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Images, Words, and Questions: Variables That Influence Beliefs about Vision in Children and Adults

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In three studies we used animated computer graphics to examine beliefs among children and adults that vision involved input to the eyes (the intromission theory) or emissions from the eye (the extramission theory). Results supported previous findings which showed a decrease in extramission and an increase in intromission responses across age. The findings also indicated that there were more extramission interpretations when subjects were tested with graphic images, and more intromission interpretations when the questioning was purely verbal. However, the magnitude of the effect was highly dependent upon question format. The differences between graphic and verbal question presentations (A) are consistent with our theory on the origins of extramission beliefs, (B) suggest that beliefs can vary as a function of form of symbolization, and (C) are contrary to long-standing beliefs of educators and psychologists that emphasize the importance of concrete, pictorial representation.

Recent investigations have shown that many children and adults entertain what might appear to be a strange belief to those who are knowledgeable about vision, namely, that there are emissions from the eye, such as waves, rays or energy, when people see, although with development there are noticeable declines in such so-called extramission beliefs (Cottrell & Winer, 1994; Winer, Cottrell, Karefilaki & Chronister, 1996). Evidence for extramission beliefs and their decline with age has occurred when a variety of different question formats were employed (Cottrell & Winer, 1994; Winer, Cottrell, Karefilaki, & Chronister, 1996) such as: group versus individually administered items; pictorial versus purely verbal questions; and questions referring

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to verbally described and to physically present referents of various types.[1] Moreover, the extramission beliefs seem relatively immune to variations in visual referents. Thus, although intromission answers increased when subjects were questioned about seeing a lit bulb, as opposed to a nonluminous object, extramission responses remained high and, furthermore, intromission responses given to the lit bulb did not transfer to questions about non-luminous objects (Winer, Cottrell, Karefilaki, & Chronister, 1996). Finally, there is evidence that extramission beliefs cannot easily be changed by exposure to common introductory psychology assignments and/or lectures on visual perception (Winer, Cottrell & Karefilaki, 1994; Hedman, 1995).

This recent research on intromission–extramission beliefs was originally sparked by observations of Piaget (1929/1969), who noted that children's beliefs about vision appeared to be consistent with Empedocles' theory, which held that there are emissions from the eye (Piaget, 1929/1969, p. 48). Piaget (1971) later claimed to have found strong support for the existence of children's extramission views, although his work on the topic has apparently remained unpublished (Piaget & Papert, 1971; Piaget & Lannoy, 1971, which are both included as references in Piaget, 1971, but which are cited without being referenced in the English version of the text, Piaget, 1974). Other writers, such as Guesne (1984, 1985), have found evidence consistent with extramission notions (see Cottrell and Winer, 1994, for a review), although these other investigators have sometimes argued against the existence of such beliefs.

As Piaget noted, beliefs about emissions from the eye parallel ancient theories of perception. In fact the extramission theories of perception were accepted by a number of ancient philosophers, including Plato, Euclid, Ptolemy and the eminent Muslim scholar, al Kindi. The history of extramission theories is documented in texts on the history of science (Lindberg, 1992) or of perception (Lindberg, 1976; Meyering, 1989).

Findings on extramission beliefs parallel results of research on naive physics, which have revealed that (A) both children and adults show a number of misconceptions in science (see McCloskey, 1983 and McCloskey & Kargon, 1988, for a review of earlier work; Vosniadou & Brewer, 1987), (B) ontogenetic development sometimes seems to parallel developmental trends in the history of science (Kaiser, McCloskey & Proffitt, 1986; McCloskey, 1983; McCloskey & Kargon, 1988; and Strauss, 1988), and (C) education often fails to change mistaken beliefs (see Chinn & Brewer, 1993; Eaton, Anderson, & Smith, 1984; Helm & Novak, 1983). However, the extramission conception of vision seems somewhat more unusual and counterintuitive to us

[1] One apparent exception to this age trend occurred when subjects were asked whether they could feel the stares of an unseen person, seemingly a question about extramission. Here, more older than younger subjects reported experiences of feeling stares, although that research also suggested that the phenomenon of feeling stares was conceptually different from intromission-extramission beliefs subjects held about visual perception (Cottrell, Winer, & Smith, 1996).

than, say, other scientific misconceptions. To begin with, as was noted, the process of vision is commonly taught in school systems and tends to be repeatedly taught, whereas other misconceptions often involve physical principles that are not commonly taught to all students and certainly that are not commonly taught repeatedly (see McCloskey's work on predicting trajectories or paths of objects, e.g., Kaiser, McCloskey & Proffitt, 1985; Kaiser, Proffitt & McCloskey, 1986). Nor does there seem to be anything that is intuitively evident about one's experience that would lead to extramission misconceptions, as for instance would occur in such misconceptions as a flat earth, where one often receives cues as to the flatness of the earth's shape (Vosniadou & Brewer, 1992). Indeed, the source and apparent strength of extramission beliefs in children and adults is somewhat of a mystery.

However, this report largely concerns a finding which might provide some insight into the source of extramission beliefs and which potentially has both theoretical and practical import. The finding, which appeared in three separate experiments (Cottrell & Winer, 1994, Studies 2 & 4; Winer, Cottrell, Karefilaki, & Chronister, 1996), indicated more evidence of intromission responses on purely verbal questions than on items that were accompanied by line-drawn representations of vision. In the items with pictures, we portrayed vision graphically by presenting subjects with line drawn profiles of a face, with visual input and output indicated by single arrows pointing toward or away from the figure's eyes. Subjects were instructed to choose among three renditions of vision: one indicating visual input only, another indicating visual output only, and a third portraying both input and output.

The finding that extramission responses seemed to increase with pictorial representations suggests a source of these beliefs: the cue for extramission, specifically, the arrows pointing out from the eye, might have resembled what can be termed the orientational, attentional or directional quality of vision, namely, the focusing, aiming and orienting toward a referent that appears to us to be more critical to vision than any of the other senses. It is possible that it is precisely this experience of visual orientation that provides the phenomenological underpinnings for extramission beliefs. When subjects are asked questions about whether vision involves input or output, the outerdirected quality of visual experience, that is the subject's awareness of visual orientation, might provide the basis for the extramission belief.

According to this interpretation, subjects receiving graphic representations of output would experience a match between their phenomenology of visual orientation and the directionality shown in the extramission representations. That is, the vectorial quality of directionality, inherent in looking and seeing, and the vectorial quality of outer-directedness in the pictorial representations of extramission should be phenomenologically similar. Such subjects would thus be especially prone to express a belief in extramission. Subjects given the purely verbal question could also rely on this same phenomenological experience and likewise profess a belief in extramission. However, since their phenomenological experience of the outward nature of visual orientation would not have been reinforced by the drawn arrow it would be weaker than that which occurred in the pictorial condition, and beliefs having other bases, such as those acquired through tuition, might be more potent. Knowledge acquired either formally or informally would also account for the age trends. That is, as subjects gain more experience, presumably their declarative knowledge would supplant influences from the phenomenology of vision.

The difference in responses to purely verbal versus pictorially based questions not only provides possible insight into the origins of extramission beliefs; on a more general level it also suggests that when different types of symbols are employed, different phenomenological experiences might be evoked, and thus different interpretations might occur. In other words, the nature of one's interpretation, say, of certain scientific phenomena, might vary as a function of the medium in which the scientific process is represented. What is particularly intriguing about the findings comparing verbal versus pictorial items, is that the difference is contrary to what we believe is a common assumption in education, namely, that there should be more technically accurate performance with pictorial than with purely verbal items.

