clude, among others, learning number names (e.g., "one," "two," "three"), complex arithmetic (e.g., 34 + 46 = ?), and most features of more complex mathematical domains (e.g., algebra).

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Does Anything Leave the Eye When We See? Extramission Beliefs of Children and Adults

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Could an erroneous, ancient theory of visual perception still be a commonly held belief of children and adults at the end of the 20th century? A number of ancient philosophers, including Plato, Euclid, and Ptolemy, believed in what has been termed the extramission theory of visual perception. This extramission theory stressed that there were emanations from the eyes during the act of seeing. That is, essences or the like were thought to leave the eye during the act of visual perception. With advances in the sciences of optics and physiology, the extramission theory was replaced by what is called the intromission theory. This theory holds that there is only input to the visual system and that this information alone allows people to see. The extramission theory was ultimately put to rest in scientific and philosophical circles in the early 17th century, although informed opinion had generally dismissed extramission notions as early as the 13th century (personal communication, D.C. Lindberg, March 29, 1996).

Our research on extramission beliefs was prompted by one of Piaget's observations. Piaget (1926/1929) first suggested that children believe in visual extramissions when he noted a child expressing the idea that looks mix when they meet, a comment which seems to suggest that emanations from the eyes of two people who are looking at each other make contact and mix together. Later, in unpub-

Recommended Reading

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

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lished papers, Piaget claimed to have found evidence for such beliefs (see Piaget, 1971/1974). The idea that children might believe there is actually output from the eyes represents a striking instance of a scientific misconception.

Children and adults hold a number of misconceptions about scientific phenomena. For example, young elementary school children tend to believe the earth is flat (Vosniadou & Brewer, 1992); and both children and adults have many incorrect ideas about, for example, the movement of objects and the extent to which objects conform to principles of Newtonian physics. Thus, people often believe that an object dropped from a moving body will fall straight down, as opposed to following a curved path to the earth (Kaiser, Proffitt, & McCloskey, 1985; McCloskey, Washburn, & Felch, 1983); or they believe that an object expelled from a curved tube will continue to move in a circular direction instead of following the path of a straight line (Kaiser, McCloskey, & Proffitt, 1986; McCloskey, Caramazza, & Green, 1980).

Despite findings about these and other scientific misconceptions, one might suspect that children, and particularly adults, would resist affirming output from the eye. After all, vision represents a major perceptual modality, and the process of vision is taught repeatedly at all educational levels, as are facts about other senses whose processes are not unrelated to vision. Moreover, people have various daily experiences reminding them of visual input, such as the sun shining in their eyes.

Therefore, what we have discovered is surprising: Not only do children hold extramission beliefs, but many adults do as well, although there is a clear tendency for extramission beliefs to decline between childhood and adulthood. Moreover, as it turns out, extramission beliefs are highly resistant to many experimental interventions designed to alter them.

Our first studies on this topic focused on simple questions that required a "yes" or "no" response, such as, "When we look at someone or something, does anything such as rays, waves, or energy go out of our eyes? . . . into our eyes? . . . first go out of the eyes and then go back in?" However, we also included a three-part, forced-choice item asking participants whether anything goes into the eyes, out of the eyes, or both into and out of the eyes. These questions were presented to children in the first, third, and fifth grades and to college students.

The findings showed an unmistakable increase in correct intromission interpretations between childhood and adulthood, and a corresponding decline in incorrect extramission responses. For example, on the simple question asking whether anything goes into the eyes, a question asking about intromission, we found that 54% of first graders, 60% of third graders, 31% of fifth graders, and 88% of college students answered correctly. On the simple question asking whether anything goes out of the eyes, we found that 49% of first graders, 70% of third graders, 51% of fifth graders, and 33% of college students affirmed extramission (Cottrell & Winer, 1994, Study 2). We also found that the form of the question made a difference for the children. For example, when we presented the item asking for a choice among "in," "out," or "both," 75% to 80% of the children selected one of the two extramission responses (Cottrell & Winer, 1994, Study 2).

Although we consistently obtain differences between children and adults, it appears that there is not always a linear decline in extramission responses across increasingly higher grade levels in the elementary school years. Thus, in some of our first studies, extramission interpretations increased from first- to third-grade children (see Cottrell & Winer, 1994, Study 2), and in some of our subsequent studies, there was an increase from third to fifth graders (Winer, Cottrell, Karefilaki, & Chronister, 1996, Studies 2 and 3). It is as if an extramission interpretation requires some cognitive maturity. Interestingly, analogous developmental trends have been observed with respect to other scientific misconceptions (Kaiser et al., 1986).

