

Conditions Affecting Beliefs about Visual Perception among Children and Adults

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Children and adults were tested on their beliefs about whether visual processes involved intromissions (visual input) or extramissions (visual output) across a variety of situations. The idea that extramissions are part of the process of vision was first expressed by ancient philosophers, including Plato, Euclid, and Ptolemy and has been shown to be evident in children and in some adults. The present research showed that when questions about vision referred to luminous as opposed to non-luminous objects, under certain conditions there was some increase in intromission beliefs, but almost no corresponding decline in extramission beliefs, and no evidence of transfer of intromission responses to questions referring to nonluminous objects. A separate study showed that college students, but not children, increased their extramission responses to questions providing a positive emotional context. The results are inconsistent with the idea that simple experiences increase or reinforce a coherent theory of vision. The results also have implications for understanding the nature of beliefs about scientific processes and for education. © 1996 Academic Press, Inc.

Over the past several years investigators have shown an interest in how children develop concepts and ideas in various areas, often focusing on science (see Chinn & Brewer, 1993). The impetus for much of this work is an idea that has proven to be a challenge to traditional structural theories of development, namely, that development of particular beliefs is not necessarily linked to particular stages of development, or indeed, to particular processes that are stage or age dependent (see Vosniadou & Brewer, 1987). For example, it has been proposed that during development there is a shift from naive to expert reasoning that can occur at different ages (Carey, 1985, 1988). In fact, Carey (1985) has de-

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scribed such shifts as changes in structure that might be likened to paradigm shifts that have occurred in the history of science.

Theory and research on the development of belief systems have revealed many issues. One issue concerns the processes through which such beliefs develop. What is the source of such beliefs and the mechanism of their development? Are they acquired by tuition, for example, or by induction or generalization from different experiences, or indeed, at least partially through developing logic? With regard to the nature of such belief systems, do seemingly advanced belief systems represent mature, coherent, tightly woven, and ultimately well-integrated theories, or do they consist of correct chunks of knowledge coexisting with fragmented bits of incorrect information (see Vosniadou & Brewer, 1992)?

The present investigation deals with the development in children and adults of part of the well-known scientific theory that holds that vision is caused by input to the eyes (and does not involve output from the eyes). While these notions may seem obvious to scholars today, and thus would not seem likely to be misunderstood by either children or adults, incorrect theories once dominated academic explications of the nature of vision. Some of the earliest and best-known scholars, including Plato, Euclid, Ptolemy, and the eminent Muslim thinker, al Kindi, subscribed to an extramission notion of perception, which held that the act of vision involves emissions from the eye. Plato, for example, believed that essences leave the eye, coalesce with an object, and travel back to the eye (see, Lindberg, 1976, for perhaps the best review of such theories; see also Lindberg, 1992; and Meyering, 1989, for treatments of the history of vision).

Several investigations of the understanding of vision (Anderson & Smith, 1986; Eaton, Anderson, & Smith, 1984; Guesne, 1978, 1984, 1985; Kärrqvist & Andersson, 1983; Repp, Callanan, Meier, & Miller, 1992; Shapiro, 1989) have focused on children's or adolescents' conceptions of light and seeing. Subjects in these studies generally showed a poor understanding of light and its function in vision; for example, they often lacked correct, i.e., intromission theories. In some cases there was also evidence of extramission beliefs (Anderson & Smith, 1986; Kärrqvist & Andersson, 1983; Guesne, 1984; 1985).

Few developmental investigations, however, have specifically focused on an analysis of intromissions and extramissions as processes of vision. Piaget (1929) was perhaps the first to identify the possibility that young children might believe in extramissions, when he cited observations by G. Stanley Hall and a friend indicating that children believed that their looks could mix. He (Piaget, 1974) later claimed to have found convincing evidence of extramission beliefs in children, although his report of this finding is apparently unpublished. In fact the complete reference to the unpublished papers is included only in the French version of the text (Piaget, 1971) as studies by Piaget and Papert (1971) and Piaget and Lannoy (1971). In any event, his conclusion about beliefs in extramissions appears to have been challenged by Guesne (1984, 1985), who reported findings that might be considered as evidence for extramission beliefs, but who ultimately dismissed the possibility. However, Cottrell and Winer (1994), con-

ducted an extensive investigation of intromission–extramission beliefs in children and adults, showing that on a number of measures intromission beliefs increased and extramission beliefs decreased with age. Many adults, though, also demonstrated extramission beliefs.

The first three studies in this report deal with some of the variables that might be related to the presence and acquisition of correct intromission beliefs about vision and, conversely, with possible factors that might account for the decline of incorrect extramission beliefs in development. In these studies we asked about intromission–extramission beliefs in questions making reference to luminous objects, namely, shining lights, as opposed to reflective, non-light-emitting objects. Demonstrating a variation in intromission–extramission beliefs across such situations could provide information about the source and/or mechanism through which children develop correct intromission ideas and abandon incorrect beliefs about extramission. We hypothesized, for example, that people’s beliefs in the importance of visual input would increase when they are asked about “seeing” in reference to a shining light. Subjects might then generalize these intromission views when answering questions about reflective objects. Such a process would occur if subjects inferred or induced a principle of intromission from experience with luminous objects. However, the probability of subjects making such an induction would seem to be remote given that the ancient philosophers failed to derive the correct intromission theory from their experiences with luminous objects. Thus, it would be more likely that the experience with luminous objects would remind the subjects of intromission concepts that they had been taught when learning about vision and light. We were also interested in whether we would be able to find extramission responses to questions that made reference to luminous objects. Such a finding would constitute evidence for the strength of extramission beliefs.

Thus one goal of our studies was to investigate the presence of intromission–extramission beliefs across stimulus situations that should encourage intromission interpretations to different degrees, in order to explore possible mechanisms for the development of such beliefs and in order to test the strength of extramission concepts as well. Another goal was to explore the specific nature of subjects’ intromission–extramission notions. This goal was addressed in two ways. First, we extensively questioned subjects about the logic and nature of their beliefs. Second, in the last study to be presented we employed an experimental manipulation to test a particular hypothesis about the meaning of the subjects’ intromission and extramission beliefs. In this last study we examined the possibility that what appear to be extramission beliefs might in fact represent statements about processes other than visual ones.