While the results of previous studies suggested more extramission and fewer intromission interpretations with pictorial, as opposed to purely verbal items, there were certain limitations in the prior research. To begin with, in some studies the structure of the questions presented with the verbal and pictorial items differed (Cottrell & Winer, 1994); in another instance, the difference in responses to the two treatments occurred only under one of several conditions (Winer, Cottrell, Karefilaki, & Chronister, 1996). Finally, in the previous research there was a limitation in the way in which vision was depicted graphically, namely, through schematic, line-drawn representations using single arrows pointing inward and/or outward.

Consider some possible problems associated with the use of arrows to depict vision. To begin with, a single arrow is highly schematic and thus might not be very representative of the idea of transmission of light. Light, after all, does not enter the eye in a single straight line. Thus, if arrows were to be used, there should be multiple arrows emanating from the seen object to the eye to represent vision. Second, a single arrow pointing outward might unduly cue the phenomenology of visual orientation, which includes line of sight, or attending and focusing. Indeed, often line of sight is represented by a single outward pointing arrow. However, the main limitation of the static drawings in the previous research was that it was difficult to present sequences of events depicting different temporal relations between input and output, such as input occurring first, followed by output, or initially occurring output, followed by input. These interpretations had been proffered by subjects in follow-up questions in prior research.

One way of avoiding some of the aforementioned problems is to use animated graphic renditions of vision. In the studies described in this report, we presented subjects with animated computer graphics that showed one or more profiles of a face looking at a rectangular object. Visual input was designated by what appeared to be moving dotted lines that came from several points across the span of the rectangle and that converged toward the eye; visual output was indicated by lines showering outward from the eye toward the rectangular figure. Use of these dynamic images should minimize the strong cue for extramission presented by a single outward arrow in the static drawing. However, the dynamic quality of lines appearing to emanate from the eyes in a computer presentation, should still match a subject's phenomenological experience of the orientational quality of vision and thus stimulate extramission interpretations. The use of computer graphics also permitted us to present the variations of input and output sequences suggested by subjects in past research.

Other reasons justify using animated graphic representations of vision. Such graphics allow us to represent extramission as the exact opposite of intromission and thus to present a clear distinction between input versus output. Moreover, when investigators in previous research (e.g., Cottrell & Winer, 1994; Winer, Cottrell, Karefilaki, & Chronister, 1996) asked whether anything goes into, or out of the eye, during vision, subjects might have interpreted emission to refer to the diffuse reflection of light out of the eye, as opposed to rays or the like which might travel directly from the eye toward an object (although their explanations did not suggest such interpretations and in fact often indicated a functional type of extramission). Another advantage of employing computer representation is that we assume that the animated graphics are inherently interesting, thus encouraging a high degree of attention among subjects.

This report describes three studies examining responses to animated computer renditions of vision, two of which directly compared questions with and without computer graphics. In the first study, a comparison was made between verbal and computer items that required a yes or no answer in response to questions asking about visual input and output. The results were consistent with our hypothesis, although the difference between computer and verbal formats was small. The second study did not directly compare the two formats of question presentation, computer and verbal. Instead it examined grade changes in response to computer items that presented questions requiring a forced choice between different interpretations of vision. The results of Study 2 indicated that responses to the forced-choice question were different from those of the yes–no items used in Study 1, thus suggesting the importance of a comparison between verbal and computer items on the forced-choice type of question. Study 3 thus once again examined responses to questions with and without computer graphics, but this time using the forced-choice format.

STUDY 1

The purpose of Study 1 was to compare purely verbal questions with identical questions presented along with computer graphics. We were specifically interested in whether there were different performance levels and grade level changes for each type of question, and whether prior appearance of one type of item, verbal or computer, would affect responses to the other type.

As was stated, we had both theoretical and empirical reasons to predict that there would be more intromission interpretations in response to the verbal than computer presentation. However, we did not expect this difference to be large, for two reasons. First pilot studies using only computer items revealed age trends that paralleled those found in other research using noncomputer items. Second, a strong cue indicating the directionality or orientational quality of vision used in the previous research, namely, the arrow, was replaced by representations of input and output in the form of moving dots.

Method

Subjects. Subjects were 22 boys and 23 girls in the third grade, (mean age = 9.1 years; range = 8.4–10.3 years); 31 boys and 23 girls in the fifth grade (mean age = 11.1 years; range = 10.3–12.3 years); and 26 male and 25 female college students (mean age = 20.6 years; range = 18.7–42.2 years). The elementary school students were attending a school located in a rural suburb of a major city; the college students participated in the study for course credit.

Regarding our selection of ages, it should be noted that a preliminary study examining age trends on computer items identical to the ones in this study indicated a ''J''-shaped curved, with first graders showing more intromission than third graders, with no difference between third and fifth graders, and with college students showing significantly more intromission than children in any grade. Some evidence of this J-shaped curve has also been found in other research which questioned subjects without use of a computer, sometimes among first, third, and fifth graders and college students (Cottrell & Winer, 1994), and sometimes among third and fifth graders and college students (Winer, Cottrell, Chronister, & Karefilaki, 1996). However, trends reported in these studies or observed in pilot research have generally not been significant.

In all experiments described in this report the youngest subjects tested were third graders, for two reasons. First, our main interest was to examine the extreme points on the developmental continuum, i.e., subjects showing the most and fewest intromission responses. Our previous research indicated that third and fifth graders showed even more extramission than younger children (although we have not compared preschoolers with school-aged children). Second, the question sets we used in the studies in this report were longer and/or more complicated than those in the pilot work.

Questions. Subjects were individually tested and initially instructed: ''I am going to ask you a few questions about how we see. Some questions may seem very easy, and others may seem harder. Please give the very best answer that you can to each question. We just want to know what you think about how we see.'' Elementary school students were also told, ''Your teachers will not see your answers.'' Subjects then received the same set of five main test questions on vision twice: once in a purely verbal form and once with a computer graphic accompanying each question. After receiving one set of questions, subjects were told, ''Now I am going to ask you some similar questions without the computer (as we look at the computer).''

The five main vision questions asked, ''When people look at someone or something, do you think that anything goes (1) into their eyes; (2) out of their eyes (3) first comes into their eyes and then goes out again (4) first goes out of their eyes and then comes back in (5) goes into and out of their eyes at the same time . . .'', ''. . . like rays, or energy or anything else?'' Notice that the technically incorrect response is a ''no'' to item 1, which asks about intromission, and a ''yes'' to the remaining items, which ask about some form of extramission. Subjects who have a response set to answer ''yes'' should thus give one correct and four incorrect responses.

Each computer question referred to an image of a person facing a rectangularly shaped object. Dotted lines appeared to move between the rectangle and the eye in each graphic representation, demonstrating the type of visual process described in the question. Thus in the question asking about input, it appeared that moving lines converged from the rectangle to the eye of the human figure in a triangular fashion and on the single question asking about output, it appeared that moving lines showered outward from the eye toward the rectangular figure. The item asking about input followed by output portrayed moving lines converging from the rectangle to the eye and returning back to the rectangle, and the question asking about the reverse order showed lines that first appeared to move outward from the eye to the rectangle and then seemed to return to the eye. The question asking about simultaneous input and output showed two sets of lines which appeared to move at the same time: one seeming to go from the eye toward the rectangle; the other from the rectangle to the eye. Key words from the questions were also presented on the screen next to each graphic. Finally, for approximately half the sample, the five computer items were presented first, followed by the same five questions in a purely verbal format. For the other subjects the order was reversed.