EXTRAMISSION INTERPRETATIONS OCCUR UNDER A VARIETY OF CIRCUMSTANCES

Because the results on extramission surprised—indeed, shocked—us, despite the findings and observations of Piaget, we conducted a number of studies to determine the extent to which extramission interpretations persist in the face of conditions designed to promote the correct intromission interpretation of vision. In one instance, for example, we assumed that there would be more intromission and fewer extramission interpretations to questions asking about hearing and smelling than to items asking about vision. Furthermore, we hypothesized that initial intromission interpretations given to questions on smelling and hearing would generalize to subsequent questions on vision. The results supported the hypothesis that questions on hearing and smelling would prompt more intromission interpretations than questions on vision. But in only one of three studies (Winer & Cottrell, in press, Experiment 2, vs. Winer & Cot-

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trell, in press, Experiment 3, and Cottrell & Winer, 1994) did we find evidence of transfer from initial items on hearing to subsequent items on vision.

In another investigation, we presented questions that directly asked about objects that varied in luminosity or potential luminosity and were present during the testing: a shining lightbulb, the same lightbulb with the light turned off, and a white, styrofoam ball. We assumed that intromission interpretations given to the lit bulb would transfer when participants responded to subsequent questions referring to the reflective objects, namely, the unlit bulb and the styrofoam ball. The results again surprised us. Although many, but not all, participants affirmed visual input in response to our intromission question referring to the lit bulb, there was no generalization of the intromission interpretation when participants responded to subsequent questions referring to the nonluminous objects. In fact, it appeared as if some people took the turning off of the light as a signal that intromission had ceased. We had also assumed that it would be practically impossible for adults or children to deny intromission or affirm extramission when asked about a lightbulb that was shining in their eyes. However, in the combined results of two studies, 6% to 8% of adults and fifth graders and 24% of third graders denied intromission, and 33% of the adults and 35% of the third- and fifth-grade children affirmed extramission, in reference to seeing a lit bulb (see Winer et al., 1996; the data come from Studies 2 and 3, although they are not reported in this form).

We have found that many other stimulus manipulations have little or no effect on responses of children and college students to our vision questions. For instance, thinking that participants might have a predisposition to respond "yes" to our "yes" or "no" questions, which would have biased results toward extramission responses, we initially asked some participants absurd questions that required "no" responses (e.g., "Do you hear with your eyes?"; see the pilot study referred to in Winer, Cottrell, Karefilaki, & Gregg, in press). The absurd questions were used in case participants might be inclined to view our questions about vision as equally absurd. The absurd items had no impact on subsequent intromission-extramission questions on vision. Inclusion or exclusion of words such as "rays," "waves," or "energy" had no effect on responses, nor did asking participants to respond only about what was absolutely necessary for visual perception, nor did asking questions about "looking" versus asking questions about "seeing."

ORIGINS OF EXTRAMISSION BELIEFS: THEORY AND FINDINGS

What are the origins of extramission beliefs? One idea that occurred to us is that extramission notions are related to other superstitions about emanations from the eye. For centuries, for example, it has been supposed that the eye casts spells or transmits love or emotion (see Cottrell, Winer, & Smith, 1996, for a review of such themes in literature and science). Also, Titchener (1898) and others (e.g., Coover, 1913) in the history of psychology have studied beliefs that people can feel stares of an unseen other, such as would occur if you were standing on a street corner and someone stared at you from behind, causing you to turn and look. In a series of studies, we examined the assumptions that adults and children hold about feeling stares. However, one of the most interesting findings was that the belief in the ability to feel stares, which occurs at a high level among children as well as adults, seems, if anything, to increase with age, as if irrationality were increasing rather than declining between childhood and adulthood! Given that we have found extramission interpretations to decline between childhood and adulthood, it is perhaps not surprising that we found no correlation between beliefs about feeling unseen stares and beliefs about visual extramission. Only when we specifically asked participants about extramission in the context of the feeling-stares questions, that is, when we asked whether rays or the like go out of the eyes of a starer, were there correlations between a belief in feeling stares and a belief in extramissions (Cottrell et al., 1996).

Some conditions, however, have proven effective in altering responses to intromission-extramission questions, and these findings have not been irrelevant to our theory about the origins of extramission beliefs. In one case, we compared responses to purely verbal questions with responses to questions referring to animated computer graphics. The computer graphics portrayed various interpretations of the process of vision by displaying one or more renditions of a person looking at a rectangle, with visual input and output depicted by lines that appeared to move between the person's eye and the rectangle. Thus, in one graphic, lines, presumably representing rays, appeared to move inward from the rectangle to the eye of the figure on the screen, demonstrating the process of intromission. In another graphic, lines appeared to move outward from the eye toward the rectangle, demonstrating pure extramission. Other representations included lines first

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going toward the eye and then returning to the rectangle, lines going away from the eye toward the rectangle and returning back to the eye again, and simultaneous input and output. We presented as few as one graphic per trial, or as many as four on a screen simultaneously (i.e., four faces, each looking at a separate rectangle, each with a different process of vision represented). When we presented single representations of vision we asked "yes-no" questions, whereas when more than one graphic was displayed simultaneously we asked participants to select the graphic that best demonstrates how people see.