STUDY 1

Subjects were asked questions in reference to a shining light bulb, a balloon, and an ambiguous “something.” In this study, unlike the two that follow it, the

referents were only described in the questions or presented pictorially, that is, they were not physically present.

Method

Subjects. Subjects were 34 boys and 31 girls in the third grade (mean age = 9.4 years, range = 8.8 to 10.5 years), 33 boys and 19 girls in the fifth grade (mean age = 10.9 years; range 9.9 to 12.3 years), along with 40 male and 22 female college students (mean age = 20.7 years; range = 18.6 to 43.7 years). The children were attending a school in a middle-class neighborhood; the college students participated for course credit.

Questions, design, and procedure. Subjects were initially presented with a set of five questions designed to break an acquiescence set. Of the five questions, three had obvious “yes” answers (e.g., “Do you touch with your fingers?”) while two, the second and third questions presented, had obvious “no” answers, (e.g., “Do you hear with your eyes? ...see with your ears?”). Responses to these items and to an additional set breaking question that appeared in the middle of the test questions will not be presented since almost all subjects answered them correctly.

Subjects were then instructed that we were going to ask them some questions about how we see things and that we were interested in how the senses are used to learn about other things or people. Three main questions followed: (1) an extramission question, “When we look at _____ (a shining light, a balloon, or “something”) do rays, or waves or anything else go out of our eyes?” (2) an intromission question, “...do rays, waves or anything else go into our eyes?” and (3) a three-term, forced-choice question, “...go into our eyes, out of our eyes, or both into and out of our eyes?” The three-term question was used because it is possible that extramission beliefs co-exist with intromission ones, as in Plato’s extramission theory. Approximately half the subjects initially received the extramission item followed by the intromission question; for the remaining subjects the intromission item preceded the extramission question. The three-term, forced-choice question appeared last.

For each subject, the three main test questions made mention of only one of three visual referents: a shining light, a balloon, or an ambiguous “something.” That is, each subject received questions making reference to one visual referent. The wording for the balloon and shining light bulb items was, “When we look at something like a balloon (shining light bulb) does....?” The wording for the “something” item was, “When we look at something does....”

Finally, we also varied the format of the last question, i.e., the single item forcing the subject to choose among, “in,” “out,” and “both.” For approximately half the subjects this question was purely verbal. For the remaining subjects, the question made reference to line drawings. The drawings presented three profiles of a face: one with arrows pointing toward the eye, another with arrows pointing away from the eye, and a third with arrows going both toward and away from the eye. For those subjects receiving questions referring to the shining light bulb or the balloon, the corresponding referents were also pictured in line drawings. The

drawings for the two referents were identical in shape, the only difference being the addition of short irradiating lines for the light bulb and a string for the balloon. Subjects in the "something" condition were shown only the three profiles of a face and arrows as described above, with no referent depicted. For each of the pictorial items, subjects were asked to select the picture showing what happens when we look at an object. Previous work by Cottrell and Winer (1994) suggested that subjects might give more extramission responses to the pictorial than to the purely verbal questions.

We also extensively probed to test the nature and extent of subjects' beliefs about vision. These probes consisted of a series of questions that followed each of the two main items asking about intromission, extramission, and the third main item forcing a choice among three possibilities. For the intromission and extramission questions these probes were administered only if the subject gave an affirmative answer to the question of rays or the like entering or leaving the eye, respectively. Among these items were several critical questions. Thus, if the subject answered either the intromission or the extramission question affirmatively, we asked what it is that comes into or leaves the eyes; whether it starts from outside the eye and comes in, or inside the eye and goes out; whether we would still be able to see if nothing came into or went out of the eyes; and whether what comes in or goes out of the eye helps us to see or understand what we see. The probe questions for the last, three-term, forced-choice item were used only if the subjects answered "both." In this case, we asked whether what comes into the eye is the same as what goes out, which happens first, something coming in or going out of the eyes, and what it is that goes into and out of the eyes. We also asked whether we would still be able to see if nothing came in but something went out of the eyes or if something came in and nothing went out of the eyes.

Results

A 3 (Grade) \times 3 (Question Referent: balloon, light bulb, or something) \times 2 (Order: extramission versus intromission first) analysis of variance was conducted on the number of correct responses to the three main questions. (A separate analysis showed that sex had no effect). An intromission response was defined as a correct response and given a score of one, while all other responses received a score of 0. The analysis revealed that only an effect for grade was significant, $F(2,164) = 12.5, p < .0001$, and the analysis of means indicated that scores for subjects in each of the elementary school grades were significantly lower ($M = 1.6$, out of a possible maximum score of 3 for third graders; $M = 1.5$, for fifth graders) than scores for the college students ($M = 2.2$). Surprisingly, and contrary to our predictions, the object referred to in the questions had absolutely no effect, $F(2,164) = 1.58, p > .20$.

A separate 3 (Grade) \times 3 (Referent: balloon, light bulb, or something) \times 2 (Question Mode: verbal versus pictorial) \times 2 (Sex) analysis of variance was performed on responses to the single, three-term forced-choice question. In the

analysis, responses to the three-term item were assigned a score of 1 for intromission or 0 for anything else (extramission or both). The analysis showed the expected grade effect, $F(2,149) = 6.55$, $p < .002$, with college students ($M = .56$) outperforming fifth ($M = .27$) and third graders ($M = .28$). There was also a significant interaction between referent and question mode, $F(2,149) = 3.19$, $p < .05$. Analysis of the means showed that the highest mean occurred on the verbal item referring to something ($M = .59$). This mean was significantly higher than the means for pictorial-something item ($M = .22$), the pictured shining light bulb ($M = .29$) and the verbal item making reference to the ball ($M = .31$). It was also nearly significantly higher ($p < .08$) than means on the remaining items.

Answers to the probe questions suggested that most subjects who affirmed intromission had correct beliefs about visual processing. For instance, on the question asking whether we would be able to see if nothing came into the eye, approximately 79% of these subjects correctly answered in the negative when we combined data from all grades. On a separate question, asking whether incoming rays begin inside or outside the eye, most subjects were correct (93% college, 76% fifth graders, and 86% third graders).

