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The persistence of a misconception about vision after educational interventions

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Children and adults, like many ancient philosophers, believe that seeing involves emissions from the eye. Several experiments tested the strength of these "extramission" beliefs to determine whether they, like other scientific misconceptions, are resistant to educational experiences. Traditional college-level education had little impact. Presenting a simplified lesson, stressing visual input, and a lesson directly counteracting the vision misconception had an impact, but for older participants the effect was evident only on short-term tests. Despite some gain due to learning, overall the results demonstrated the robustness of extramission beliefs.

For many years it has been known that children and adults hold a number of misconceptions about scientific phenomena. Much of the ground-breaking work in this area has dealt with problems such as projecting trajectories of objects in space (Kaiser, Proffitt, & McCloskey, 1985; McCloskey, Caramazza, & Green, 1980; McCloskey, Washburn, & Felch, 1983). Since that time, there has been a virtual explosion of research on a variety of misconceptions (see Novak, 1987). One apparent feature of scientific misconceptions is that they are difficult to overcome (see Guzzetti, Snyder, Glass, & Gamas, 1993; McCloskey, 1983; Sandoval, 1995, for reviews), although under certain circumstances, such as providing refutational (Guzzetti et al., 1993) or conflicting (Chinn & Brewer, 1993) information, educational success has been achieved.

This report analyzes what appears to be a scientific misconception in the area of psychology—namely, the erroneous belief that during vision there is not only input to the eye, but also emissions from the eye, as if rays were exiting the eyes. This belief in visual output resembles the ancient extramission theory of perception, held by such thinkers as Plato, Euclid, and Ptolemy (see Gross, 1999, Lindberg, 1976, and Meyering, 1989, for historical reviews). Piaget (1929, 1974) was perhaps the first to document this belief in children. Subsequently, several investigators have reported extramission-like interpretations of vision in children (Anderson & Smith, 1986; Guesne, 1984, 1985; Kärrqvist & Andersson, 1983; Winer & Cottrell, 1996); others have shown that, while extramission beliefs decline with age, they are also present in adults (Cottrell & Winer, 1994; Winer, Cottrell, Karefilaki, & Gregg, 1996).

In the present study, we examined the persistence of extramission beliefs in the face of common educational instruction on vision, mainly to determine whether such beliefs were like other scientific misconceptions in their resistance to education. We initially hypothesized (Experiments 1 and 2) that adults' extramission concepts might stem from a lack of basic training in vision, or, given that such training had occurred, the fact that people might fail to access previously acquired information or to consider the extramission questions in the context of such prior learning. In the latter instances, extramission beliefs would be unlike other scientific misconceptions that are difficult to overcome.

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EXPERIMENTS 1 AND 2

In Experiments 1 and 2, we tested the effects of introductory psychology course experiences and readings about visual perception on *intromission–extramission* (i–e) tests administered to college students before and after the students received their introductory psychology units on perception. The two experiments were similar except that (1) across the experiments, we changed the readings from one introductory text to another; (2) the control groups in the two studies differed; (3) in Experiment 2, we added an experimental condition in which we explicitly instructed participants that they would be tested on what they were going to read; and (4) we used different posttests.

Tests, Procedure, and Sample

In all experiments, we repeatedly presented two or more different representations of vision on a computer screen, described them, and asked the participants which one indicated how we see. Each representation had a profile of a unisex human head on the left side of the screen, staring at a green rectangle on the right side of the screen. Visual input was designated by animated computer graphics, in which five separate dotted lines appeared to emerge simultaneously from the top to the bottom edge of the rectangle closest to the profile and to move so as to converge on the eye of the profile. Output was represented by the same lines fanning out from the eye and moving toward the rectangle. The animated graphics, plus our description of input and output (e.g., "This (pointing) shows rays, waves or energy coming into the eye... out of the eye..."), ensured that the participants were not interpreting input or output metaphorically.

Three other representations were employed: input followed by output (lines moving from the rectangle toward the eye and returning to the rectangle), output followed by input, and simultaneous input and output. (See Winer et al., 1996.)

