

The Experimental Detection of an Emotional Response to the Idea of Evolution

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ABSTRACT

Evolution is widely regarded as biology's unifying theme, yet rates of rejection of evolutionary science remain high. Anecdotal evidence suggests that cognitive dissonance leading to an emotional response is a barrier to learning about and accepting evolution. We explored the hypothesis that students whose worldviews may be inconsistent with the acceptance of evolution generate detectable emotional responses in the form of physiological changes when exposed to evolutionary themes. Physiological data (respiratory rate, galvanic skin response, and heart rate) were collected from participants while they were asked "yes/no" questions, some of which referenced evolution. Questions were of three categories: relevant, irrelevant, and control. Authenticity of response rates to relevant questions such as "Do you believe in evolution?" were verified using visual inspection to compare degree of response rates with control questions, such as "Have you ever cheated on a test?" Our results support our hypothesis. Of the 33 participants included in our study, a majority of them produced detectable physiological changes indicating emotional responses when asked questions referencing evolution. The highest response rate (79%) was generated by the question "Do you believe in evolution?" The implications of an emotional response in students when presented with instruction in evolutionary theory are discussed.

Key Words: Evolution education; emotion.

"...let us endeavour for a moment to disconnect our thinking selves from the mask of humanity...."

T. H. Huxley, 1863

○ Background

Darwin's theory of evolution by natural selection has tremendous explanatory power and unifies the biological sciences as a scientific discipline. It also is among the most robust of all scientific

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theories, being supported by volumes of evidence collected from numerous lines of inquiry, and it has survived decades of the most intense scrutiny science can bring to bear. Blackwell et al. (2003) notes that "Without evolutionary theory, biology is divested of needed theme, coherence, understanding, and interpretation of relationships." And in the words of the eminent geneticist Dobzhansky (1973), "Nothing in biology makes sense except in the light of evolution."

Despite the stature of evolutionary science, polls and studies reveal that many American citizens not only have a poor understanding of evolution, but also reject it as a valid explanation for the diversity of living forms, past and present (Recer, 1996; National Science Board, 2000; Miller et al., 2006). A Gallup poll conducted in May, 2014, revealed that 42% of Americans believe that "God created human beings pretty much in their present form at one time within the last 10,000 years or so," a number that has been essentially stable since 1982 (Gallup, 2014). In another poll, conducted in March, 2014, by the Associated Press and GfK, 42% of participants indicated they were "Not too confident" or "Not confident at all" about the statement "Life on Earth, including human beings, evolved through a process of natural selection" (AP-GfK Poll, 2014). Americans may reject this foundational core of knowledge for various reasons, but as de Beer (1958) wrote, "Only ignorance, neglect of truth, or prejudice could actuate those who, in the present state of knowledge, without discovering new facts in the laboratory or in the field, seek to impugn the scientific evidence for evolution." It is perhaps the ultimate irony

that the most complex machine in the known universe – the human brain – can so easily be persuaded to reject the very force that created it.

Scientists may fail to understand how any student, when presented with the overwhelming evidence in favor of evolutionary theory, can still reject it. Research from psychology, however, reveals that emotions can (and often do) cloud the intellect. For example, studies suggest that adolescents use scientific reasoning selectively. Klaczynski and Narasimham (1998) found that when presented with bogus research studies, some of which described participants' religion in a negative light, some in a positive light, and some neutrally, students employed biased reasoning by raising their standards to dismiss findings that were inconsistent with or appeared to threaten their beliefs, while lowering them to admit findings compatible with their beliefs. Researchers noted that their "reasoning is systematically biased to protect and promote their preexisting beliefs" (Klaczynski & Gordon, 1996).

A psychological approach to evolution education provides a fresh look at an old problem: once we verify students' hypothesized emotional responses, we can then seek ways to defuse them, so they can begin to think rationally about evolutionary biology. It is reasonable to expect that using high-quality instructional strategies focused on clear explanations of how natural selection and other mechanisms of evolution work, along with examples of the overwhelming supportive evidence, will lead to better understanding and acceptance. Unfortunately, this view has not been supported: most students who enter a biology course with nonscientific views on the origin of biological diversity have been shown to retain these views after instruction on evolutionary theory (Johnson & Peeples, 1987; Bishop & Anderson, 1990; Lawson & Worsnop, 1992).