Answers to the probe questions on extramission and on the "both" items, showed considerable evidence for extramission beliefs, although many more subjects at each grade affirmed a belief in intromission than in extramission. Subjects who affirmed a belief in extramission on the extramission items were asked, "If nothing came out of the eye could we still see?" Out of 60 extramissionists, the majority ($n = 35$) denied that we would be able to see if nothing came out of the eye.

These various extramission interpretations were not equally divided across grades, however. Table 1 shows the number of extramission responders who believed they could or could not see if no rays exited the eyes, at each grade level. Notice the presence of a disproportionate number of extramission responses among fifth graders. (The same trend of an increase in extramission responses across the early grades has sometimes occurred in other studies; see Cottrell & Winer, 1994). The vast majority of these extramission fifth graders believed that if nothing exited the eyes they would not be able to see. The difference between subjects in the fifth and other grades was statistically significant.

It might appear that the extramissionists who did not claim the necessity of

TABLE 1

Percentages of Extramission Responders at Each Grade Level Believing They Could or Could Not See If No Rays Exited the Eyes, in Study 1 on the Extramission Question for the Three Referents

Grade level	Could see	Not see
Third	59%	41%
Fifth	21%	79%
College	60%	40%

extramissions for vision ($n = 25$, cf. Table 1) attributed no role to extramission in vision. However, Table 2 shows that in response to the question asking whether what went out of the eye helped them to see or understand what they saw, all the children who affirmed extramissions responded that emanations from the eye aided vision, as did 12 of 15 extramissionist college students! Analysis of responses to the question asking about the origin of the outgoing rays showed that 48% of the elementary school versus 27% of college student extramissionists believed that the outgoing rays originated inside, as opposed to outside, the eye.

Among those subjects who answered that "both" intromissions and extramissions occurred on the three-part, forced-choice item, there was evidence for both intromission and extramission interpretations. In one question, we asked which happens first, "in" or "out." Of the total number of subjects affirming that "both" occurred ($n = 95$), the majority at each grade level claimed "in" (approximately 61% when data from all grades were combined, with no significant grade differences). The size of the minority (almost 39%) claiming "out" was considerable, though. On the item asking if we could see if rays or the like only went in but not out, a bare majority answered "yes" (approximately 56%, with grades combined). When we asked whether vision would be possible if rays only went out and nothing came in, most fifth graders (74%) and college student (83%) "both" responders answered "no," but the third graders were almost as likely to answer "yes" (48%), as "no."

Discussion

The results replicated the development trend, reported in earlier research (Cottrell & Winer, 1994), of increasing intromission and decreasing extramission responses as a function of age. Nevertheless, the adults were far from perfect. In fact, one of the more surprising findings in the present study was the large number of college students whose performance was imperfect on the three questions asking about vision. Cottrell and Winer (1994) also found similar failure rates among adults, but their study had no conditions designed to facilitate intromissions.

One of the main goals of this study was to determine if the nature of the object mentioned in the question might influence subjects' beliefs about intromissions and extramissions. The results unexpectedly indicated no differences when re-

TABLE 2

Percentages of Extramission Responders at Each Grade Level Believing That Extramissions Did or Did Not Help Seeing or Understanding, in Study 1 on the Extramission Question for the Three Referents

Grade level	No help	Help
Third	0	100%
Fifth	0	100%
College	60%	40%

flective as opposed to luminous or unspecified referents were mentioned in the question. These results suggest that beliefs are not easily influenced by reference to different environmental cues. Moreover, the fact that extramission responses occurred in response to questions referring to a lit bulb suggests the robustness of extramission beliefs.

Another major goal of the study was to explore the logic and nature of subjects' beliefs about intromissions and extramissions. Certainly the most striking finding from this set of analyses was that all of the children who expressed a belief in extramission claimed that emanations from the eyes facilitated vision or understanding, as did several college students. Another striking finding was that the majority of fifth grade extramissionists believed that if nothing came out of the eyes they would not be able to see. Nor did we anticipate the number of subjects who stated that outgoing rays originated within, as opposed to outside of, the eyes. Moreover, similar incorrect ideas were also found among sizable minorities of intromission responders.

The increase in extramission responses across the early grades deserves comment. We have frequently found this trend in published (Cottrell & Winer, 1994) and unpublished studies although it was not always significant. It might be attributable to any of a number of factors: perhaps some cognitive maturity is required to believe in extramission; perhaps young children respond more concretely than slightly older children and think of things like the sun coming into their eyes in response to our questions; and various cultural experiences, such as with Superman's X-ray vision, might also play a role.

Finally, the interaction between verbal-pictorial presentation and referent object suggested that the highest scores were for the verbal item making reference to something. Notice that this item was the most abstract in that it was presented in purely a verbal manner and with no specific referent. The results thus suggest that extramission responses might vary as a function of the extent to which questions involve concrete versus abstract representations of vision. This explanation is admittedly ad hoc, though, and warrants further investigation.

STUDIES 2 AND 3

One obvious limitation of Study 1 was that the various referents in the questions were only described or presented pictorially. It is therefore possible that direct experience with real objects of varying luminosity or potential luminosity might affect beliefs about vision. Studies 2 and 3 addressed this hypothesis by comparing responses to questions referring to an actual shining light bulb, the same bulb turned off, and a white, styrofoam ball.

Another difference between these studies and the first investigation was a test for order effects. Thus, unlike Study 1, in which each subject received test questions referring to only one referent, each subject in Studies 2 and 3 received questions referring to all three referents, with the order varied. This allowed us to investigate the possibility of transfer among responses from one visual referent to the others.

We expected that the initial presentation of questions about the lit bulb would engender an increased number of intromission responses and a decreased number of extramission interpretations. Indeed, we thought that it would be practically impossible to give anything but an intromission response to a lit bulb. We also hypothesized that an intromission response to the question referring to the lit bulb would generalize to items involving the nonluminous objects. This type of generalization would be expected if subjects had previously learned, but subsequently forgotten, that vision was caused by light making an impression after entering the eye. The lit bulb would certainly prove a reminder of the input of light and thus stimulate previously learned interpretations of vision that could be applied to the nonluminous referents.