Results

Correct performance was defined as ''yes'' to the two questions (one with and one without a computer) asking whether anything went into the eye, and a ''no'' to any of the other questions which made some reference to the process of extramission. A correlational analysis of the children's responses showed that correct performance on the two questions asking only about intromissions was generally negatively related to correct performance on the other items. Out of 16 correlations, only 3 were not significant. The magnitudes of the significant correlations ranged from $-.21$, $p < .04$, to $-.43$, $p < .001$. This pattern of results is exactly what would be expected if subjects were responding with a ''yea'' or ''nay'' saying bias. For example, if subjects answered ''yes'' to the question asking only about visual input, they would be scored as correct, and if they answered ‘‘yes’’ to the remaining items, which all included an extramission choice, they would be scored as incorrect, thus creating a negative correlation between the items. In order to control for ‘‘yea’’ or ‘‘nay’’ saying biases, in the subsequent analyses we eliminated all subjects who had a pattern of all ‘‘yes’’ or ‘‘no’’ responses on either the five computer or five purely verbal items. This left a sample of 28 third graders (17 boys and 11 girls), 38 fifth graders (23 boys and 15 girls), and 53 college students (23 males and 20 females).

A 2 (Sex) × 2 (Presentation Order: computer items first versus second) × 3 (Grade) × 2 (Presentation Mode: computer versus verbal items) repeated measures analysis of variance, with repeated measures on presentation mode, was conducted on the number of correct responses. The analysis revealed a significant effect for grade, $F(2,97) = 45.29$, $p < .0001$, with college students showing significantly higher scores ($M = 3.9$) than fifth ($M = 2.6$) or third ($M = 2.9$) graders; and a significant effect for presentation mode, $F(1,97) = 9.14$, $p < .004$, with higher scores for the verbal ($M = 3.3$) than computer ($M = 3.0$) items. (The same analysis, conducted with the total sample, yielded the same effects).

Discussion

The results demonstrated, as predicted, more correct performance on the verbal than on the verbal plus graphic questions, an outcome which is consistent with prior findings and which might be explained by assuming a match between the subject’s experience of the outward orientation of the act of vision and the graphic demonstrating extramission. Presumably, the graphic representation more strongly signals the outward directional quality of vision than does the purely verbal form of the question, thus yielding an increased number of extramission responses. The verbal condition might also contribute to intromission responses because of information that was verbally presented in lessons on vision. Such lessons would undoubtedly make use of verbal and pictorial material, but presumably the verbal content would outweigh the pictorial content in quantity.

However, it should be emphasized that the difference between questions with and without graphic images, although statistically reliable, was not large, and the developmental trends for responses to each type of question were indistinguishable. Thus at first blush it appears that use of the computer to test one’s understanding of vision does not yield dramatically different results from use of the purely verbal type of question.

Finally, the response set is of interest. In our pilot study, which used only computer items, we employed a pretest condition that was designed to hinder the very type of set observed in the present study. However, there was not much evidence of such a set and hence no difference between the experimental conditions designed to break the set. Perhaps the repetition of the items in the present study, due to the repeated measures design (which effectively doubled the number of questions), contributed to the response bias in children.

It is also of interest that the response set was more evident in children than adults.

STUDY 2

In the previous study we asked questions requiring a ''yes'' or ''no'' response. In Study 2 we changed the question format so that we required subjects to choose among different representations of vision. For each question we presented two or more renditions of vision from which subjects indicated the one that best demonstrated how we see.

This forced-choice technique was designed to be a more sensitive measure of the relative strength of extramission versus intromission beliefs than the simple ''yes–no'' items. For example, on the ''yes–no'' questions used in the previous study subjects could affirm a belief in both intromission and extramission, and we would have no indication of the strengths of their relative beliefs in each process. Forcing a subject to choose between the two processes, however, should provide an indication of which belief is the stronger of the two. Moreover the ''yes–no'' questions in the prior research might have allowed subjects to hedge or to respond according to a simple acquiescence or negation bias. Forcing a choice among different options should minimize or eliminate these problems.

This study was not aimed at comparing verbal and computer items. We assumed that the choices we offered in many of the questions were complex and they should be at least initially demonstrated to subjects graphically in order to avoid confusion. However, the results of this study provided more evidence of extramission responses than occurred in Study 1 and in the prior research, and thus suggested a further need to compare graphic and verbal items. Study 3 thus returned to a comparison between items with and without computer graphics.

Procedure

Subjects. Subjects were 21 boys and 20 girls in the third grade, (mean age = 9.0 years; range = 8–9.5 years), 24 boys and 18 girls in the fifth grade (mean age = 11.1 years; range = 10.3–12.3 years), 21 boys and 27 girls in the eighth grade (mean age = 14.3 years; range = 13.7–15.0 years), and 39 male and 15 female college students (mean age = 19.5 years; range = 18.1–22.9 years). The elementary school students were attending a parochial school located in a major metropolitan area. The college students participated in the study for course credit.

Questions and procedure. In this study we used the same computer graphic images employed in the previous study, except that for each item we simultaneously presented from two to four images on a single computer screen, each representing a different interpretation of vision, and required the subject to select one of the choices presented. Thus each of seven main computer questions included a choice between two or more of the interpretations used in

Study 1. The choices were always aligned vertically, i.e., faces and visual referents appeared above and below one another.

Each computer question had from two to four choices. A single, two-choice question required subjects to select between visual input and output: two profiles of a face, each looking at a separate rectangle, one with dashed lines appearing to converge inward toward the eye, the other with the lines appearing to shower outward from the eye. This is the first time that we have presented a forced choice between simple input versus output interpretations. In prior research, forced choices have always included three choices (see Cottrell & Winer, 1994).

Each of the six additional computer questions always contained the same two choices representing input and output plus one or two of three other possibilities: input followed by output, output followed by input, and simultaneous input and output. Three of these questions required subjects to select among four choices and three other questions required subjects to select among three choices. A final purely verbal item asked subjects to select among all five choices.

We did not include an item with all five choices on the computer screen at once, for two reasons: First, the figures would have had to be very small to fit on the screen. Second, in designing the graphics it also appeared that presenting more than four pictures on the screen at once would have created visual overload.

As was indicated, each of the seven computer questions always offered the simple intromission and the simple extramission choices among the options. The simple intromission choice was retained because it represented the only technically correct answer. We retained the simple extramission option so that there would be more than one representation repeated across all questions.

Order was counterbalanced in two ways. One ordering variable involved the serial position of the simple, two-choice question and the remaining questions involving a greater number of choices. For approximately half the sample we proceeded from the two-choice item to the three- and four-choice items; for the other half this order was reversed.

The second ordering variable involved the positioning of the various choices on the screen. In all instances, the different representations were positioned with one below the other on the screen, as was noted. Moreover, for all questions, the two simple representations of input alone and output alone appeared as the top two choices on the screen. However, for approximately half the subjects the input image appeared as the topmost representation on the screen, whereas for the other half, the output image appeared as the topmost. For all questions in all orders, we always started the questioning by referring to the item at the top of the screen and proceeded downward.

