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A NEUROSCIENCE-BASED METHODOLOGY TO IDENTIFY THE IMPLICIT ASSOCIATIONS OF BRAZILIAN SCIENCE TEACHERS TOWARDS NUCLEAR TECHNOLOGY

***Roberta de Carvalho Barabás, Ana Cecília de S. Lima and Gaianê Sabundjian**

Doctoral Student, Av. Professor Lineu Prestes, 2242, Brazil

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ABSTRACT

Science, technology, and innovation play an essential role in helping countries increase the quality of life they offer their citizens. Since the discovery of nuclear fission in the 30s, the peaceful applications of nuclear technology have benefited several fields. Improved crops, preservation of food, health, environment protection and a stable supply of energy can be cited as contributions of nuclear technology for global wellbeing. Despite all benefits that result from the peaceful uses of nuclear technology, it is still addressed with prejudice. Prejudices may be explicit (conscious) or implicit (unconscious). Either explicit or implicit, prejudices interfere with individuals' attitudes. This paper aims to assess the implicit associations of Brazilian science teachers towards nuclear technology by administering the Implicit Association Test (IAT). Identifying their implicit associations will contribute for the understanding of prejudices that may interfere with their teaching. A pretest with nuclear specialists was administered to check the consistency of the IAT. Subsequently, it was administered to the science teachers. The results of the IAT demonstrated more positive associations towards oil. The next step consists of proposing a methodology to change implicit associations of Brazilian science teachers towards nuclear technology.

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INTRODUCTION

Science, technology, and innovation play an essential role in helping countries increase the quality of life they offer their citizens. Since the discovery of nuclear fission in the 30s, the peaceful applications of nuclear technology have benefited several fields. Improved crops, preservation of food, health advance – especially for the diagnosis and treatment of cancer –, environment protection and a stable supply of energy can be cited as contributions of nuclear technology for global wellbeing (IAEA, 1996). Despite all benefits that result from the peaceful uses of nuclear technology, it is still addressed with prejudice by the society probably due to lack of knowledge about its peaceful applications (Barabás and Sabundjian, 2013). Moreover, accidents in nuclear plants have contributed for its negative image leading to the formation of prejudiced beliefs and attitudes against nuclear technology (Visschers and Siegrist, 2012).

Corresponding author: **Roberta de Carvalho Barabás,**
Doctoral Student, Av. Professor Lineu Prestes, 2242, Brazil.

A literature review demonstrated that studies on nuclear technology education have been conducted worldwide since the 80´s. The conceptual and practical issues of nuclear energy have been addressed by authors. Most studies reported that a better physics teaching could improve public awareness through education of the benefits and relative safety of nuclear technology and that the students should be encouraged to research more about the theme and have positive attitudes towards science (Barabás and Sabundjian, 2013). By facilitating the acquisition of knowledge, skills, values, and beliefs, education is the starting point for a better understanding about the peaceful uses of nuclear technology, and may contribute for changing harmful concepts, prejudices, stereotypes, and behavior towards it. Educational neuroscience is a scientific field that explores the interactions between biological processes and education. It includes the study of neuronal and brain mechanisms that may underlie learning. By providing new measures of the effects of learning and teaching, including brain structure and activity, neuroscience has contributed for designing and adopting different types of educational methods (Ansari and Coch, 2006; Ansari and Coch, 2008; Goswami, 2006 and Meltzoff *et al*., 2009)

Prejudice and stereotypes regarding any theme may be explicit – at the conscious level – or implicit – operating outside awareness. While an explicit attitude is thought and reported deliberately, the implicit attitude occurs outside of conscious awareness and control. Nevertheless, either explicit or implicit, prejudices impose barriers on individuals and interfere with attitudes (Schacter and Tulving, 1994; Greenwald andBanaji, 1995; Fazio and Olson 2003). Although prejudices against nuclear technology emerge from different reasons, there are evidences in the literature demonstrating that implicit prejudices might be avoidable, reduced and even reversed with specific social situations through sensible changes in the social environment (Lowery *et al*., 2001; Rudman *et al*., 2005; Bargh, 1999; Devine, 1989 and Dovidio *et al*., 1997). Therefore, implicit prejudices against the use of nuclear technology may be reduced or even extinguished by an assertive and balanced teaching on its benefits, safety, potential risks, and peaceful applications in several fields. As far as prejudices are reported in the nuclear technology education scenario implicit measurement techniques can be an effective tool to identify and measure prejudices against nuclear technology.