In addition, although some studies have linked understanding of evolutionary theory with its acceptance by teachers (Rutledge & Warden, 2000; Trani, 2004), a number of studies have found no correlation between understanding of evolution and its acceptance by students (Bishop & Anderson, 1990; Lord & Marino, 1993; Sinatra et al., 2003). In contrast, Ingram and Nelson (2006) found that their students already held positive attitudes toward evolution, which became somewhat more positive at the conclusion of a semester-long course in evolution. These results are not surprising, however, given that students in their study were juniors or seniors majoring in biology. Regarding acceptance versus understanding of evolution, these researchers noted that "neither was a prerequisite nor necessary condition of the other."

Moreover, some science teachers reject evolutionary theory themselves – in part or in whole – and refuse to teach it, even though they are mandated by state science standards to do so (Moore, 2002; Bandoli, 2008; Berkman & Plutzer, 2011; Bland & Moore, 2011). To determine the malleability of preservice science teachers' attitudes, Nehm and Schonfeld (2007) designed an intervention course specifically for this demographic. Results of the study were disappointing: while students showed an increase in their mastery of evolutionary concepts, they did not change their views on teaching nonscientific origins of biological diversity. Clearly, we need a new approach to this problem.

○ Theoretical Framework

Conflicts over teaching and acceptance of evolution will never be resolved unless we begin to learn about the root cause, which we suggest is the emotional reaction to evolutionary theory that many

have. A model is provided by Westen et al. (2006), who devised a way to test whether voter reasoning was influenced more strongly by emotion or by intellect. Westen used functional magnetic resonance imaging (fMRI) to examine the brain activity of 30 committed partisan men before the 2004 U.S. presidential election as they listened to positive and negative statements about their candidates of choice. The results revealed that brain areas responsible for reasoning did not show increased levels of activity while participants formulated their conclusions. However, brain areas in control of emotions did increase in activity. Participants also were asked to score the degree to which the negative statements were, in fact, conflicting. Participants not only scored the degree of conflict significantly lower for their candidate of choice as compared to the opposing candidate, but when they "twisted the facts" to enable exoneration of their candidate, the reward-processing centers of their brains showed increased activity. This suggests that participants were engaging in "motivated reasoning" – that is, they were motivated to draw emotionally satisfying conclusions in the face of contradictory statements about their chosen candidates.

This model is further bolstered by the work of Dolcos and McCarthy (2006). In their study, participants were asked to memorize images of three human faces. Participants then were exposed to one of three types of distracters: emotional images such as aggressive behavior; neutral images of people performing "ordinary" tasks such as shopping; and scrambled, meaningless images. An image of a face was then shown to participants, and they were asked whether it was one of the images they were asked to memorize. Not surprisingly, researchers found that emotional images activated a "ventral affective system" of the brain encompassing regions responsible for emotional processing. Likewise, the cognitive tasks of memorization activated the "dorsal executive system." What was surprising was the discovery that emotional distracters not only activated the "ventral affective system" but also *deactivated* the "dorsal executive system," impairing performance on the memory tasks.

These models suggest the important effect that emotional factors have on rational thought and learning, which thus far have been largely ignored in education (Pekrun, 2006; Zhang & Lu, 2009). Regarding instruction in evolution, anecdotal evidence suggests that emotional reactions are a barrier to student learning (Sinatra et al., 2008). We hypothesized that students whose worldviews are inconsistent with the acceptance of evolution generate detectable emotional responses when exposed to evolutionary themes, as manifested in measurable physiological changes under controlled conditions.