Subjects were individually tested. They were initially told: ‘‘We are interested in how people see. We want to know what you think happens when a person sees something. You will be shown a series of pictures on a computer screen. You will be asked to pick the one on the screen that best shows how we see.'' As the items were displayed, we pointed to each graphic representation and described the process, e.g., ''Here the pictures show something coming into the eye and going out of the eye. Which one shows how or why we can see?'' Key words describing the process were also presented on the screen next to each animated graphic. If subjects wanted a choice other than the ones presented, testers were instructed to ask them to select one of the alternatives shown on the screen. However, virtually no subjects made any such request in this or in any of the numerous subsequent studies using the same questioning procedure that we have conducted.

The eighth question, which was always the last main item and thus not manipulated in ordinal position, presented a choice among all five possibilities and was purely verbal. Although this was the most complex of the questions, we assumed that after having had the preceding items, graphically demonstrating each possible interpretation, the subjects might not find it too taxing. Finally, we followed the subjects' responses to the single, five-choice item with probe questions designed to determine more precisely what subjects believed about intro- and extramission. These questions asked: ''Does what comes into (goes out of) our eyes help us see?'' and ''If nothing came into (went out of) our eyes, do you think we could still see?''. When the subject's response to the last question admitted to both intromission and extramission the probe questions asked about input and output.

Results and Discussion

A 4 (Grade) × 2 (Sex) × 2 (Complexity Order: two-choice questions first versus last) × 2 (Question Position: In versus out questions on top) analysis of variance on the number of correct, i.e., intromission-only, responses to the computer questions showed a significant effect only for grade, $F(3,151) = 15.68$, $p < .0001$, with college students showing higher scores ($M = 3.8$) than eighth graders ($M = 2.0$), fifth graders ($M = 1.3$) and third graders ($M = 1.3$). The difference between eighth graders and the younger children was not significant, $p < .11$. An additional analysis, which included responses to the single, five-choice verbal question, yielded the same outcome.

Grade effects in the responses to individual questions were analyzed by chi square tests. In these analyses subjects were classified as responding with intromission (an ''in'' only response) versus at least some extramission. The frequencies of performance appear in Table 1, for each question.

Although chi square analyses indicated that the grade effects were significant for each question, the grade change for the simple two-choice question pitting intromission against extramission was the most even and in certain respects the most dramatic. Here, third graders favored the extramission over the intromission choice by about a 3 to 1 ratio and college students showed the opposite trend, preferring the intromission to extramission interpretation, by nearly a 7 to 1 ratio. Notice also that on this item there was a shift between fifth and eighth grades with the majority of fifth graders choosing extramission and the eighth graders choosing intromission over extramission by a 2:1 ratio.

TABLE 1
Frequencies of Subjects at Each Grade Level Showing Intromission (I) or Some Extramission (E) Responses as a Function of Question Type, in Study 2

	Question type															
	In/Out		In/Out/ First in		In/Out/ First out		In/Out/ Simultaneous		In/Out/First in/First out		In/Out/ First in/ Simultaneous		In/Out/ First out/ Simultaneous		Verbal—Five choices	
Grades	I	E	I	E	I	E	I	E	I	E	I	E	I	E	I	E
3	10	31	6	35	8	33	10	30	4	37	5	36	8	33	4	36
5	18	24	6	36	7	34	7	35	5	37	4	38	7	35	8	34
8	32	16	10	38	19	29	12	36	6	42	8	40	11	37	10	38
College	47	7	26	28	35	19	32	22	19	35	18	36	24	30	22	32

Note. Unequal *ns* across question types reflect missing data.

On the seven other test questions, which involved at least a three-part forced choice, many more children selected a choice which had extramission than the choice that depicted only input. Interestingly, although the college students' performance was better than that of the children, more college students gave incorrect rather than correct responses on 5 of the 7 items. Thus the difference between college students and children does not often appear to be as dramatic for these items.

The finding that there were more extramission interpretations on the 7 items offering more than two choices, as compared to the two-choice item, might have occurred for a number of reasons: The increased number of alternatives, statistically, gave those subjects who might have been responding by chance a greater opportunity to select extramission interpretations; for some subjects, increasing the choices might have engendered confusion; and the increased number of choices might have given subjects a response option that was more in keeping with their beliefs. However, a person with a firm understanding of vision should not have been flummoxed by an increased number of choices, as evidenced by the fact that 16 college students gave consistent intromission responses across all trials.

Finally, inspection of the data indicates that the most complex item, the verbal, five-choice item that always came last, was no more difficult than any of the four-choice items. This outcome was not particularly surprising, however, given the fact that subjects had much practice with several complex items before receiving the five-choice question.[2]

Results of analyses of the follow-up questions confirmed findings from previous studies by Cottrell and Winer (1994). Thus a large number of subjects who admitted to extramission on the last question claimed that what went out of our eyes helped us see (third grade, 93%; fifth grade, 92%; eighth grade, 84%; college, 77%, with no significant grade differences). Among these same subjects, the majority claimed we would not be able to see if nothing went out of our eyes (third graders, 60%; fifth graders 59%; eighth graders and college students, 63%; again, with no significant grade differences).

A similar analysis was conducted on the responses from those subjects

[2] There is an apparent contradiction in the fact that in designing the computer program we allowed for only four choices, thinking five representations would overload subjects, while in the final verbal question of this study, subjects seemingly had no difficulty in responding to five verbal choices. It must be emphasized, however, that in designing the program for this study it became obvious that including five representations on the screen required reducing the size of each representation. The resulting representations were very small, and when five items were presented on the screen, appeared to be nearly chaotic, visually. It is conceivable, of course, that after appropriate practice, the five representations might have been manageable for children and adults. But it is also conceivable that even with appropriate prior practice, the five-choice visual item might have been overwhelming, at least for children—even despite the fact that the 5-choice verbal item was not. In any event, we decided not to allow for 5 choices on the screen, realizing that we were sacrificing a potentially interesting item.

TABLE 2
Frequencies of Subjects at Each Grade Level Showing the Various Responses to the Five-Choice, Verbal Item of Study 2

	Response type				
Grades	In	Out	First in	First out	Simultaneous
3	4	9	7	7	13
5	8	4	10	8	12
8	10	2	7	7	22
College	22	0	14	6	12

who admitted to intromission. The results showed that 80 to 92% of this sample indicated that input aided vision (third grade, 87%; fifth grade 92%; eighth grade 80%; college, 87%). However, among the oldest subjects, 7 (of 54) college students and 9 (of 48) eighth graders claimed that input did not aid vision. When asked whether vision was possible without input, 78–91% correctly stated that we would not be able to see if nothing went into the eyes (third grade, 83%; fifth grade, 78%; eighth grade, 78%; college, 91%). Thus it appears that, overall, there was a stronger conviction in the necessity of input than that of output.

Analyses of explanations given to the follow-up questions showed that most children and adults did not give explanations or did not give explanations that could be interpreted. However, among subjects giving interpretable extramission explanations, the largest category of response was one in which subjects merely reiterated that it was necessary for something to go out of our eyes, i.e., if something did not go out we would not be able to see. Some subjects believed that output helped improve the act of vision, i.e., sharper focus, less blurry, clearer seeing, or that output actually projected the image of the object outward so that it could be seen (like a movie projecting on a screen). Others referred to the fact that output aided color perception or illuminated visual referents.

