beliefs than was reported by other investigators, such as Kärrqvist and Andersson (1983), Guesne (1985), Anderson and Smith (1986), and Repp et al. (1992). Note that these studies used different kinds of questions and sometimes examined subjects of different ages from the children in our studies. They often used a more open-ended type of questions, which revealed limited evidence of both intromission and extramission. Moreover, their focus was often on the relation among the perceiver, a light source, and an object of vision, whereas ours was focused on vision.

One question that can be raised about the results concerns the extent of the children's belief in the responses they gave. It might be argued, for instance, that the subjects were influenced by the question and gave responses that otherwise would be foreign to them. To be sure, it is not very likely that children spend much of their lives thinking about the nature of vision and visual processes, and the implications of the questions might have led them to state certain beliefs that they otherwise might not have expressed. These prospects have been raised by Piaget (1929/1969) who, in analyzing responses of children, distinguished between romancing and several types of conviction. In admitting the possibility that children might invent solutions during the course of an experiment, however, Piaget pointed out that such a solution "is not invented from nothing. It implies previously formed schemas, tendencies of mind, intellectual habits, etc." (Piaget, 1929/1969, p. 13).

Although it is possible that children had not given much thought to the issues involved in the questioning before the study, we have anecdotal evidence suggesting that they have a strong conviction in extramission-type beliefs. Repeatedly, in classroom debriefing sessions, we find that students vigorously argue with us when we inform them that there are no emissions from the eyes during vision. In a related instance, one of the authors of this study was trying to describe the field of psychology to a group of elementary school children and to differentiate how psychology differs from physics (in assisting a classroom teacher who was trying to explain the Dewey decimal system). The elementary school students were informed that psychologists like to study the thinking and perception of children as well as what children know about thinking and perception. The psychologist then went on to describe some of the findings of the present study and, in the process, let it slip out that of course nothing comes out of the eyes. Instantly, several children raised their hands and objected.

We have other interesting anecdotal data as well, including the embarrassing fact that some of the psychology students we trained to do the testing, as well as many of our subjects, asked us to tell them the correct answers to our questions. Another piece of anecdotal evidence occurred when a sixth-grade girl selected all three choices on the picture item (failing to follow directions), and then continued to write an explanation underneath each picture, although no explanation was called for. For the arrows-in picture, she articulated the process of vision beautifully, describing the inversion of the image on the retina and the subsequent projection of the information through the optic nerve to the brain. It appeared to be an explanation worthy of a knowledgeable undergraduate student. But then she went on to describe in the other pictures how images were projected out of the eyes.

How then do we explain the results of this study? We assume that early in development children believe in both intromission and extramission and that with development there is a shift toward a belief in intromission. The belief change can be represented as a change from naive or intuitive beliefs (or theories characteristic of the novice) toward theories that are currently accepted by science (Carey, 1985; see Vosniadou & Brewer, 1992, for different possibilities). Early extramission beliefs might stem from exposure that children have to representations of visual-like processes (e.g., the X-ray eyes of Superman), or they might represent a generalization from a constructivist belief that psychological processes originate from the shelf. As children become educated or more cognitively mature, their beliefs presumably then shift toward theories consistent with an individual's scientific understanding of vision. The results are also consistent with more traditional developmental interpretations, such as the notion that children first egocentrically learn or understand by making reference to the body and then generalize their understanding to the external world.

The findings of this study have several general implications. As was noted in the introduction, there has been much work documenting the young child's knowledge of perception, and indeed, there has been much theorizing on the preschool child's developing theory of mind and of mental processes. Findings on the developing theory of mind are consistent with current trends in developmental psychology showing that children are substantially more advanced than we would expect on the basis, for example, of Piaget's (1929/1969) theory. The work represented in this study suggests that children (and in some cases college students) are amazingly naive with respect to understanding some of their basic perceptual and, by implication at least, mental processes. The work also possibly challenges some specific assumptions about children's conceptions, such as Chandler's (Chandler & Boyes, 1982) belief that children have a naive realism that is based on a ballistics theory of perception, according to which they are bombarded with information from without. The results of the present study suggest that although children may have a ballistics theory, the direction of the ballistics is open to question. Finally, our findings may have possible educational implications. Many of the extramissionists in our study were beyond the age at which vision is taught. Thus the results imply that teaching children scientifically accurate theories does not necessarily erase their misconceptions. Teaching children, for example, about an intromission theory of perception apparently does not totally abolish an extramission conception. Rather it becomes important not only to teach the correct information but also, in the process, to dispel myths that are part of children's belief systems. Of course, to dispel these myths, we must know in advance what they are.

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Received May 15, 1992
Revision received June 10, 1993
Accepted June 30, 1993 ■