These reactions are understandable when one considers the ongoing societal perpetuation of the evolution controversy, coupled with the conservative religious upbringing that many have. Moreover, students' emotional reactions may be exacerbated by regular exposure to teachings about the "evils of evolution" by church leaders who utilize strategies specifically designed to evoke emotional responses. Carl Wieland, in writing for the organization *Creation Ministries International*, provides an example: "[B]ecause amorality is logically consistent with evolution, and inconsistent with biblical Christianity, an evolutionary worldview gives a much more fertile ground for the exhibition of the sin nature in all its aspects" (Wieland, 2005). In a study focused on students' views of evolution in the Deep South, researchers found that religiosity was more important than measured educational variables in attitudes toward

evolution, that highly religious students were more likely to reject evolution, and that the least religious students were the only ones who showed an increase in their acceptance of evolution at the end of a biology course (Rissler et al., 2014). Students who receive no formal instruction in evolution until they reach high school, or perhaps even college, are at an even greater disadvantage.

We suggest that what results under these conditions is cognitive dissonance, or anxiety from holding what they view as incompatible constructs (McKeachie et al., 2002). The emotional response elicited not only reduces activity in the cognitive centers of their brain, but students also use “motivated reasoning” to abate cognitive dissonance. Hence, teaching these students the details of evolutionary science is problematic at best, because not only are they unable to think logically and rationally about it, but they also are more likely to reject it through motivated reasoning in order to arrive at an emotionally satisfying conclusion. In short, many students will not accept instruction in evolution, regardless of how robust the presentation is.

While studies documenting students’ rates of acceptance of evolution are abundant (Cavallo & McCall, 2008; Moore & Cotner, 2009, and references therein; Rutledge & Sadler, 2011, and references therein), very little work has been done regarding students’ emotional response to evolution. A few studies have reported results of student attitudes toward evolution (Verhey, 2005; Ingram & Nelson, 2006; Partin et al., 2013). Partin and colleagues utilized the Biology Attitude Scale (BAS; Russell & Hollander, 1975), as one of several measures thought to predict an understanding of the nature of science (NOS), but the BAS only measures students’ attitudes about biology in general, and they did not compare BAS scores with students’ acceptance of evolution. However, the authors did suggest that controversial topics such as stem cell research and evolution “may cause cognitive conflict” (Partin et al., 2013).

Assuming that the anxiety students feel when learning about evolution interferes with retention, Heddy and Sinatra (2013) developed an instrument designed to measure basic emotions (enjoyment, hope, pride, anger, anxiety, shame, hopelessness, boredom). Students in their treatment group utilizing an intervention (Teaching for Transformative Experiences in Science, TTES) showed an increase in levels of enjoyment related to learning about evolution, which the researchers speculated would be an important factor when evolutionary theory conflicts with students’ worldview: “It is possible that when a student recognizes the usefulness of learning evolution to his or her everyday life anxiety decreases and enjoyment increases which could make them more open to such information.” What Heddy and Sinatra claim to be “well-documented emotional and motivational barriers to overcome,” however, are not empirically based conclusions; rather, they are merely logically formulated arguments regarding the obstacles to learning evolution generated by “commonsense reasoning” (Sinatra et al., 2008).

In their study on conceptual change in evolution, Demastes et al. (1995) reported findings confirming the disjunction between content understanding and students’ personal beliefs. They note that “conceptual change [in evolution] has significant affective components” and then call for more research on “the influence of a learner’s motivational and affective orientations in science learning.”

In the most relevant study found to date, Brem et al. (2003) surveyed undergraduates regarding the impacts of accepting

evolutionary theory. Their results suggest that consequences of students’ acceptance of evolutionary theory “might be considered undesirable: increased selfishness and racism, decreased spirituality, and a decreased sense of purpose and self-determination.”