Finally, Table 2 presents the frequencies of subjects giving each of the 5 choices, presented on the last, verbal question. Visual inspection of the table reveals that across grades there was a steady increase in the number of pure intromission responses and a decline in pure extramission responses, $\chi^2(12, N = 184) = 33.5, p < .001$. The simultaneous choice was favored by many students of all grades, and among the college students the graphic demonstrating input followed by output (first in) was also favored.

In summary, this study provided some of the strongest evidence for extramission that has been reported. Nothing in the Cottrell and Winer studies or in the previous studies in this document would have led us to expect as much evidence of extramission as was obtained. The scores demonstrated that most subjects at every age gave at least some extramission responses.

Perhaps the most important grade change occurred when we examined responses to the simple two-choice item, since this item required a simple choice between what is commonly accepted as the correct interpretation of vision and the exact opposite, namely, a response admitting of pure extramission with no apparent input. Several points should be noted about responses to this question. First, there were exceptionally large numbers of extramission responders among the youngest children, especially in terms of the number of extramission responders reported in previous research. What makes the extramission findings for the younger children—and indeed for subjects of all age levels—even more compelling is that an extramission response on this two-part item required a rejection of intromission. The high performance of the college students on this item also made the developmental trend appear particularly dramatic. However, we should not overlook the fact that 7 out of 54 college students chose extramission over intromission when given the choice between the two. We had expected that virtually no college student would give such a response. This expectation was based on the supposition that all students would have been schooled in the basic facts about perception. In fact the college students were tested after their introductory psychology units on sensation and perception. (Subsequent studies have revealed that all college students, and indeed many elementary school students had knowledge about certain basic facts about perception, such as the inversion of an image on the retina, thus indicating that they had instruction in visual perception.)

STUDY 3

There were two reasons for Study 3. To begin with, since the forced-choice items of Study 2 provided some of the most striking evidence of extramission among both children and adults we wanted to use this same type of question to compare purely verbal items with questions addressed to animated computer graphic representations of vision. Given the results of Study 1, we expected a small difference between verbal and computer items, with higher numbers of intromission interpretations on the purely verbal questions.

We were also interested in determining whether more elaborate instructions would facilitate performance. Thus in one condition of this study, prior to the main test questions we not only specifically instructed subjects that we were going to ask about how they see; we also specifically instructed them that we were going to ask about whether anything came into or left the eye during vision. This forewarning should have allowed subjects time to reflect on the content of the questions and thus presumably would improve performance.

We assumed that part of the reason for subjects' extramission responses is that they respond to our questions impressionistically, without relying on scientific knowledge that might have been acquired through tuition. Presumably part of the reason for this impressionistic response is that the phenomenology of the outerdirected quality of vision matched the dynamic quality of movement of outward lines, portrayed graphically. The tendency to respond intuitively and impressionistically should diminish, we hypothesized, if subjects were allowed an initial opportunity without any graphics to consider whether vision involves input or output. In that case subjects should be more influenced by declarative knowledge, presumably acquired through education.

Method

Subjects. Subjects were 12 boys and 22 girls in the third grade (mean age = 9.0 years; range = 7.3–9.8 years), 9 boys and 27 girls in the fifth grade (mean age = 11.1 years; range = 10.4–11.9 years), and 12 male and 28 female college students (mean age = 19.8 years; range = 18.0–31.2 years). The elementary school students were attending a parochial school located in a major metropolitan area; the college students participated in the study for course credit.

Questions and procedure. There were three conditions. In two we instructed subjects that we were interested in having them tell us how they see, just as in Study 1. We then proceeded to the first question, which was a two-part, forced choice between intromission and extramission. In one of these two conditions the initial question was presented purely verbally, and in the second, the same question was presented with computer graphics.

Subjects in a third condition initially received elaborated pretest instructions forewarning them about the nature of the upcoming computer question: ''We are interested in how people see. I am going to ask you about how we see. I want to know whether anything goes into the eyes or out of the eyes when we see. I am going to show you two pictures on computer of a person who is seeing something. One picture will show something going into the person's eyes. One will show something going out of the person's eyes. You will have to choose and tell me which one best shows how or why we see.'' They were then administered the two-part (intromission versus extramission) question with computer graphics.

In each of the three conditions, after presenting the initial two-choice item, we proceeded to a single, four-choice computer item designed to allow subjects to explain, in greater detail, the meaning of their responses to the first question. For example, if the subject initially gave an intromission response we instructed the subject that there were different ways something might come into the eye. We then presented four possibilities on the screen, describing each: input only (a repetition of the choice the subject selected on the first item), input followed by output, output followed by input, and simultaneous input and output. The subject was asked to select the graphic that best demonstrated how or why we see. If the subject gave an extramission response to the first question, the subsequent questions included a single extramission graphic, along with three additional depictions of how extramission might occur, i.e., input followed by output, output followed by input, and simultaneous input and output.

The fact that the response to the initial question was included among the choices on the second question might suggest to subjects that they should change their initial answer. That is, the second question might implicitly cue subjects to give something other than the response provided to the first item. However, if subjects firmly believe in, say, intromission, then the additional cuing should not matter. In a sense, then, the second item can be seen as a test of the strength of the belief in the first response given.

Results

An initial analysis was conducted on responses to the first two-choice item received. The results are presented in Table 3, which shows, by grade, the frequencies of intromission and extramission responders for each type of question. As can be seen, there was a striking difference depending upon the condition or type of presentation. Notice, to begin with, that when the questions were presented via computer and without warning, the grade effect generally replicated the finding in Study 2, where there was about a 3:1 ratio of extramission responses to intromission responses, among the third graders, and an increase in correct responding across grades. However, in the present study, more college students affirmed extramission (6 of 15) than in Study 2 (7 of 54), a difference that might be attributable to sampling effects.

The age trend was completely eliminated, though, when subjects received the purely verbal item. Here, almost all subjects at every grade level expressed a preference for the intromission response. A chi square analysis, which combined subjects across grades and compared subjects who received the purely verbal item versus the computer items, on intromission versus extramission responses, showed that the difference between computer and purely verbal presentations was statistically significant, χ^2 (1, N = 110) = 13.91, $p < .001$.

An analysis of responses to the single computer item which was preceded by a warning that the upcoming questions would ask specifically about input or output, revealed a somewhat unexpected pattern of performance. At both the third grade and college levels subjects who received the warning did, at best, only slightly better than subjects given the same computer question without the warning. At the fifth grade level, however, this pattern was reversed: Only 1 of 12 subjects given the advanced warning answered with the intromission response versus 5 of 12 given the same item without warning, $p < .08$, Fisher exact test. Note that there was a decline between Grades 3 and 5 and an increase between Grade 5 and college in intromission responding, on the computer items given with warning.