Method

Subjects. The subjects consisted of 51 third graders (Mean age = 8.9 years, range = 8.2–10.1 years, 38 5th graders (mean age = 10.9 years, range = 10.0–11.8 years), and 84 college students (mean age = 20.4 years, range = 19.9–36.3 years). It was planned at the outset of the experiments to combine the results of third and fifth graders, although in the analyses presented they are often treated separately. The children were attending a parochial school located in a working class neighborhood. Subjects were relatively evenly divided by sex, except in the college sample of Study 2 where males outnumbered females by about a ratio of 2:1.

Materials. The materials consisted of a 40-W light bulb, mounted on a board with a switch, and a white styrofoam ball, approximately 4 inches in diameter, mounted on the same board. The white styrofoam ball was used to approximate the light bulb in size, shape and brightness. All objects were visible to subjects throughout the entire testing procedure.

Questions and Design of Studies 2 and 3

In each of Studies 2 and 3, which were conducted nearly simultaneously, the same set of 9 core questions was presented to each subject. The questions were formed by cross-matching each of three types of question, intromission, extramission and three-part, forced-choice (“in,” “out,” or “both”) with each of three referent objects: an actual shining bulb, the same bulb, unlit, and a white ball. The questions were administered as Study 1. After receiving an initial series of the same set-breakers used in Study 1, subjects were instructed that we were interested in how they see, and they were then presented with intromission–extramission questions asking, “When you look at a shining light bulb (ball) does....?”

The main difference between Studies 2 and 3 was in the ordering and blocking of the questions. In Study 2 we divided the questions into three blocks of three questions, with the first block consisting of a series of three intromission questions (...does anything...go into your eyes?), a second block of three extramission questions (...out of your eyes?), and the third block of three, three-part (“into, out

of or both into and out of your eyes”) forced-choice questions. Within each block, one question referred to the shining light bulb, another to the unlit bulb and a third to the ball. Thus as we progressed from one question to the next, we changed the referents in the questions. Questions within each of the three blocks were presented in one of two orders, with each subject receiving only one order: (1) lit bulb first, followed by unlit bulb and ball; or (2) ball first, unlit bulb next, and lit bulb last.

In Study 3, the questions were also divided into three individually presented blocks of three items, but here the questions were blocked by referent object. Thus three questions on the lit bulb were presented in a block, three on the unlit bulb were presented in another block, and three on the ball were presented in an additional block. Within each block, questions were ordered so that the intromission question came first, the extramission question second, and the three-term, forced-choice item last. The questions in this study (and in Study 2 as well) were specifically ordered with the intromission items first so as to maximize the possibility that intromission responses would generalize to subsequent items, especially when the lit bulb question was first.

The three blocks of questions used in Study 3 were presented in one of two orders: (1) lit bulb block followed by unlit bulb and ball blocks, (2) ball items followed by unlit bulb and lit bulb blocks. Therefore, in one order the three questions with the most obvious cue about intromission, the lit bulb, came first and the questions with the referent presenting the least obvious cue for intromission, the ball, came last. In the other order, the sequence was reversed. Subjects received only one order.

The design of Study 3 was expected to lead to a smaller referent (lit, unlit bulb and ball) effect than the design of Study 2. Thus, whereas in Study 2 we changed referents eight times, i.e., with the presentation of each new question, in Study 3 we changed the referent objects twice, i.e., between each block of three questions.

Finally, a series of probe questions was presented after the last item given in each study. These probe questions addressed the subjects' responses to the last three-term, forced-choice question. Subjects were thus asked, “Does what goes into (out of) our eyes help us see...?” “If nothing went into (out of) our eyes could we still see...?” We also asked where visual input and output originated. After answering a set of such probe questions subjects were asked to respond in their own words to two or three other questions which depended on their previous responses, such as: “What do you mean by something going into (out of, both into and out of) our eyes? What happens?; or Why did you give different answers to...?”

Results

Results for both studies were initially analyzed with a repeated-measures analysis of variance, using the number of correct responses as the dependent variable. To be scored as correct, subjects had to affirm intromission on the

question asking about visual input and on the three-term, forced-choice item and to deny extramission on the question asking if anything goes out of our eyes.

In Study 2, whose design presumably maximized the impact due to referent, a 2 (Order: lit bulb first and ball last, versus ball first and lit bulb last) \times 3 (Grade) \times 2 (Sex) \times 3 (Referent Object: lit bulb, unlit bulb and ball) repeated measures analysis of variance, with repeated measures on referent object, showed a significant effect for grade, $F(2,45) = 4.65$, $p < .02$, and a significant effect for order, $F(2,45) = 4.14$, $p < .05$. Analysis of the grade means showed lower scores for children in the third grade than for college students ($M_s = 1.5, 1.8, \text{ and } 2.3$, for third graders, fifth graders and college students, respectively). The order effect revealed that when the lit bulb appeared first, there were significantly fewer correct responses ($M = 1.6$) than when the ball appeared first ($M = 2.1$). In other words, the initial appearance of the lit bulb seemed to depress the number of correct responses on subsequent questions, precisely the opposite of what was expected!

Because the order effect was not as anticipated we conducted additional analyses of individual questions within the first block of three questions (intromission or "in" questions) subjects received, comparing responses to the lit bulb questions when they were the first versus last the items to appear and, in a separate analysis, comparing responses to the items referring to the ball, when they were the first versus the last questions to appear.

The analysis in which responses to the lit bulb were the dependent variable showed that order had no effect, with most subjects at each age responding correctly. Among the children, when we combined grades, approximately 69% affirmed intromission when the lit bulb was first compared to approximately 86% when it was last, $\chi^2(1, N = 33) = 1.31$, $p < .26$.

However, when responses to the questions referring to the ball were analyzed, the number of intromission responses varied significantly as a function of order for the children. Thus the children more frequently gave intromission responses to the question on the ball when it was the first item to appear (64%, 9/14) as compared to the last item in the set (26%, 5/19) ($\chi^2(1, N = 33) = 4.76$, $p < .03$). The outcome for the adults was in the same direction, although not statistically significant: Seventy-five percent of the adults were correct when the ball item was the last of the block versus 92% correct when it was the first. Thus, the initial appearance of the lit bulb question depressed children's performance within the first block of trials.

Because of the order effect we also examined the number of correct and incorrect responses to the ball versus the lit bulb condition, when these were the first questions to appear. The results showed that the vast majority of subjects in both conditions responded correctly. Variations in referent thus had no effect on the first trial.