We tested our hypothesis – that students whose worldviews may be inconsistent with the acceptance of evolution generate detectable emotional responses in the form of physiological changes when exposed to evolutionary themes – by collecting physiological data (heart rate, respiration rate, and the galvanic skin response, or GSR) as a way to characterize students’ emotional reactions to evolution. The GSR measures changes in the skin’s electrical resistance as a result of an outflow of the sympathetic nervous system, indicating anxiety. These types of data are collected by polygraph examiners because the emotional stress generated while falsifying information produces changes in these parameters (Hammond, 1983; Office of Technology Assessment, 1983). Although difficulties in using polygraph tests to detect deception have been well documented (Saxe et al., 1985, and references therein), these physiological indicators are used in biofeedback studies because they are sensitive to one’s level of emotional arousal (Fuller, 1977; McKinney et al., 1980; Office of Technology Assessment, 1983; Saxe et al., 1985; Nikula, 1991; Bradley et al., 2001; Vrij & Mann, 2007; Zysberg, 2012).

Polygraph examiners typically ask subjects three types of questions – relevant questions, neutral questions, and control questions (Office of Technology Assessment, 1983). Relevant questions, which are expected to induce stress, focus on details about which the examiner is interested, whereas the second type – the neutral, irrelevant questions – serve to generate baseline, nonstressful readings. The control questions also are designed to induce stress, but focus on details the administrator is not truly interested in (e.g., “Have you ever stolen from an employer?”). Hence, responses to control questions serve to validate the emotional response generated from relevant questions. If a subject lies when asked relevant questions, his or her responses to these will resemble responses generated by the control questions, and vice versa.

Because wide variations in physiological activity exist among subjects (Ekman, 2001), polygraph examiners do not use a quantitative system for data analysis; rather, visual inspection and comparison of reaction patterns produced by the three question types is used for each subject. Indicators of a physiological/emotional response include changes in heart rate, a downward or upward stair-step pattern on either or both pneumograph recordings (indicating a change in breathing patterns), and strong, sustained GSR peaks (indicating an increase in perspiration rate).

○ Methods

Institutional Review Board clearance was obtained prior to the study. All students read and signed a consent agreement upon reporting for data collection and were verbally briefed on its contents. Participants (n = 33) were recruited from a nonmajors biology course at a midsized, regional university in Arkansas. To minimize bias, participants reported for data collection before evolution was treated in both lecture and the required laboratory. Students were offered a small number of extra credit points in the class for their participation. Because acceptance rates of evolutionary theory are particularly low in the United States (Miller et al., 2006)

and we wished to focus on this demographic, data collected from international students were removed from this study.

To collect evaluative data, we used the same indices and question patterns used by interrogation experts (Office of Technology Assessment, 1983; Saxe et al., 1985). A Lafayette Model polygraph instrument was used for physiological data collection. Room temperatures were kept at 21°C for consistency in GSR readings, and data were collected in a vacant faculty office to eliminate interruptions during testing.

Data on the rate and depth of respiration were measured using two pneumographs, one strapped around the upper chest and the other around the abdomen. In addition, two electrodes that measure electrical conductance were strapped to the index and middle fingers of the left hand for GSR data. Finally, a sphygmomanometer (blood pressure cuff) was strapped to the right bicep of participants to measure cardiovascular activity.

A simple card test was used to calibrate the instrument sensitivity to each participant. Participants were told to pick a card with face values ranging from 2 to 6 and were instructed to answer “no” to all subsequent questions. Playing cards numbered 2 to 6 then were shown randomly to participants, and they were asked whether the card number was the number they had chosen. Only the participant knew when he or she answered truthfully.

Participants then were asked 12 questions in 15-second intervals: four relevant questions, two control questions, and six irrelevant questions in the sequence shown below. We used this question sequence because it follows the format most commonly used by polygraph examiners, known as the Control Question Test (CQT; Office of Technology Assessment, 1983; Saxe et al., 1985). The exact content for each question was suggested by our polygraph

consultant. We recorded participants’ answers to these questions and physiological data pertaining to the questions.