Analyses of the responses to the follow-up question revealed, perhaps most importantly, that almost all children and many adults who initially gave an intromission response failed to give this same response on the second trial in which more choices were presented. That is, they abandoned the technically correct intromission choice and opted for a choice of some combination of extramission and intromission. Thus out of a total of 34 grade school children who gave an intromission response to trial 1, only 3 repeated the same response on trial 2. And of 30 college students who initially gave an intromission

TABLE 3

Frequencies of Subjects at Each Grade Level, Showing Intromission versus Extramission Responses, by Conditions on the Question Asking for a Choice between Intromission and Extramission Interpretations, in Study 4

	Grades					
	3		5		College	
	Response types					
Conditions	Extramission	Intromission	Extramission	Intromission	Extramission	Intromission
Computer	8	3	7	5	6	9
Verbal	2	10	3	9	1	11
Computer/ Warning	5	6	11	1	3	10

response, only 10 gave the same response on the second trial. Clearly, neither children nor adults have a firmly grounded intromission notion. Further analyses showed that on trial 2, the most popular responses were the choices making reference to (A) input followed by output and (B) simultaneity of input and output.

What about subjects who selected the extramission choice on trial 1? They, too, abandoned the choice they had made on the first trial. Thus, only two third graders selected the pure extramission choice on trial 2. When we examined the distribution of responses among the various possible choices on question 2 we found a tendency for children to select the representations depicting, (A) input followed by output, and (B) simultaneity of input and output, the same interpretations that were selected by those who initially gave an intromission response to the first question. The college students who initially chose the graphic depicting only output rejected that choice on the follow-up question and were relatively evenly divided on the remaining items.

Discussion

The results of this study were quite unexpected. Although we had anticipated more intromission responses when subjects were tested with the verbal as opposed to the graphic items, we certainly did not expect a virtual total acceptance of intromission over extramission—especially given the results of Study 2, which showed a large number of extramission responses among the young children given the two-choice problem, and the results of Study 1, which showed that the verbal-graphic effect, although reliable, was not large. Clearly under conditions of purely verbal presentation there is a strong tendency for subjects of all ages to prefer a belief in intromission as opposed to extramission.

The magnitude of the effect can perhaps be put into perspective when we consider that we have conducted more than 20 studies, using a variety of techniques, and have always found strong evidence for extramission beliefs among children. Moreover, we have found it exceedingly difficult to change subjects' responses by use of experimental interventions. For example, college students have not made dramatic changes toward intromission beliefs as a function of having received lessons, readings, and tests on perception, in introductory psychology classes, and they have failed to change consistently as a function of having received readings on visual perception, immediately prior to our tests (Hedman, 1995; Winer, Cottrell, & Karefilaki, 1994).

The change in responses seen across trials deserves some comment. The fact that subjects who gave the extramission responses to trial one changed on trial 2, is not as significant as the change shown by those subjects who were intromissionists on the first trial. That is, the change shown by the extramissionists was from one type of extramission response to another, while the change shown by the initial intromissionists was from intromission to extramission.

The change demonstrated by the initial intromissionists is likely due to the fact that the non-intromission choices offered on the subsequent trial were more appealing to them than the simple non-intromission choice offered on trial one. That is, some of these choices might have provided a better fit with their concept of vision than the simple intromission or extramission response. Other factors might have been influenced their behavior as well. The fact that some choices in the questions were repeated might have suggested that subjects change their responses. There was also a statistically greater opportunity for an error on the second trial, which offered four, as opposed to the two, choices of trial one. The increased number of choices on the second trial perhaps tempted some subjects with a strategy of taking a middle of the road position, in which they could include mention of both options, i.e., allowing what might have appeared to be a safer bet. Finally, the increased number of choices might have confused some subjects.

It was surprising that there was practically no overall effect from the initial warning that the upcoming items would specifically ask about input versus output. In fact, at the fifth grade level the difference, although slight, was in the opposite direction from that predicted. There is no simple explanation for this outcome. Recall, however, that in past research older children sometimes demonstrated more extramission than younger children. There (see Winer, Cottrell, Karefilaki & Chronister, 1996) it was assumed that perhaps some cognitive sophistication was required for extramission. The fact that extramission interpretations seemed to be particularly strong among fifth graders given the advanced warning is thus consistent with the earlier findings.

Finally, the difference between questions with and without computer graphics in this study and in Study 1, complement findings using arrows to depict vision, in prior research. In fact, the results suggest that cues from the arrows did not yield more signs of extramission interpretations than the moving lines in the present research.

GENERAL DISCUSSION

At least three main findings emerged from the present studies. To begin with, all three studies revealed some evidence of a decline in extramission and an increase in intromission responses across age, thus replicating previous findings. Second, the results demonstrated more technically correct intromission responses in the verbal versus the computer conditions. Third, the difference between the verbal and graphic presentations depended on the type of question asked. On items asking for a simple affirmation or denial of intromission or extramission, the difference, although significant, was slight, and it did not alter the developmental trend that occurred. Indeed, our initial interpretation of the difference between computer and verbal conditions of Study 1 was that the graphic and verbal presentations were almost interchangeable. For the questions that forced a choice between intromission and extramission responses, however, a dramatically different finding appeared. Here, on the graphic items we obtained particularly strong evidence for extramission interpretations in children, and, in comparison to findings from our other research, in adults as well. But, surprisingly, on the verbal items, the vast majority of subjects of all ages chose intromission, with no grade differences.

One major question that arises from the results is whether the forced-choice computer items enhanced extramission performance, or whether the forced-choice verbal items increased intromission responses, or whether, in fact, both effects occurred. This question especially applies to the results of Study 3, which showed a striking difference between responses to the two types of item. While there is no conclusive way to answer this question based on the results of the studies in this report, a comparison of the outcome of Study 3 with findings from other studies (Cottrell & Winer, 1994; Winer, Cottrell, Karefilaki, & Chronister, 1996) or, indeed, with findings in Study 1, suggests that perhaps both types of response, intromission and extramission, were enhanced by the verbal and pictorial conditions, respectively. Consider, for example, that on the two-choice items, given to the youngest children, there was strong evidence for extramission in Study 2 and in the computer condition of Study 3, given without warning: a ratio of about 3 to 1. Results of other studies, on the other hand, often showed that young children were relatively evenly inclined to admit to intromission and extramission when asked questions on each possibility, requiring a ''yes'' or ''no'' answer (see Cottrell & Winer, 1994; cf. means of Study 1 in the present report). Similarly, on the two-choice item, in the verbal condition of Study 3, there were practically no extramission responses, whereas in other studies many children gave extramission interpretations.

One other central issue regarding the results should be addressed, namely, whether what appear to be extramission beliefs are an artifact of the question asked. The fact that the extramission response was virtually eliminated under one condition in Study 3 might be taken as evidence that children really are not extramissionists by nature. However, an intromission response on the two-part, forced-choice question in Study 3 did not necessarily mean that subjects were not also extramissionists, as was shown in their responses to the next question, which were almost unanimously extramissionist. Note, too, that there was considerable evidence for extramission beliefs on the last, purely verbal, trial in Study 2. Finally, as was noted in the introduction, prior research has demonstrated extramission interpretations under a variety of different question types and formats.

How then do we account for the effects? We have already mentioned one possible explanation of the bias for extramission under conditions of computer representation, namely, that the computer representation of extramission matches the subject's phenomenology of the outerdirected, orientational quality of vision. That is, phenomenologically, we experience ourselves as looking outward, at and toward objects, and this phenomenology of outerdirectedness might be related to the belief in emissions from the eye. The form of the relation could involve a syncresis in which the outward dynamics of the phenomenology of vision become fused and incorporated with the idea of extramission. The dynamic and directional quality of the outward moving lines in the graphic representations might underscore the phenomenology of the outerdirected quality of vision and thus promote this syncretic process. Another way of describing this process is to say that subjects might assimilate the directional or vectorial quality of their orientational experiences into their concept of visual output. Opposed to such an assimilative process is an understanding of vision that is based on information acquired through learning or education. Additional research, comparing drawing and verbal responses (Winer & Cottrell, 1995) supports this interpretation.