In Study 3, correct responses to the main questions were also analyzed in a 3 (Grade \times 2 (Order: lit bulb-unlit bulb-ball, versus ball-unlit bulb-lit bulb) \times 2 (Sex) \times 3 (Referent Object) with repeated measures on the referent object. This

analysis showed the expected effect for grade, $F(2,102) = 3.91, p < .03$; a highly significant effect for referent, $F(2,183) = 14.46, p < .0001$; a significant grade by referent interaction, $F(4,183) = 4.73, p < .008$; and a significant grade by referent by sex interaction, $F(4,183) = 4.01, p < .004$. The means for the triple interaction are presented in Table 3.

To interpret the triple interaction, we conducted separate analyses of variance for each sex. The analysis for males showed a significant effect for grade, $F(2,52) = 3.88, p < .03$; a significant effect for referent, $F(2,92) = 14.59, p < .0001$, and a significant grade by referent interaction, $F(4,92) = 7.09, p < .0001$. An analysis of the grade by referent interaction showed that at the third and fifth grades, the means for the ball condition were significantly lower than the means for the lit bulb condition. Analyses of grade effects, in the interaction, showed that the only differences occurred when the ball was the referent, and here third and fifth graders had significantly lower scores than the college students.

The analysis for females showed a significant effect for referent, $F(2,91) = 3.23, p < .05$, and a nearly significant grade by referent effect $F(4,91) = 2.33, p < .07$. Analysis of the referent effect showed lower scores for the unlit bulb than for the lit bulb condition ($p < .02$). The mean for the ball referent was also lower than the mean for the lit bulb condition, but the difference only approached significance ($p < .06$). Although the grade by referent interaction was not quite statistically significant, we examined the effects of different referents across grades. The analysis revealed that significant referent effects for females occurred only at the fifth grade level, where the ball and unlit bulb conditions yielded significant lower means than the lit bulb condition (see Table 3). Analysis of grade effects showed no significant differences.

In sum, although there were some differences between the sexes, for both boys and girls there were referent effects in the expected direction. That is, for each sex, there was more evidence for extramission when reference was made to a lit bulb than when reference was made to a ball or to an unlit bulb.

Analyses of combined results. In additional analyses we combined results from both studies, which yielded at least three points of interest that will be summa-

TABLE 3
Means and Standard Deviations of Intromission Responses to the Three Referents, in Study 3

Sex	Grade	Referents					
		Ball		Unlit bulb		Lit bulb	
		<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>
Male	3rd	1.3	1.4	1.6	1.4	2.7	1.4
	5th	1.0	1.6	1.5	1.6	2.0	1.5
	College	2.4	1.5	2.3	1.5	2.3	1.5
Female	3rd	1.7	1.4	1.2	1.4	1.6	1.4
	5th	1.3	1.4	1.5	1.5	2.2	1.4
	College	1.8	1.5	1.9	1.5	2.0	1.5

rized. First, there was an increase in intromission responses across grade level to the questions asking about input, but no grade changes on the items asking about visual output. There were also relatively large numbers of subjects showing extramission, even on the single question asking about the lit bulb, where approximately 35% of the children and 33% of the adults affirmed extramission. We assumed that virtually no one would be able to say that something goes out of the eyes with such a potent intromission cue. Finally, there were large percentages of subjects at all grade levels who gave correct responses to the single intromission question asking about the shining light bulb.

Analyses were performed on qualitative responses from both studies combined to the probe questions that followed the three-term, forced-choice question asking about "in," "out," or "both." Among the subjects who answered "in" or "both" (78% of the third graders; 70% of fifth graders; 92% of the college students) there was a clear increase across grades in the tendency to answer correctly that what comes in helps us see and that if nothing went out, we would be able to see. Thus there was evidence of increasing understanding of intromission as children matured. However, there was also evidence of misconceptions about intromission among subjects giving "in" or "both" answers. For example, 25% of these third graders claimed that intromissions did not help us see. Moreover a substantial minority of the "in" or "both" responders answered that visual input began inside the eyes (26% among third graders, 33% among fifth graders, and 17% among the colleges students)! Large minorities of subjects also surprisingly believed that we could still see if nothing came into our eyes (61% of the third graders, 36% of fifth graders, and 13% of college students, who believed either in intromission or both).

There were other interesting findings among those subjects who were pure extramissionists (17%). A majority of them (66%) answered that extramissions help us see, while a similar number (approximately 52%) also claimed that we would not be able to see if nothing went out of our eyes. Interestingly, most of these subjects (76%) answered that emissions started inside the eye (including the four college extramissionists).

Additional analyses indicated that subjects who believed in both extramissions and intromissions gave explanations that generally fell into one of four types: (1) A distinction between luminous and nonluminous objects: "If it's shining (i.e., light bulb) it goes in. If it's off nothing does," or "When the light is on something shines into our eyes and goes out at the same time. Otherwise it just goes out;" (2) Application of a simple, general heuristic: "Something goes in, it has to go out;" (3) Different functions for in and out rays: "When something goes out it gets the picture, and when it comes back in it gets it so we can see it;" or "Rays come into our eyes to form an image and out to clear the image - to make it more clear;" (4) An explanation affirming that extramission aided understanding: "In order for you to see the ball and the light bulb something has to go out of your eyes; (For the ball) Your vision is connecting with the ball and telling you what you're sensing."

Although 12 college subjects and four fifth graders used the word "reflection," only four college students used the term correctly to refer to nonfunctional reflections off the eye or retina. All the other subjects who mentioned reflection referred to an erroneous concept, as in the following college student's explanation: "Waves going into the eye but must get reflection out to be able to see."

Discussion

Studies 2 and 3 both compared intromission-extramission responses as a function of the referent employed in the questions and an analysis of order effects. Study 2 was expected to produce the most noticeable referent effect since there was a change of referents across successive questions. However, the results showed no such finding. Instead an order effect was found, namely, that the initial presentation of the lit bulb caused a decline in the number of correct responses. Analysis of the initial block of questions indicated that the order effect occurred on the first block of trials. Thus when the question referring to the ball appeared last, following the items on the lit and unlit bulbs, there were fewer intromission responses than when it was the first to appear. This effect was not anticipated. In fact, as was mentioned we had, perhaps naively, expected the opposite to occur, namely, success on the initial presentation of the lit bulb condition and positive transfer.