For each of seven computer trials, two to four representations were simultaneously presented on the screen and the participant was asked to select the one that demonstrates how we see. Pure input (the correct choice) and pure output were included on all trials. The pure extramission representation was consistently presented so that more than one representation appeared across all the computer tests. Across the seven computer trials, all five interpretations were presented, although not at the same time (because the size would have been small and the representations confusing). However, we administered an eighth, noncomputer, purely verbal trial in which we requested a choice from all five possible combinations of input and output. We also varied the order of the questions and choices in all experiments.

The reading in the main experimental conditions of each study consisted of photocopied sections from a relatively high-level introductory psychology text. We used a different book in each experiment (see Appendix A for descriptions; references are available on request) describing parts of the eye, the nature of light, and the process of transmission of light to form an image on the retina. Although nothing in the readings hinted at extramission, both passages clearly described visual input, thus allowing for an inference that output was not involved in visual processing.

Experiment 1 had three groups. Prior to the i–e test, a control group received no reading; a second control group received a reading on audition; a single experimental group received the reading on vision.

In Experiment 2, prior to the i–e test, a control group received a reading passage on John Watson; one experimental group received a reading text on vision; and a second experimental group received the same vision reading with instructions that the participants would be tested on the text that they were about to read.

In Experiment 1, posttest questions referring to the last (purely verbal) i–e item asked the participants whether what goes into/out of their eyes helps them see; whether they could still see if nothing went into/out of their eyes, depending on how they had responded. In Experiment 2, a series of 12 yes–no posttest questions asked whether specific points were mentioned in the reading.

In Experiment 1, 30 male and 23 female students were tested approximately 1–3 weeks before receiving introductory psychology units (assignments, lectures, and a midterm test) on perception; 17 male and 15 female college students were tested approximately 3 weeks after receiving units on perception. In Experiment 2, 27 males and 50 females were tested approximately 1–3 weeks before class perception units; 42 males and 49 females were tested approximately 4 weeks after class perception units. Except for balancing for sex, participants were randomly assigned to conditions.

Results and Discussion

In both studies, a correct response was selection of the single choice that demonstrated only input. Data from both studies were analyzed by a sex × reading condition (vision reading vs. alternatives) × time of test (before vs. after introductory psychology unit) analysis of variance (ANOVA) performed on the sum of the seven computer items and the single purely verbal item. Thus, a maximum score was 8. In Experiment 1, there was no improvement due to the vision reading, [$F(2,72) = 44$, $p >. 6$] (Ms = 4.6–5.2) nor evidence of any gain attributable to formal educational instruction [$F(1,72) = 1.90$, $p < .17$] (Ms = 4.6 and 5.5, for pre- vs. postunits, respectively), although there was a significant sex effect [$F(1,72) = 5.23$, $p < .03$]; males had higher scores ($M = 5.8$) than did females ($M = 4.3$).

Analyses of the posttests showed that among those who admitted to extramission on the last item, 76% said that output helped vision and 70% indicated that output was necessary for vision. Approximately 88% of those admitting to output thought that output either helped or was necessary for vision.

In Experiment 2, an ANOVA revealed no main effects of condition [$F(2,156) = 0.25$, $p < .8$] (Ms = 4.1–4.5 out of 8) or of whether the students were tested before or after class perception units [$F(1,156) = 2.67$, $p < .11$] (preunit $M = 3.9$; postunit $M = 4.7$). A significant triple interaction involving sex, time of testing (before or after class units on perception), and condition [$F(2,156) = 4.13$, $p < .02$] revealed significant possible learning effects but only for females. Post hoc analyses indicated that control females tested before their class perception units had significantly lower scores ($M = 2.0$) than females in the experimental condition that presented the reading alone ($M = 4.2$, $p < .05$) and nearly significantly lower scores than did females in the condition that presented the reading with the additional warning ($M = 3.7$, $p < .10$). Thus, results suggested that the reading conditions facilitated the performance of the females prior to their introductory psychology units. Control females given the initial, preperception unit test ($M = 2.0$) also had lower scores than did control females given the postunit tests, suggesting that the class units facilitated performance.