This explanation is compatible with the Wapner and Werner theory of perception (Wapner & Werner, 1957), with Werner's theory of development (Werner, 1948; Werner, 1957; Werner & Kaplan, 1963) and with the Werner and Kaplan (1963) theory of language and language development. The sensory-tonic theory of perception (Wapner & Werner, 1957) suggests a possible connection between perceived dynamic properties of objects and tonic or bodily states, and Werner's theory of development provides many instances of syncretic functioning, even among adults under certain conditions. Moreover Werner and Kaplan's (1963) theory of symbolization is based on the notion that dynamic, affective qualities of external referents are an essential character of the meaning of words. We are, perhaps, extending their theory in applying it to scientific interpretations as opposed to word meanings.

Our explanation assumes that graphics demonstrating visual output matched and highlighted the phenomenology of outerdirectedness and that the vectorial quality of outerdirectedness then possibly became fused or incorporated with the idea of extramission. It does *not* assume that subjects professing extramission might have directly interpreted their outgoing responses to mean any one of a number of aspects of outerdirectedness, such as orientation or line and direction of sight. That is, we are not maintaining that subjects simply supplanted the idea of extramission with the idea of directionality of vision, essentially misinterpreting or reinterpreting the question. If that were the case, subjects would not have believed in extramission, per se. Instead, what would have appeared to be an extramission response would really have only been a belief in, say, visual orientation.

It is inconceivable from the results of the three studies in this report, as well as from other studies we have conducted, that what appear to be extramission responses are simply beliefs about visual orientation. In responses to our follow-up questions many subjects have told us how emissions from the eye function to help us see. Also, each one of our questions explicitly referred to something going into or out of the eyes, and not to visual direction or orientation. Furthermore, many of our studies have included manipulations that should have influenced responses if subjects were simply interpreting our questions as just referring to, say, line of sight. Thus one condition of Study 3 explicitly forewarned subjects that the questions were specifically about whether something enters or leaves the eye. Subjects inclined to misinterpret the questions as referring to the orientational quality of vision should have benefited from the clarification inherent in the forewarning; the results showed that the difference, if any, was in the opposite direction. Also in pilot work for the present studies we have varied inclusion of the expression, ''rays, waves or anything else,'' in our questions and have found the variation to have no effect. Again, subjects misinterpreting our questions to refer to something such as line of sight or orientation, should have been swayed from that misinterpretation when specific examples of types of input and output were mentioned. In short, we are arguing that the dynamics inherent in the outerdirectedness of vision match the dynamics of the extramission graphic and become syncretically incorporated into the meaning of extramission.

However, our results are also compatible with other interpretations. Consider Paivio's (see 1986, 1991a, 1991b, for recent summaries) dual coding model, which argues for two levels of representation, one based on what might be termed imagery, the other predominantly verbal. Here, it might be assumed that the impressions made by the computer graphics induced the subjects to reason in terms of images and perhaps to ignore knowledge that might have existed on a verbal-representational level. Paivio's model is also similar to our explanation in that it offers an account for the increased number of intromission responses under conditions of verbal questioning. It is possible that the purely verbal processing enables children or adults to tap into verbal concepts that have been learned, or perhaps even certain linguistic expressions, such as the ''the sun is in my eyes,'' that might have fostered intromission interpretations. However, this explanation must be considered as at least partially ad hoc, since it is not obvious from Paivio's theory that we should have expected a superiority of the verbal over the visual condition.

It is also possible that the demands of information processing affected performance. For example, the items presented with computer graphics required subjects to respond to verbal and pictorial information while the noncomputer items required only verbal processing. Possibly the difficulties inherent in integrating verbal knowledge and pictorial information provided a source of difficulty and did not allow subjects to access information that they might otherwise have used.

When considering the various interpretations, we should be mindful of potential limitations of the study. For example, this study presented subjects with response choices and did not use an open ended format. As was noted, in comparison to other research, the questions often presented the subjects with a number of choices, which in some instances, might have engendered confusion. In some instances, choices were repeated or seemed to be repeated, which might have suggested that subjects switch their responses. However, even with these limitations we remained surprised, if not shocked, by the number of adults, in particular, demonstrating extramission under certain conditions.

The results of this study have implications for several general issues. For example one question raised by the results concerns the relation between explicit, formal beliefs that are a product of education, such as scientific theories of vision, and implicit beliefs that people might harbor. The results suggest a dynamic interplay between these types of understanding and raise the question of the conditions under which they interact, and the manner in which they are ultimately integrated.

The results also allow for the possibility that the mode of representing a phenomenon might affect one's understanding or belief about it. That is, understanding might be at least partially dependent on the type of representation or symbols employed, a contention that is in a general sense consistent with constructivist-representational theorists (e.g., Cassirer, 1953; Lakoff, 1987). It would be particularly interesting to demonstrate transfer effects from one mode to another, for such transfer would reveal a more enduring and widespread impact of representational mode on beliefs.

While the fact that type of representation influenced judgments is intriguing, what is particularly counterintuitive about our results is the direction of the effect and its implications. For example, the differences obtained seem to contradict long-standing traditions in both education and developmental psychology regarding the relative effectiveness of verbal versus pictorial types of representation. Educators have long held that pictorial presentation is an effective means of concretizing abstract concepts and thus of aiding understanding. Developmentalists have also generally assumed that pictorial or iconic representation is developmentally less advanced than verbal or symbolic forms of representation (Werner, 1948; Bruner, 1964). Even Paivio's model is based on research that usually shows higher levels of performance on tasks involving imagery as opposed to words, and supports the use of imagery to aid learning (see Paivio, 1980). Seldom has it been suggested that more abstract, verbal presentations might enhance the performance of young children, although one can find scattered references to such possibilities. Thus Wohlwill (1968) argued in one instance that purely verbal presentations of Piaget's class inclusion problem facilitated performance, ostensibly because it removed misleading cues inherent in the pictures, although his results were contested by Winer (1974).

There are at least three other areas in which the results of this study have general significance. First, they bring into question theories such as Carey's (1985; 1988), that liken cognitive development to changes in theories or belief systems. Carey's theory, in fact, argues for a similarity between some shifts in theories comprising cognitive development and paradigm shifts that have occurred in the history of science. The fact that beliefs in the present research seemed to change as a function of question structure and mode of presentation suggests considerable variations in interpretations or beliefs. This is not what one would expect from a change in beliefs that resembles a strong restructuring or a paradigmatic shift in thinking. That so many adults erred also suggests that what might appear to be an advanced theory may rather be the insertion of correct beliefs or bits of factual information into an older theory that contains profound misconceptions.

Second, the results of this and of other intromission-extramission research relate to work on the theory of mind. Much of the theory of mind research has shown that young children are considerably more advanced in their reasoning about mental processes than psychologists had thought (see, for example, texts by Astington, Harris & Olson, 1988, or by Wellman, 1990, on theories of mind). This sophistication seemingly extends to knowledge about certain core aspects of visual perception (see Winer, 1991 for a review). The findings of intromission-extramission research document surprising shortfalls in the understanding of basic biological and psychological processes, not only among children, but also among adults. Certainly what the results demonstrate is that among adult subjects, who should have formal and explicit knowledge of perception, what appear to be naive and intuitive notions of perception remain very compelling.