Physiological Data Questions

1. (Irrelevant) Is your name _____?
2. (Irrelevant) Do you live in (state)?
3. (Relevant) Do you believe in evolution?
4. (Irrelevant) Do you own a pet?
5. (Irrelevant) Do you drink Coke?
6. (Control) Have you ever cheated on a test?
7. (Relevant) Do you think teachers lie to you about evolution?
8. (Irrelevant) Are you wearing jeans today?
9. (Relevant) Are you curious about evolution?
10. (Relevant) Do you think it’s possible to believe in evolution and still maintain religious values?
11. (Irrelevant) Do you own a cell phone?
12. (Control) Have you ever done anything your parents would not approve of?

Pneumograph, heart rate, and GSR data were visually inspected for distinctive changes indicating physiological responses to questions. To avoid confirmation bias, these results were independently confirmed by a trained polygraph examiner. Suppression or elevation in one or both pneumographs (Figure 1), pronounced and sustained peaks in GSR readings (Figure 2), and changes in heart rate (Figure 3) were visually documented, and were tallied only in cases when discernible reactions with all three measures were correlated with question timing. In two cases, the participants’ physiological activity was so high that their responses to all questions (relevant, control, and irrelevant) were indistinguishable; these data were not

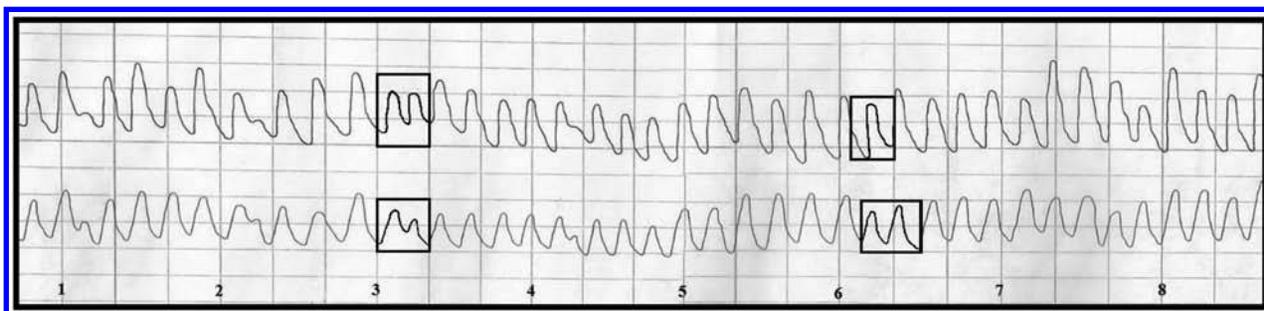


Figure 1. Examples of suppressed-breathing-rate response on pneumographs 1 (top) and 2 to relevant question “Do you believe in evolution?” and control question “Have you ever cheated on a test?” Note that physiological responses are recorded on scrolling paper by specialty pins attached to ink wells. Numbers indicate timing of the questions. Rectangles were added for emphasis.

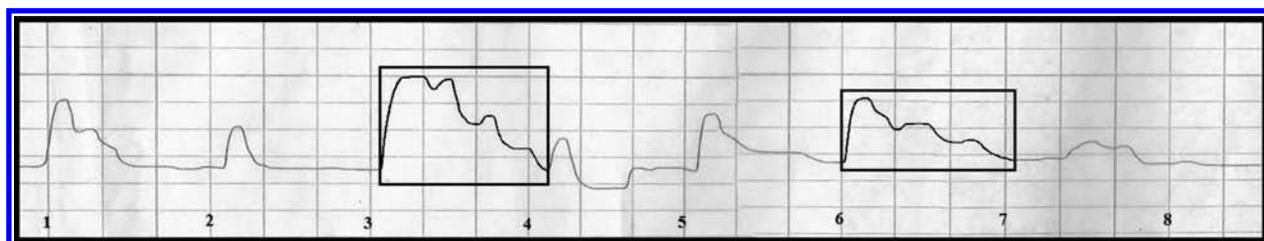


Figure 2. Examples of sustained GSR responses to relevant question “Do you believe in evolution?” and control question “Have you ever cheated on a test?”