There are various reasons for comparing responses to our purely verbal questions with responses to items involving the computer graphics, and these reasons lead to opposite predictions. On the one hand, it can be argued that the purely verbal questions used in our initial research were open to misinterpretation, perhaps leading to what only appear to be extramission responses. For example, when we asked whether anything goes out of the eye when people see, participants who answered "yes" might have believed in some nonfunctional, reflective-like scattering emission, or perhaps they believed that rays leave the eye and go to the brain, although responses to follow-up questions have not yielded evidence of such interpretations. These possible misinterpretations of our questions are not represented on our computer graphics at all and thus would not be possible responses. In short, if we assume that participants misunderstood our questions and were giving only what appeared to be extramission interpretations, we would predict that the clarification provided by the animated computer graphics would lead to fewer extramission interpretations than occurred under the purely verbal questioning.

On the other hand, there is also reason to expect the opposite trend, namely, an increase in extramission responses to questions addressing animated computer graphics. This prediction stems from our theory about the origins of extramission. We assume that core aspects of the phenomenology of vision underlie extramission interpretations. Consider one phenomenologically salient aspect of vision, namely, its orientational or outer-directed quality. When people see, they are generally oriented toward an external visual referent, that is, they direct their eyes and attention to an object in order to see it. In fact, this quality of vision is reflected in language. People talk about "looking at" things, and English has expressions such as "looking out of a window" and "looking out of binoculars." Even notions such as "piercing glances" and "cutting looks" suggest an outer directionality that is not seemingly as evident in other senses. Thus, people can hear, smell, and even feel via touch without engaging in an outer-oriented, directional response. Because our computer graphics present representations that are suggestive of the orientational aspects of vision, in displaying moving lines emerging from the eye and seemingly moving toward a visual referent, it might be the case that the graphics, in matching the orientational phenomenology of vision, would enhance extramission responses. This interpretation is similar to the views expressed by diSessa (1993), who claims that underlying scientific misunderstandings are phenomenologically primitive responses.

Consistent with the theory, the findings revealed that the questions referring to computer graphics yielded more evidence of extramission than the questions presented in the purely verbal format. For instance, when we presented a two-choice question referring to computer graphics, asking participants to choose between a display representing visual input and another representing visual output, we found large numbers of children (60% of third graders, 75% of fifth graders) and even many adults (32% of college students) selected the extramission over the intromission graphic. When this two-choice item was presented purely verbally—this was the first study in which we made such a comparison using purely verbal questions—we strongly enhanced the number of intromission responses: Approximately 83% of both children and college students answered "in" when asked whether anything goes into the eyes or out of the eyes when people see; there were no differences between children and adults. In sum, it appeared as if the graphics increased extramission interpretations, whereas the purely verbal items increased intromission responses.

The verbal item did not necessarily elicit a correct intromission belief, however. A multiple-choice follow-up question used computer graphics to ask participants to clarify their answer to the preceding two-choice verbal item. Only 3 of 34 third and fifth graders and 10 of 30 college students who affirmed intromission on the first item repeated this technically correct response on the second question (Winer et al., in press). Work in progress suggests that this change was probably not attributable to the fact that we switched from purely verbal to computer graphic items. Rather, it appears more likely that offering participants choices that better match their beliefs yields more extramission responses.

It is interesting to speculate what would have happened had

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we used a simple two-choice (in vs. out), purely verbal item when we began our research, instead of the "yes-no" questions in which we asked separately about input versus output or the more complicated three-choice problems. We might have simply concluded that there was very little evidence for extramission beliefs among either children or adults. However, such a conclusion would have been in error. Aside from our other results, there is a priori reason to expect less evidence of extramission on the items forcing a choice between "in" and "out" than on the items asking separately about input and output. Responding "out" on the two-choice item would mean either a rejection of the belief that something enters the eye or a stronger belief that something leaves as opposed to enters the eyes. On the items asking separately about input and output, however, one could affirm input as well as output, as did many participants, because an affirmation of extramission did not preclude an affirmation of intromission.

ADDITIONAL FINDINGS

Results from the forced-choice items referring to computer graphics have provided us with a number of other interesting findings. For example, participants in our studies have favored two extramission interpretations: (a) input followed by output and (b) simultaneous input and output. The least favored extramission interpretations are (a) pure output and (b) output followed by input, the interpretation that is most similar to Plato's extramission theory. Another remarkable finding is that despite the decline in extramission interpretations between childhood and adulthood, large percentages of adults give extramission responses even though each of the items we present always includes the correct choice of input alone. Thus, in one study, we found that 70% of adults given seven computer graphic items showed evidence of an extramission belief on one or more questions. Moreover, 67% of this college sample gave extramission responses on four or more of the seven computer graphic items! (These statistics come from the results of Study 2 in Winer et al., in press, although they were not reported in this fashion.)