An explanation for the effect is perhaps obvious, at least in retrospect. The initial presentation of the lit bulb probably influenced subjects to define intromission in terms of light emitting from the luminous referent. When the light was turned off, as the trials progressed, subjects probably interpreted the turning off as a sign of the absence of incoming rays. This result suggests that the lit bulb might have been inducing only a limited or restricted concept of intromission, that is, intromission defined as visual input from a shining object.

The results of Study 3 showed complex interactions between sex and other variables that cannot easily be explained. However, for each sex there was evidence of a referent effect among children with the lit bulb condition yielding significantly higher scores than the ball and/or unlit bulb conditions. There was thus some evidence for a referent effect in the expected direction. Interestingly, there was no order effect that might have been taken as evidence of learning or transfer for either sex. Thus while subjects had higher levels of correct responses when the lit bulb was referred to, the gain that resulted from the lit bulb did not transfer.

Analyses of the probe responses also provided some intriguing outcomes. While there was convincing evidence of an increase in intromission interpretations with grade, several subjects who affirmed intromissions gave interpretations inconsistent with an accurate functional intromission interpretation of vision. Furthermore most subjects, whose interpretations made mention of reflection, did not correctly conceptualize reflection as a non-functional phenomenon incidental to vision. There was also evidence indicating that the majority of extramissionists gave explanations consistent with their judgments.

Finally, there was less evidence of the decline in extramission responses in age than was obtained in the research by Cottrell and Winer (1994) and in Study 1. Perhaps sampling differences, the use of concrete referents in the present studies, or other procedural differences among the investigations might account for the different outcomes.

STUDY 4

As in the previous investigations, in Study 4 we varied the referent used in the questions. However, in Study 4 the selection of referents was more specifically based on an attempt to examine an alternative explanation for the presence of at least some extramission vision beliefs.

More specifically, we hypothesized that some subjects might confound what appear to be extramission responses to our questions with a naive and concrete conception of nonverbal communication through gaze. That is, although the questions asked about vision, they might have been misinterpreted to mean something like communicative or affective emanations proceeding from the eyes. Such emanations would have little to do with vision, but they would have much to do with the communication of, say, feeling. This hypothesis was suggested by pilot data from a few college subjects.

To test the hypothesis, the nature of the situation or context referred to in the stimulus questions was varied to suggest different degrees or types of communicative or affective significance. In some cases, for example, the questions referred to looking at a loved object, person, or animal, while in others they referred to looking at referents that were presumably neutral with regard to affect. We assumed that if people could have a tendency to interpret intramission-extramission vision questions as referring to the communication of affect, then providing a context of looking at a person or object with whom there is an emotional closeness should foster what might otherwise appear to be extramission responses. Likewise, assuming a gradient of emotional closeness, in which people are liked more than animals, and both are liked more than objects, varying the referents among people, animals and objects should also have an impact on the number of what appear to be extramission interpretations.

There was one other major variable. In previous studies the questions always involved the term "look" or the phrase "look at" although the initial instructions asked about the act of seeing. Our hypothesis in this study was that subjects' understanding of vision might perhaps be more directly tapped by the word "see" instead of the phrase "look at." For example, the phrase "look at" seems to refer to an active process, one of focusing on something, whereas the term "see" appears to connote a more passive process. Also, "look at" implies more of an outward orientation (i.e., we look at something), which might be more likely to induce an extramission interpretation than reference to seeing.

Method

Subjects. The subjects were 40 male and 25 female third graders (M age = 9.25 years, range = 8.33 years to 11 years) and 49 male and 29 female fifth

graders (M age = 11.25 years, range = 10.5 years to 12.5 years), attending a school in a mostly working class area, and 31 male and 29 female college students (M age = 20.33 years, range = 18.5 years to 30 years). The college students participated in the research for course credit.

Procedure. Subjects, individually tested in 10- to 12-min sessions, initially received pretest questions to avoid positive/negative response sets and to draw attention to the task. As in the previous studies subjects were informed that we were interested in their understanding of how we see, before receiving the main questions.

The main questions were of the form "When you look at (see) a person (animal or object) ... do you think there are rays, or energy or something else coming into your eyes (going out of your eyes, or going first out of and then into your eyes)?" After each positive response, the subject was asked to identify what entered or emanated from the eyes.

Each subject received a total of 18 such items, 9 neutral and 9 affective questions. The 9 affective items referred to looking at or seeing someone or something described in positive terms; the neutral items referred to referents described with no emotional terms. Thus the affective item for a person read, "Say the person you love most is here and you are looking at him/her. Do you think that" The affective items for the other referents mentioned "your favorite animal," and "your favorite object." The 9 items referring to a neutral referent described "a person who passes by in the street," "an animal, like a cat, a dog, or a horse," and "an object, like a chair, a desk, or a book."

Each set of 9 neutral and 9 affective items consisted of three questions referring to a person, three to an animal and three to an object. Among the three questions referring to each referent, person, animal, or object, one item asked about intromissions, one about extramissions, and the third asked about extramissions followed by intromissions. Note that the question asking about extramissions followed by intromissions presented an extreme example of an extramission process of vision.

There were two other variables, both employed as between-subjects factors: One consisted of varying the use of the words "see" and "look at" in the main questions. Each subject received questions with only one wording. The second was the order in which the affective and neutral items were mentioned. Thus for approximately half the sample the neutral items were presented first, and for the other half the affective questions were the first ones given. Within each set of 9 neutral or affective items, the questions were randomly ordered.

Results

Subjects' answers to the questions about "rays, energy, or something else" coming "into" or "out of" or "out of and then into" the eyes were scored as correct if subjects mentioned anything entering the eyes (intromissionist), and as incorrect if they mentioned anything exiting the eyes (extramissionist). All analyses were computed on the numbers of correct answers.