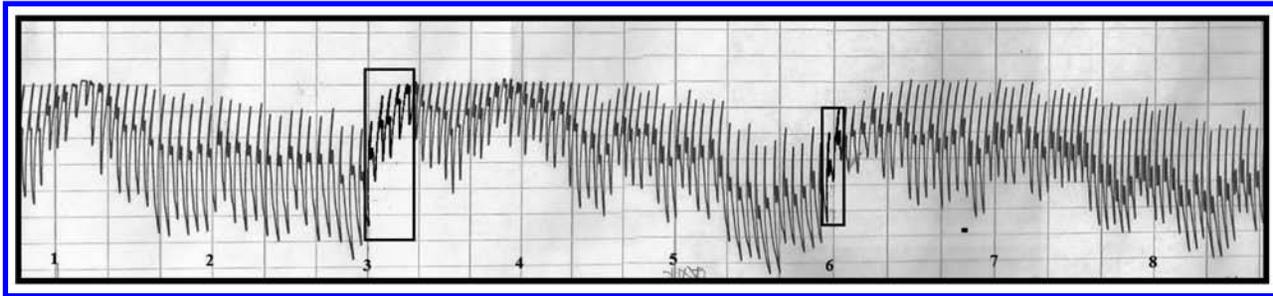


Figure 3. Examples of heart-rate response to relevant question “Do you believe in evolution?” and control question “Have you ever cheated on a test?”

evaluated for the present study. In addition, data collected from three participants were removed because of technical problems with the equipment. Finally, testing was halted in one case by question 3 when the participant asked “Who is evolution?”

Results of physiological reactions to relevant questions were authenticated using visual inspection to compare them with control-question responses. To assess whether there were statistically significant differences between documented physiological/emotional reactions to select questions, a chi-square test of association (Glass & Hopkins, 1996) was performed on participant responses.

○ Results

The majority of participants produced physiological responses to questions on evolution similar to those shown in Figures 1, 2, 3. These changes were correlated not only with each other but also with question timing. The most striking response came from question 3 (*Do you believe in evolution?*): 79% of participants exhibited a detectable physiological response. The majority of participants also generated detectable physiological responses to questions 6 (*Have you ever cheated on a test?* – 67%), 9 (*Are you curious about evolution?* – 52%), and 10 (*Do you think it’s possible to believe in evolution and still maintain religious values?* – 64%).

Sixty-one percent of participants answered “yes” to question 3 (*Do you believe in evolution?*) (Figure 4). The majority of participants also answered “no” to question 7 (*Do you think teachers lie to you about evolution?* – 76%), “yes” to question 9 (*Are you curious about evolution?* – 62%), and “yes” to question 10 (*Do you think it’s possible to believe in evolution and still maintain religious values?* – 79%). Despite participants’ verbal responses to these questions, however, physiological data reveal that these questions elicited an emotional response in the majority of them (Figure 5).

A chi-square test of association (Glass & Hopkins, 1996) was performed on participant responses to selected questions. The results reveal a significant difference in the frequency of physiological reactions generated by question 3 (*Do you believe in evolution?*) compared with all irrelevant questions ($P < 0.01$). Significant differences also were found in comparing questions 6 (*Have you ever cheated on a test?*) and 10 (*Do you think it’s possible to believe in evolution and still maintain religious values?*) with irrelevant questions ($P < 0.05$), but not for questions 7 (*Do you think teachers lie to you about evolution?*), 9 (*Are you curious about evolution?*), and 12 (*Have you ever done anything your parents would not approve of?*) ($P > 0.05$). It is worth noting that these results do not explain the unexpected high numbers of reactions generated by question

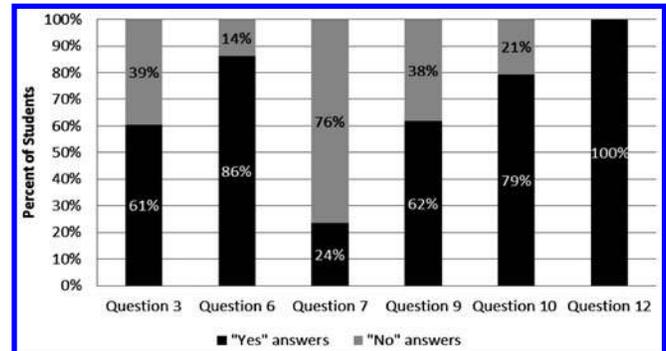


Figure 4. Verbal responses to control and relevant questions (n = 33).