We have also consistently followed up our main items with questions asking whether participants believe that input and output aid vision and are necessary for vision. Results of these follow-up questions confirm that large percentages of children and adults believe in visual extramission that is functional. For example, in one study, 93% of third graders, 92% of fifth graders, 84% of eighth graders, and 77% of college students who affirmed extramission also believed that output aids vision; 59% to 63% also believed that if nothing went out of the eyes, people would not be able to see (i.e., they believed output is necessary for vision). Disturbingly, our participants did not always believe in the correct intromission theory of perception. For example, of those participants who affirmed intromission, 13% of college students and 19% of eighth graders responded that input did not aid vision (Winer et al., in press).

In another study, we examined responses to questions that presented participants with a diagram of a human profile facing a visual referent and that required the participants to draw how people see, using arrows (Winer & Cottrell, in press). We recorded the direction of each arrow drawn, toward or away from the eye, and had participants number their arrows to show us the sequence of events that occurred during the act of seeing. Most participants drew arrows pointing away from the eye, toward the external visual referent, and very few participants drew arrows pointing inward only. We suspected that part of the reason for these findings was that participants were representing the outward-oriented, line-of-sight aspect of vision in their drawings—an interpretation consistent with the idea that the orientational quality of vision underlies extramission responses. This interpretation was supported when we found that there were more inward-drawn arrows when participants were asked to draw specifically whether seeing involved visual input or output than when they were simply asked to draw how people see. However, even when participants were specifically asked to draw whether there is visual input or output, the drawings of 49% of the adults included at least one outward arrow (Winer & Cottrell, in press).

Both the act of drawing and graphic representations of vision seem to have qualities that match the outer-directed phenomenology of vision: Drawing involves an outer-directed act; the graphic representations, as we noted, portray images that might correspond to the orientational experience of vision. The results thus support our theory that the phenomenology of visual experiences underlies extramission beliefs. It is important to emphasize, however, that this theory does not claim that extramission responses result from people simply misinterpreting our questions to refer to line of sight or visual orientation. The specificity of our questions, the precision of our displays of computer graphics, and, indeed, the responses to our follow-up questions leave no doubt that many people believe in visual extramissions. Instead, we assume that there is possibly a

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syncretic fusion between the phenomenology of visual orientation and responses to our items. It is as if the dynamic outer-oriented experience of vision becomes assimilated into one's understanding of the nature of visual processing.

The findings from the studies comparing the drawing or the computer graphic items with verbal questions are also of significance to educators, who often assume that visual presentations or drawings assist understanding. Our results show that at least in some instances these modes of representation seem to hinder correct responses. The results are also theoretically significant in that they show that one's understanding of a phenomenon might depend on the symbolic representation of that phenomenon. Indeed, it is possible that different systems of representation lead to different understandings of the same phenomenon.

Given that the extramissionists in our studies affirm extramission even though they have been taught about vision, our attention is now directed to understanding whether education can eradicate these odd, but seemingly powerful, intuitions about perception. Other research has shown that expertise and high levels of academic achievement typically do not override certain erroneous intuitions (Proffitt, Kaiser, & Whelan, 1990). Nevertheless, as professionals and "experts," we and many of our colleagues still find it difficult to accept the idea that college students could believe in visual extramission under almost any set of circumstances. In fact, a reviewer of one of our manuscripts commented that our work should be held to a higher standard of proof than other research is because evidence about extramission beliefs was so difficult for the reviewer to accept. It seems unusual, then, that education has produced a correct understanding for some of us, but has apparently failed to influence many children and adults in the same way.

CONCLUSIONS

In conclusion, our results have implications for three areas: education, current understanding of the metacognitive abilities of children and adults, and theories of development. The implications for education are obvious. Among several points we have raised about education, there is one fundamental theme, which has been raised by others who study misconceptions in science: Education, in the form of providing correct information, is not sufficient to dispel erroneous beliefs.

The implications for metacognitive abilities are also clear. Much research in developmental psychology suggests that young children are knowledgeable about perception (see Winer, 1991). Our results, however, show striking limitations in children's and adults' knowledge about a basic perceptual process.

Consider also the implications of our findings for theories that describe cognitive development as a succession of beliefs or theories. First, some of the developmental trends we have found suggest that with increasing grade or age, scientific misconceptions might increase, rather than decline, in frequency. Second, if development in reasoning represents changing theories, then the theories that exist at different ages might change in response to changes in mode of representation. Finally, new theories, such as correct intromission beliefs, do not necessarily supplant erroneous beliefs or intuitions. Instead, the correct beliefs seem to coexist with incorrect notions that are strikingly resistant to change.

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Note

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