The effects found with females must be treated with caution since they did not appear in Experiment 1 and in another study in which we compared pre- versus post-psychology unit test performance. We suspect that the effects were due to the fact that the control females given the preunit tests had inordinately low scores. In any event, the effects were not strong (the highest mean score shown by females in any group was 4.8). In fact, overall, irrespective of sex, the scores were low. In the total sample (pre- and postunit groups), 32 of the 59 control participants (54%) and 65 of the 109 experimental students (60%) had fewer than five of eight items correct.

Could the absence of clear-cut reading effects have been due to the particular readings used? The answer is patently no. We followed these studies up with several investigations, altering reading materials based on college texts in different ways (length, difficulty, and instructions) and still found no effect attributable to the readings.

Analyses of the erroneous choices made by participants in each study showed that most participants preferred either simultaneous in and out, or first-in-then-out choices. Analyses of the responses to the posttest items revealed that participants in the two experimental groups in Experiment 2 showed evidence of having identified the content of the text: The mean numbers of correct responses for the two experimental groups, out of a total of 12, were 9.3 and 9.7, respectively, which differed significantly from chance.

EXPERIMENT 3

Since we used college textbook readings in the previous experiments and follow-up studies, the materials contained no explicit refutation of extramission beliefs. Moreover, one might argue that the educational content was relatively complex. In Experiment 3, we thus (1) designed one condition to refute explicitly the extramission belief and (2) radically simplified our educational message, which also allowed us to test both children and adults. Educational research (see Guzzetti et al., 1993) indicates that written texts that contain explicit refutations of misconceptions can sometimes override erroneous beliefs. In Experiment 3, the effects of the refutation and standard learning experiences were analyzed on both immediate and delayed posttests.

Sample and Procedure

The sample consisted of: 30 male and 44 female fifth graders (age range: 11 years, 3 months–11 years, 9 months); 34 male and 28 female eighth graders (age range: 14 years, 11 months–15 years, 3 months); and 45 male and 40 female college students (age range: 17 years, 8 months–43 years, 5 months), of whom 48 were available for both testing occasions. College students participated in the study as part of a requirement for an introductory psychology course; elementary school students were attending a parochial school in a middle-class neighborhood.

In this experiment, the effect of a control videotape, presenting a lecture on a topic irrelevant to vision, was compared with the impact of each of two experimental videotape lectures on vision: a standard learning and refutational lesson. We presented a videotape because we thought it would be of greater interest to children than would be a reading. As in the other studies, the participants received only one condition.

Each of the two experimental lectures presented the same core of basic vision facts: Some parts of the eye were mentioned, and the process of vision was described, including the pathway from the eye to the brain, with accompanying diagrams. The role of light in vision was stressed, and the fact that light enters the eyes was mentioned about 20 times. The material was designed with the assistance of a sixth-grade science teacher (entire scripts are available on request). In addition to the simple explanation included in the standard learning treatment, the other experimental tape contained refutational statements, both at the beginning and end, emphatically denying the idea of extramission by explaining that nothing leaves the eye during the act of vision, despite beliefs to the contrary (see Appendix B). In fact, the placement of the refutational statements made the entire tape appear to be directed toward counteracting the extramission belief.

The participants were exposed to the videotapes in small groups. Learning was measured immediately after the participants had viewed a tape and approximately 3–5 months later on the same eight-item, i–e test previously described. Following the first testing session, the participants received a simple five-item comprehension test on the content of the videotape presentation.

Results

A 3 (grades: 5, 8, and college) × 3 (condition: refutational, standard learning, and control tape presentations) × 2 (time of testing: immediate vs. delayed) repeated measures ANOVA, restricted to those participants who were available for both testing sessions, revealed an effect for grade [$F(2,160) = 3.22$, $p < .05$], with college students having higher scores ($M = 5.3$ out of 8) than fifth ($M = 4.4$) and eighth ($M = 4.4$) graders, an effect for sex [$F(1,160) = 4.36$, $p < .04$], with males ($M = 5.1$) outscoring females ($M = 4.3$), and a grade × test time × condition interaction [$F = (4,160) = 2.51$, $p < .05$].

In explaining the triple interaction, we will focus on three separate condition × test time ANOVAs, one for each grade. (See Table 1 for the means in the interaction.) The ANOVA for the fifth graders revealed only a significant condition effect [$F(2,68) = 17.02$, $p < .001$]. Means for the refutation ($M = 5.98$) and standard learning ($M = 4.8$) conditions were each significantly higher than scores for the control group ($M = 2.4$). The difference between the refutation and standard learning groups was nearly significant ($p < .10$).