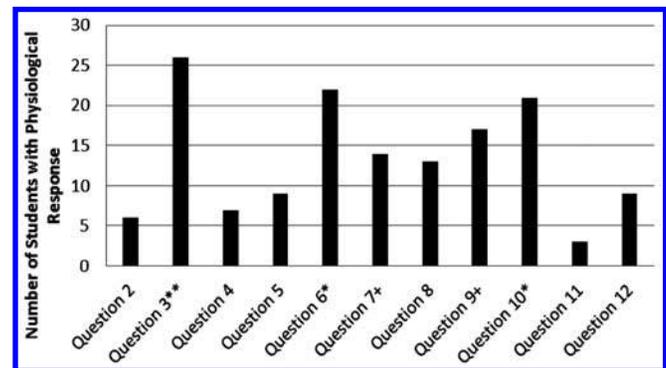


Figure 5. Detectable physiological response data for questions 2–12 (n = 33). Statistical significance was found when relevant questions were compared with irrelevant questions under the following conditions: * $P < 0.05$, ** $P < 0.01$, + $P < 0.05$, with question 8 removed.

8 (*Are you wearing jeans today?*). When question 8 is removed, the frequency of responses to relevant questions are all significantly different from those of irrelevant questions, with the exception of question 7 ($P = 0.196$).

○ Discussion

Conflicts over teaching evolution have been ongoing since the famous “Scopes Monkey Trial” in 1925, when substitute teacher John Scopes was convicted of the crime of teaching human evolution (Moore, 2001). The U.S. Supreme Court has since ruled it unconstitutional to forbid the teaching of human evolution. Likewise, many other important court cases have been tried, all of

which were ruled in favor of teaching evolution and against teaching creationism (or “creation science”) in public schools (Moore et al., 2003). Because the nature of court trials is to render a decision in favor of either the plaintiff or the defendant, these circumstances perpetuate the misconception that science and religion, in this context, are opposites in a simple dichotomy and are diametrically opposed. The view that one must make a choice between science and religion seems especially common among students.

Such conflicts inevitably produce cognitive dissonance in the minds of learners who are unable to use cognitive appraisal to minimize emotional responses (Lazarus, 1982). We suggest that students’ cognitive dissonance resulting from exposure to evolution leads to motivated reasoning as a way to abate this dissonance. McKeachie et al. (2002) reported that a disproportionately high percentage of students who rejected evolution either dropped their introductory biology course or chose not to respond to their questionnaire at the end of the term, which the researchers interpreted as one way for students to resolve their internal conflict between course content and their beliefs. Students who experience these conditions will, at best, struggle to learn and/or accept the details of evolutionary science, and at worst will outright reject any attempts by their instructor to teach them this important concept.

This is not a new challenge. Thomas H. Huxley (known as “Darwin’s Bulldog” for his defense of Darwin’s theory), when discussing the classification of humans among other mammals in *Man’s Place in Nature* (1863), wrote:

Bearing this obvious course of zoological reasoning in mind, let us endeavour for a moment to *disconnect our thinking selves from the mask of humanity*; let us imagine ourselves scientific Saturnians, if you will...discussing the relations they bear to a new and singular ‘erect and featherless biped,’ which some enterprising traveler [sic]...has brought from that distant planet for our inspection.... [emphasis added]

And three paragraphs later:

Being happily free from all real, or imaginary, personal interest in the results thus set afoot, we should proceed to weigh the arguments...with as much judicial calmness as if the question related to a new Opossum.