An initial 3 (Grade: third vs fifth vs. college) \times 2 (Visual Action: "see" vs "look") \times 2 (Order: neutral-affective vs affective-neutral sets) \times 2 (Sex) \times 3 (Referent: object vs animal vs person) \times 2 (Emotional Context: affective vs. neutral) analysis of variance was performed on the number of correct responses, with repeated measures on two factors, emotional context (affective vs neutral context), and type of referent (object vs animal vs person). The analysis showed that there were no effects for the wording of visual action ("see" vs "look at"), $F(1,177) = .15$, type of referent (person, animal, object), $F(2, 815) = .57$ or emotional context (neutral or affective context), $F(1,815) = 3.08$, $p < .08$. However, there was a strong main effect for grade level, $F(2,177) = 12.5$, $p < .001$, a significant interaction between grade, order, and emotional context, $F(2,177) = 6.57$, $p < .01$, and a significant six-way interaction among all the variables, $F(4,815) = 2.39$, $p < .05$.

Examination of the data suggested that among college students, the effect of emotional context on the first set of questions generalized to the second set. Because the possibility of complex interactions increases when there are transfer effects in repeated measures analyses, (see Winer, 1962, p. 301 who recommends against using repeated measures analyses of variance when there are transfer effects), we conducted a separate 3 (Grade: third vs fifth vs college) \times 2 (Visual Action: "see" vs "look") \times 2 (Sex) \times 3 (Referent: object vs animal vs person) \times 2 (Emotional Context: affective vs neutral) analysis of variance on responses to the initial set of questions, neutral or affective context items, given to each subject. In this follow-up analysis, then, emotional context was a between-subjects variable, whereas in the previous analysis it was a within-subjects variable. The analysis showed a significant effect for grade, $F(2,177) = 12.80$, $p < .0001$, a main effect for emotional context, $F(1,339) = 6.66$, $p < .02$, and significant interaction between grade and emotional context, $F(2,177) = 3.17$, $p < .05$). There was also a significant interaction between visual action ("see" vs "look at") and referent, $F(2,339) = 3.44$, $p < .05$.

Analysis of the interaction between grade and emotional context showed that among college students those given the neutral context had significantly more correct responses ($M = 2.4$) than those receiving the affective context ($M = 1.8$). (It was this difference that generalized to the second set of questions, so that college students who had initially received the affective context items continued to respond with lower scores than those given the neutral context, $p < .08$).

Analysis of the age trends in the interaction showed that adults given the neutral context had significantly higher scores than fifth graders ($M = 1.7$) and third graders ($M = 1.6$). For those subjects given the affective context, the difference between college students ($M = 1.8$) and third graders ($M = 1.5$) approached significance, $p < .06$, with the scores of the fifth graders ($M = 1.6$) falling between scores of subjects in the other grades.

The interaction between visual action ("see" vs "look at") and referent indicated that the subjects receiving the "see" wording, which was supposed to enhance intromission responses, had fewer correct responses when the questions

were addressed to seeing a person ($M = 1.6$) than when they were addressed to seeing an animal ($M = 1.9$). Recall, that we expected fewer intromission responses with a person as a visual referent. There was also a difference between questions referring to seeing a person ($M = 1.6$) versus looking at an object ($M = 1.9$).

We also conducted a separate analysis of the second set of items subjects received. Here we found a significant effect for grade, $F(2,162) = 9.1, p < .0001$, and a number of interactions including grade by sex, $F(2,162) = 3.12, p < .05$, type of visual action by sex by emotional context, $F(1,162) = 6.29, p < .02$, and an interaction between grade by visual action by referent, $F(4,162) = 2.74, p < .03$. However, since the complex interactions were presumably a product of transfer, the nature of the interactions will not be described.

Table 4 presents the percentages of subjects showing perfect and imperfect performance on the three question sets comprising items using each referent, for the affective and neutral context conditions. The results are presented by grade and by question type. A visual comparison of the results for each question type across neutral versus positive affect conditions, shows how strongly the affective context influenced the college students. In the neutral context the majority of the subjects was perfect; in the affective context, the majority was imperfect.

A comparison of neutral and positive affect context conditions also shows that among the college students, the emotional context produced both a denial of intromission interpretations and an affirmation of extramission interpretations. This was not the only possible outcome, since it was conceivable that the emotional context condition might have produced only a decrease in intromission responses (i.e., by increasing the number of denials that intromission occurred) or an increase in extramission interpretations.

Finally, analyses of the responses to the follow-up questions, designed to determine the meanings attached to subjects' judgments, suggested that in fact

TABLE 4
Percentages of Subjects Showing Perfect (+) versus Imperfect (–) Performance on Three^a Questions with Neutral or Positive Emotional Context, in Study 4

Question type	Affect condition											
	Neutral*						Positive**					
	"In"		"Out"		"Out-In"		"In"		"Out"		"Out-In"	
Grade	+	–	+	–	+	–	+	–	+	–	+	–
Third	7%	93%	32%	68%	26%	74%	12%	88%	24%	76%	26%	74%
Fifth	30%	70%	35%	65%	35%	65%	32%	68%	39%	61%	34%	66%
Coll	63%	37%	87%	13%	83%	17%	34%	66%	38%	62%	41%	59%

^a The three items referred to person, animal and object.

* The χ^2 for each question type was significant, $p < .001$.

** The χ^2 for each question type was not significant.

some of the extramission adults under the positive affect condition were in fact at least partly interpreting the question to refer to emotional or communicative emanations. Thus out of a total of 23 adults in the positive affect condition who gave at least one extramission answer to either of the two questions asking about emissions ("out" only or "out" then "in") 8 college students mentioned emotion (e.g., love or feelings or communications) when responding to the follow-up question asking what it was that went out. None of the 5 adult extramissionists in the neutral condition provided interpretations involving emotions. The analysis was restricted to the first set of questions subjects received. Interestingly similar numbers of third (9 of 27) and fifth (6 of 29) grade children gave interpretations referring to emotions in the affective condition, versus a total of 4 who gave such interpretations in the neutral condition.

Discussion

The main goal of this study was to explore the linkage between extramission perception beliefs and beliefs about nonverbal expressions of emotion through the eyes. In other words, to what extent could the questions about vision be interpreted as involving the communication of emotion through the eyes?

The findings showed that positive emotional context cues increased extramission responses, but only in adults. That is, the adults offered fewer intromission and more extramission responses when the questions asked about the referents that were described in positive versus neutral terms. Why, then should the effect occur in adults rather than in children?