Finally, when we consider the large literature on misconceptions in science (see, Chinn & Brewer, 1993; Helm & Novak, 1983; Vosniadou & Brewer, 1987) the results of the present study are of particular relevance since they suggest that the misunderstandings of children and adults depend on the medium of representation. We know of no other instances in which apparently dramatic differences in beliefs have emerged as a function of the type of symbol employed.

REFERENCES

Astington, J. W., Harris, P. L., & Olson, D. R. (Eds.) (1988). *Developing theories of mind.* Cambridge: Cambridge Univ. Press.

Bruner, J. S. (1964). The course of cognitive growth. *American Psychologist,* **19,** 1–15.

Carey, S. (1985). *Conceptual change in childhood.* Cambridge, MA: MIT Press.

Carey, S. (1988). Reorganization of knowledge in the course of acquisition. In S. Strauss (Ed.), *Ontogeny, phylogeny and historical development* (pp. 1–27). Norwood, NJ: Ablex.

Cassirer, E. (1953). *The philosophy of symbolic forms, Vol. 1.* New Haven: Yale University Press.

Chinn, C. A., & Brewer, W. F. (1993). The role of anomalous data in knowledge acquisition: A theoretical framework and implications for science instruction. *Review of Educational Research,* **63,** 1–49.

Cottrell, J. E., & Winer, G. A. (1994). Development in the understanding of perception: The decline of extramission perception beliefs. *Developmental Psychology,* **30,** 218–228.

Cottrell, J. E., Winer, G. A., & Smith, M. C. (1996). Beliefs of children and adults about feeling stares of unseen others. *Developmental Psychology,* **32,** 50–61.

Eaton, J. F., Anderson, C. W., & Smith, E. L. (1984). Students' misconceptions interfere with science learning: Case studies of fifth-grade students. *The Elementary School Journal,* **84,** 365–379.

Guesne, E. (1984). Children's ideas about light. In E. J. Wenham (Ed.), *New trends in physics teaching* (Vol. 4, pp. 179–192). Paris: UNESCO.

Guesne, E. (1985). Light. In R. Driver, E. Guesne, & A. Tiberghien (Eds.). *Children's ideas in science* (pp. 10–32). Philadelphia: Open University Press.

Helm, H., & Novak, J. D. (Eds.). (1983). *Proceedings of the International Seminar: Misconceptions in Science and Mathematics.* Ithaca, NY: Cornell University.

Hedman, K. E. (1995). *College students' beliefs about vision: Effects of learning experiences.* Unpublished honor's thesis, Ohio State University.

Kaiser, M. K., McCloskey, M., & Proffitt, D. R. (1985). The development of beliefs about falling objects. *Perception and psychophysics,* **38,** 533–539.

Kaiser, M. K., McCloskey, M., & Proffitt, D. R. (1986). Development of intuitive theories of motion: Curvilinear motion in the absence of external forces. *Developmental Psychology,* **22,** 67–71.

Lakoff, G. (1987). *Women, fire and dangerous things: What categories reveal about the mind.* Chicago: University of Chicago Press.

Lindberg, D. C. (1976). *Theories of vision from al-Kindi to Kepler.* Chicago: University of Chicago Press.

Lindberg, D. C. (1992). *The beginnings of Western science: The European scientific tradition in philosophical, religious and institutional context, 600 B.C. to A.D. 1450.* Chicago: University of Chicago Press.

McCloskey, M. (1983). Intuitive physics. *Scientific American,* **284,** 122–130.

McCloskey, M., & Kargon, R. (1988). The meaning and use of historical models in the study of intuitive physics. In S. Strauss (Ed.), *Ontogeny, phylogeny and historical development* (pp. 49–67). Norwood, NJ: Ablex.

Meyering, T. C. (1989). *Historical roots of cognitive science: The rise of a cognitive theory of perception from antiquity to the nineteenth century.* Dordrecht: Kluwer Academic Publishers.

Paivio, A. (1980). Imagery as a private audiovisual aid. *Instructional Science,* **9,** 295–309.

Paivio, A. (1986). *Mental representations: A dual coding approach.* New York: Oxford University Press.

Paivio, A. (1991a). Dual coding theory: Retrospect and current status. *Canadian Journal of Psychology,* **45,** 255–287.

Paivio, A. (1991b). *Images in mind: The evolution of a theory.* London: Harvester Wheatsheaf.

Piaget, J. (1929/1969). *The child's conception of the world.* Totowa, NJ: Littlefield, Adams & Co.

Piaget, J. (1971). *Les explications causales.* Paris: Presses Universitaires de France.

Piaget, J. (1974). *Understanding causality.* New York: Norton.

Piaget, J., & Lannoy, J. de. (1971). *La projection de la lumière et de la chaleur.* (Referenced in Piaget, 1971).

Piaget, J., & Papert, A. (1971). La vision et la lumière. (Referenced in Piaget, 1971).

Strauss, S. (Ed.). (1988). *Ontogeny, phylogeny and historical development.* Norwood, NJ: Ablex.

Vosniadou, S., & Brewer, W. F. (1987). Theories of knowledge restructuring in development. *Review of Educational Research,* **57,** 51–67.

Vosniadou, S., & Brewer, W. F. (1992). Mental models of the earth: A study of conceptual change in childhood. *Cognitive Psychology,* **24,** 535–585.

Wapner, S., & Werner, H. (1957). *Perceptual development: An investigation within the framework of sensory-tonic field theory.* Worcester, MA: Clark University Press.

Wellman, H. (1990). *The child's theory of mind.* Cambridge, MA: MIT Press.

Werner, H. (1948). *The comparative psychology of mental development.* New York: International Universities Press.

Werner, H. (1957). The concept of development from a comparative and organismic point of view. In D. B. Harris (Ed.), *The concept of development. An issue in the study of human behavior* (pp. 125–148). Minneapolis: University of Minnesota Press.

Werner, H., & Kaplan, B. (1963). *Symbol formation: An organismic-developmental approach to language and the expression of thought.* New York: John Wiley & Sons.

Winer, G. A. (1991). Children's understanding of perception and perceptual processes. In. R. Vasta (Ed.), *Annals of child development* (pp. 177–213). London: Jessica Kingsley Publishers.

Winer, G. A., & Cottrell, J. E. (in press). *Effects of drawing on directional representations of the process of vision. Journal of Educational Psychology.*

Winer, G. A., & Cottrell, J. E., & Karefilaki, K. (1994). *Extramission perception beliefs: Effects* *of education.* Presented at the 1994 Meetings of the American Psychological Society, Washington, D.C.

Winer, G. A. (1974). An analysis of verbal facilitation of class-inclusion reasoning. *Child Development,* **45,** 224–227.

Winer, G. A., Cottrell, J. E., Karefilaki, K. D., & Chronister, M. (1996). Conditions affecting beliefs about visual perception among children and adults. *Journal of Experimental Child Psychology,* **61,** 93–115.

Wohlwill, J. F. (1968). Responses to class-inclusion questions for verbally and pictorially presented items. *Child Development,* **39,** 449–465.

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