Likewise, Professor Sir Arthur Keith wrote in the opening pages of *Darwinism and What It Implies* (1928) that “unless the theory of evolution was accepted as a truth it was impossible to give any satisfying or intelligent explanation of the anatomy of the human body.” He then states:

When the anatomist, human as he may be, emerges into the thoroughfares of life and seeks to apply Darwin’s theory to the behavior of his fellow men and women he finds himself encompassed by a sea of resentment so angry that, if he seeks peace rather than truth, he keeps the secrets of the dissecting room, of the physiological laboratory, and of the clinical ward to himself and lets the world wag as it will.

In the present study, we sought to document students’ hypothesized emotional responses to the concept of evolution. Our results supported our hypothesis. Although this was the first study of its

kind, the results were definitive: 79% of participants (n = 33) generated documentable physiological reactions to question 3 (*Do you believe in evolution?*). The majority of participants also generated detectable physiological responses to the other relevant questions. Interestingly, participants’ behavior often changed after question 3 was asked, becoming visibly uneasy and sometimes aggressive toward the researcher. In addition, more than 60% of participants responded “yes” to question 9 (*Are you curious about evolution?*), yet fewer than half generated a detectable physiological response to this question. We suspect that this may reflect the lack of coverage of evolutionary theory in public schools.

○ Limitations

It could be argued that detection of a physiological response to evolution does not necessarily mean a negative one, and we allow for this possibility. However, because of the contentious nature of evolution education in general and in the Mid-South in particular, we do not view this as a strong possibility. Indeed, recent research reveals that among the 50 states, Arkansas ranks 50th in acceptance of evolution, while two contiguous states (Oklahoma and Mississippi) rank 45th and 48th, respectively (Heddy & Nadelson, 2013). Rates of acceptance in other contiguous states are not much higher: Tennessee, 44th; Louisiana, 37th; Missouri, 36th (Heddy & Nadelson, 2013). Therefore, the possibility of participants’ detected physiological reactions reflecting anything but negative emotional responses is remote. The nature of this testing also does not allow for discrimination between different forms of negative emotions, such as fear, anger, and anxiety. However, this was not our goal in the present study.

Finally, as noted above, these results do not explain the unexpected high numbers of reactions generated by question 8 (*Are you wearing jeans today?*). When this question is removed, the frequencies of responses to relevant questions are all significantly different from those for irrelevant questions, with the exception of question 7. We suspect that this unanticipated result stems from an unexpected focus on the participant, with a resulting physiological response.

○ Conclusion

Religious beliefs may play a crucial interfering role in classroom learning. According to the most recent Gallup poll, 46% of respondents replied with “inconsistent” to the question, “Do you think the theory of evolution is consistent or inconsistent with your religious beliefs?” (Gallup, 2014). For this study, an unexpectedly high number of participants answered “yes” to question 10 (*Do you think it’s possible to believe in evolution and still maintain religious values?* – 79%), yet the majority of participants also generated a physiological response to this question, suggesting cognitive dissonance. Accepting or even considering evolutionary theory as a valid scientific concept may be viewed as a threat to a lifetime of religious upbringing in the minds of these students.

Although solutions to this issue are not presented here, we have provided compelling evidence that these emotional responses are real. Informed biology teachers are encouraged to keep this in mind when teaching evolutionary theory and to acknowledge this response. Moreover, we encourage those who teach evolutionary

theory to actively seek ways to defuse this response in ways that are individually effective. For example, although results are mixed (e.g., Rutledge & Sadler, 2011), some researchers have found that an understanding of the nature of science correlates positively with acceptance rates of evolution, even after controlling for education and attitudes toward evolution in students (Johnson & Peeples, 1987; Lombrozo et al., 2008).

The experimental detection of a measurable physiological response to evolution is consistent with countless anecdotal observations by those who teach (or attempt to teach) evolutionary science. We have much to learn about the emotional dynamics of students and how these dynamics affect their learning. As Miller and Toth (2014) noted, this is indeed a “serious social problem.” Further research and development of instructional strategies is needed to improve the efficacy of teaching evolutionary science.

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