One answer is based on possible statistical effects stemming from differences in the belief systems of adults and children. Adults, presumably because of their educational experience, more often than children believe in intromission. Statistically, this gives adults more of a chance than children to be influenced toward extramission responses. A second possibility is that in comparison to children adults are more responsive to and capable of using metaphors or reacting to subtle variations in meanings. Thus the different contexts might have stimulated metaphorical thinking in adults. One problem with this interpretation, though, is that similar numbers of children and adults gave interpretations suggestive of emotions or communications. A third possibility is that the affective cues might have produced a more impressionistic, less scientific, more intuitive mode of thinking in the adults. This interpretation is in accord with Werner's (1948, 1957) theory. Werner argues, for instance, that adults are generally more abstract and conceptual, while children are more inclined to have thoughts and percepts that are liable to be dominated by affect and emotion. (see Werner's distinction between geometrical technical perception and physiognomic perception). Werner's theory allows, however, for a mobility or a shifting between different levels or types of responses, depending upon any one of a number of task or subject variables. Emotional contexts might be conducive to a dynamic, affectively based, and nontechnical mode of response (for another example of situations in which adults respond intuitively under certain conditions see Winer & McGlone,

1993). Such conditions would affect adults more than children, since children would more frequently use the developmentally more primitive type of response, in the first place.

Whatever the interpretation, though, the results demonstrated context effects that cannot easily be explained by assuming that adults function as experts, with scientifically grounded, integrated theories of vision. Such theories would presumably be relatively immune to changes in context.

The fact that we showed an emotional context effect for adults when examining extramission responses and seemingly at least slight effects for children and adults when asking about interpretations certainly suggests that people can respond to intromission–extramission questions with an interpretation that involves the emission of emotion. The question that arises is how often such emotionally based interpretations occur when the test items appear in a neutral context. This is an important question. If we assume, for example, that intromission–extramission questions are interpreted emotionally in neutral conditions, then we would be led to conclude that the developmental trends found in this and in all prior research might have been demonstrating age effects in emotion-based interpretations to vision questions. However, there was little evidence in the follow-up questions that either adults or children had interpreted the questions with a neutral affective context as referring to emotion. Moreover, among the children in this study there was no particular relation between the number of extramission judgments and interpretations referring to emotions. In this connection, it is interesting that we have obtained other data, in studies conducted subsequent to the research in this report, showing that many adults give extramission interpretations when there are graphic depictions of emanations that would be difficult to construe as representing the communication of emotion or affect.

Finally the interaction between visual action words and referent is difficult to explain, although some of the differences obtained were in the expected directions. Thus, there was more extramission when the referent was a person than an animal, which was predicted, but only when the questions used the word “see,” a limitation which was not predicted.

GENERAL DISCUSSION

In four studies we varied the referents in questions that asked children and adults whether there was visual input or output in reference to the act of seeing or looking. The results of the first three studies suggested that reference to luminous, that is, shining and light projecting objects, versus reflective referents, or no specific referents at all, could affect subjects' interpretations of vision, but with some striking limitations. To begin with, Study 1 provided absolutely no evidence for an overall referent effect. One obvious potential limitation of Study 1, though, was that verbal identification of the referents might not have been sufficient to produce an effect. However, even in Studies 2 and 3, where questions referred to different physical objects, the effects were not uniform. For example, there was no overall effect from visual referent in Study 2, the very

investigation in which we had anticipated the strongest effect. Instead, the initial appearance of the lit bulb and the act of turning it off, seemingly encouraged subjects to define intromission as only occurring when there was a shining light. Only in Study 3 was there dramatic evidence that questions referring to luminous objects increased intromission responses, at least among children. In short, there was some evidence of the malleability of intromission–extramission interpretations, but only under certain conditions. Thus one conclusion to be drawn from this study is that intromission–extramission interpretations do not seem to vary broadly as a function of the nature of the object being viewed.

Moreover, and perhaps more significantly, there was virtually no evidence that subjects generalized correct intromission responses from the lit bulb condition to the remaining ones. The results show the robustness of the extramission interpretation and are also inconsistent with the assumption that people develop, or at least reinforce, intromission beliefs by generalizing from their experiences with visual input from luminous objects. Finally, there was also convincing evidence, particularly from probe questions, that subjects believed that extramissions were functionally significant in vision.

Study 4 represented an attempt to explore an alternative interpretation that subjects might have of intromission–extramission questions by comparing conditions and situations which suggested different emotional relations. The results showed that only adults gave more extramission responses when questions suggested a positive rather than a neutral emotional context. Quite possibly the adults in the affective condition were responding more metaphorically or intuitively than the adults in the neutral condition. The results also showed that overall, reference to “seeing” versus “looking” in the questions made no difference in responses.

On a more general level, the findings from these four studies have some interesting implications for theories suggesting that cognitive development can be likened to changes in belief systems, changes that might reflect a cognitive restructuring that represents a radical re-conceptualization of beliefs (see Carey, 1985; Vosniadou & Brewer, 1987, 1992). While this research was not designed to be a test of such restructuring, the results do not suggest that intromissionist ideas about visual perception are necessarily part of a correct, well-integrated theory of vision that results from cognitive restructuring. Instead what the results suggest is that intromission concepts can vary depending upon the context. Context effects were evident in Studies 2 and 3 and among the adults of Study 4. Such context effects are not what would be expected from integrated, coherent theories. That is, an integrated theory of vision, due to restructuring or reorganization, and characteristic of the expert would presumably lead one to be relatively immune to contextual cues. Other research (Kuhn, 1989) has also questioned the idea that cognitive development involves a radical restructuring of theories, and there is even debate as to models that conceptualize thought in terms of theories (see Yates, Bessman, Dunne, Jertson, & Wendelboe; Yates, 1990 versus Springer, 1990).

Our results also have obvious implications for science education. The presence of extramission, even under conditions which should have fostered intromission interpretations among both children and adults, indirectly suggests that instruction about the nature of vision is not sufficient to abolish incorrect notions that people hold about this process, a point that has been made before with respect to the learning of other scientific concepts. The failure of the subjects generally to profit from experience with the luminous objects likewise indirectly suggests that prior education on the nature of vision might have produced only a very shallow understanding of this perceptual process. Further research will have to determine precisely to what extent education interacts with what appears to be a myth about the nature of one of our most basic perceptual processes or, in fact, whether intromission explanations constitute a myth.

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