There was a significant test time × condition interaction for both eighth graders [$F(2,56) = 5.35$, $p < .008$] and college students [$F(2,45) = 7.8$, $p < .002$]. For both samples, condition effects were found only in the immediate test, but the effects were different. For the college students, the three conditions significantly differed from each other, with the highest scores in the refutation condition ($M = 7.8$), intermediate scores in the standard learning condition ($M = 4.8$), and the lowest scores in the control condition ($M = 3.5$). For the eighth graders, the refutation group had higher scores ($M = 6.7$) than the control group ($M = 3.3$), but with no difference between the control and standard learning ($M = 3.7$) conditions. Also, at both of these grade levels, scores in the refutation groups declined significantly between the immediate and delayed tests, and at time 2 there were no differences among the groups. Except for the decline in performance by participants in the refutation groups, there were no differences between time 1 and time 2 tests.

The extent of the regression, across the two testing occasions, shown by college students was dramatic. All 33 of the original college refutation group students had five or more items correct at time 1 compared with 10 of the

Table 1
Mean Number of Pure Intromission Responses (Out of Eight) for Grade × Condition × Testing Time Interaction in Study 3

	Testing Time					
	Immediate			Delayed		
	Conditions					
Grade	Control	Standard	Reference	Control	Standard	Reference
5th	2.4	5.2	6.5	2.5	4.4	5.4
8th	3.3	3.7	6.7	3.5	4.7	5.1
College	3.5	4.8	7.8	4.3	5.6	5.2

17 (59%) returning students at time 2. Moreover, 6 of the 7 participants in the refutation group, whose scores declined to fewer than five correct at time 2, had perfect scores at time 1.

Analysis of the five-item posttest data revealed a strong effect for condition [$F(2,202) = 39.8, p < .0001$]; participants in each experimental group had significantly higher scores (Ms = 4.8 and 4.7, refutation and standard learning groups, respectively) than control group participants ($M = 3.9$), indicating that the experimental students had learned facts about vision from the presentations. An additional ANOVA comparing students who returned at time 2 versus students who did not, on the number of correct responses on the first testing occasion, revealed no statistically significant differences.

Discussion

The results clearly showed that the refutation tape produced an impressive short-term effect. In fact, many in the refutation group had perfect performance. There was also some evidence of a short-term effect for the standard learning condition. However, over time, the condition effects for the college students and eighth graders dissipated. The fact that there were some enduring effects for the fifth graders, but not for the older participants, suggests a decrease in the impact of education with development, as if the misconception were becoming more firmly entrenched with age.

The immediate effects of the standard learning condition were unexpected, since prior experiments in this study, as well as several other follow-up investigations, showed no impact due to standard educational materials. The effect is not attributable to the videotapes; in follow-up studies, we presented, in written form, the same script used in the videotape and again found short-term learning effects. (We also found powerful short-term effects for written refutation material.) Delayed effects were not tested. Two qualities of the standard learning message most likely account for its effectiveness: the simplicity of the message, and repetition of the theme of input.

Evidence leads us to favor repetition of the theme of input as an explanation. As noted, in several follow-up studies, we found no effect due to readings that were considerably simplified in comparison with those presented in Experiments 1 and 2, although in no case was the reading content simplified to the reading level of fifth graders. However, in one follow-up study that did not use computer graphics, we found some improvement when a reading on vision was accompanied by a diagram displaying lines between an eye and a seen object, with arrowheads on the lines pointing toward the eye.

GENERAL DISCUSSION

The first two experiments showed that traditional college educational experiences had no consistent impact on extramission beliefs. One might argue, though, that the readings in the first two experiments were limited in that: (1) They presented information that might have been too complex; and (2) by design, they did not directly refute the erroneous extramission beliefs.

Even if we grant that the college reading materials in Experiments 1 and 2 were not optimally designed to overcome extramission beliefs, the results of Experiment 3, in which we explicitly refuted extramission beliefs, showed that a powerful immediate effect with the college students and eighth graders disappeared with time. The short-term learning effects shown in Experiment 3 by college students in the standard learning condition were surprising, given that, in Experiments 1 and 2 and in several follow-up studies using simplified college-level material, we have been unable to find effects attributable to reading. The subsequent research with diagrams portraying input with arrows suggests the importance of cues stressing input, although we still cannot completely rule out the role of radically simplified content.

Whatever the explanation, the effects of the standard learning treatment for college students were relatively limited: At time 2, there was no difference between participants in the control and standard learning treatment. In fact, overall, the long-term performance of the college students was poor: Thirty-nine percent of the college students in the two experimental groups of Experiment 3 had scores of 4 or below on the delayed test! We obtained a long-term effect only with the youngest children but again, even in the best condition, many children failed.

The results of Experiments 1 and 2 indicate that extramission concepts are not due to the absence of correct information or from people failing to consider i–e questions in the context of what they have learned about vision. The findings reveal that extramission beliefs are robust, resistant to education, and thus are not unlike other misconceptions in science. As in the case of other misconceptions, however, we would expect that, with elaborated and extensive educational interventions (see Chinn & Brewer, 1993; Hewson & Hewson, 1988; Perkins & Simmons, 1988; Posner, Strike, Hewson, & Gertzog, 1982; Stofflett, 1994, for examples), extramission beliefs could be overcome.

The findings of Experiment 3 showing a regression among the older children and college students given refutation training are consistent with attitude research findings in social psychology, which have often demonstrated that messages that counteract beliefs have a short-term effect (e.g., see Petty, Haugtvedt, & Smith, 1995). There is no a priori reason, however, to expect that the extramission idea is akin to such beliefs or that it is firmly held. In fact, our initial hypothesis was that such beliefs were simply due to students' failing to have learned or accessed previously learned facts about vision.

Finally, one of the most important implications of this research is that students are leaving introductory courses with a profound misunderstanding about vision, one of the most basic processes in psychology (see Meyering, 1989).

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APPENDIX A
Experiment 1
Reading Description

The reading consisted of passages including a short statement on the importance of vision, a brief paragraph on the eyes, neural circuits, and the brain, mentioning that the eyes respond to light energy, and a lengthy description of light energy.

Paragraphs explained that we see because of light and radiation, and the nature of light, brightness, hue, and saturation.

Next, the eye was compared to a camera, with parts of the eye identified. Image-focusing and the image-recording part of the eye, the retina, were mentioned.

Two paragraphs explained that visual sensation occurred when light rays enter the eye and are refracted and focused on the retina.

Additional paragraphs described light passing through the iris and pupil, the functioning of the pupil, light entering the lens, focusing, and accommodation.

Finally, the rods and cones were described. Included were a detailed picture of the eye and three large diagrams, one showing an inverted image.

Experiment 2
Reading Description

The electromagnetic spectrum was initially described. The remaining paragraphs described parts of the eye and their functions: the retina, cornea, iris, pupil, light entering the eye, and how light rays converge on the retina through the lens, parts and functions of the eye, retinal chemicals that are activated by light and lead to the production of action potentials in neurons, with mention of the blind spot. Four diagrams portrayed the eye, its parts, and showed light waves coming from an object and projecting an inverted image on the retina.

APPENDIX B

Information that nothing leaves the eye was mentioned at the beginning of the tape and stressed twice at the end of the video. In one instance, vision was described as being different from Superman's x-ray vision or the visual extramissions of various comic characters. A portion of the tape script denying extramission was as follows:

> Some people think that something must go out of the eyes when we see. Other people think that our eyes work kind of like Superman's eyes. Superman has rays that go out of his eyes, and the rays help him see better. Cyclops, the character from *X-Men*, also has rays that go out of his eyes. But Superman and Cyclops are just pretend or make believe. Nothing has to leave our eyes in order for us to see. When we look at the things around us, light enters our eyes, but nothing at all goes out of our eyes.

At the end of the tape, a summary of visual processing was presented, again containing an explicit denial of extramission. The last thing participants in the refutation group heard was the following

> Remember, nothing leaves your eyes in order for you to see. The only thing that enters your eyes is light rays, and nothing ever goes out of your eyes when you see. Although Superman may send rays out of his eyes to help him see, real people don't send anything out of their eyes to help them see.

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