The field of educational neuroscience has developed several types of implicit association tests aiming to assess implicit prejudices that individuals are consciously unaware (Greenwald and Banaji, 1995; Banaji, 2001; Greenwald *et al*., 1998 and Egloff and Schmukle, 2002). This paper aims to assess the implicit associations of a group of Brazilian science teachers towards nuclear technology by administering the Implicit Association Test (IAT) proposed by Greenwald *et al* (1998). Identifying the implicit associations of science teachers regarding nuclear energy will contribute for a better understanding of present prejudices that may interfere with the science teaching. Preconceived notions, nonscientific beliefs or conceptual misunderstandings may have influenced the implicit associations of science teachers, and those implicit associations can interfere with their attitudes in classroom towards nuclear technology.

Measuring implicit prejudices: Attitudes and prejudice include favorable and unfavorable assessments and affect understanding, actions and decisions in an unconscious way.
The explicit attitudes and stereotypes may be easily recognized by others; however, the implicit ones cannot be recognized except through specific types of implicit memory tests.The literature reports several types of implicit memory tests as a means of assessing what is activated from memory by the presentation of some attitude object (Banaji, 2001; Greenwald *et al*. 1998; Egloff and Schmukle, 2002; Wittenbrink, 2007 and Brunel *et al*., 2004). Probably the most well-known validated implicit measurement technique is the Implicit Association Test (IAT) (Nosek *et al*., 2007; Grenwald *et al*., 2009). The IAT is a widely used tool for assessing implicit attitudes and beliefs that subjects may be unwilling or unable to report. It has been administered worldwide assessing a great variety of themes such as race, phobia, gender, sexuality, weight, among others (Schmidt and Nosek, 2010;Xu *et al*., 2014; Danziger and Ward, 2010; Teachman and Woody, 2003; Peris *et al*., 2008; Agerström and Rooth, 2011; Gray *et al*., 2005). The test can be also be taken online on the webpage of the Project Implicit, a non-profit organization and international collaboration between cognition researches, providing a virtual laboratory for collecting data on the internet (Nosek*et al*., 2002; Nosek *et al*, 2007; Meade, 2009).

The IAT is a chronometric procedure that quantifies strength of conceptual associations by considering the latency with which participants can employ two response keys when each has been assigned a dual meaning. The IAT relies on the assumption that it is easier to make the same behavioral response (a key press) to concepts that are strongly associated than to concepts that are weakly associated. The IAT procedure aims to measure implicit attitudes by measuring their underlying automatic evaluation (Greenwald *et al*., 1998). The successful results have demonstrated IAT to be a reliable implicit measurement tool (Brunel *et al*., 2004; Schmidt and Nosek, 2010; Xu *et al*., 2014). One of the advantageous features of the IAT is its ability to produce large effects from relatively small samples, such as 20 participants (Greenwald *et al*., 1998).

MATERIALS AND METHODS

The *Free*IAT software was used to administer the IAT proposed by this study (Hair *et al*., 2006). By following the steps provided by the FreeIAT, a customized IAT was built aiming to compare the implicit associations of participants towards the use of nuclear energy and oil. For this purpose, the word stimuli for the first stimuli set was labeled and specified. Ten words were chosen being 5 positive and 5 negative. The positive words (good) were: *peace, safety, protection, healthy, and joy.* The negative words (bad) were: *tragedy, horrible, bad, harmful, and sadness.* Additionally, the word stimuli for the second stimuli set was labeled and specified. 20 words were chosen being 10 for "nuclear" and 10 for "oil". The words for "nuclear" were: *fission, radiotherapy, radioisotopes, neutron, uranium, Angra 2, radiation, reactor, radiopharmaceuticals,* and *plutonium*. The words for "oil" were: *gasoline, kerosene, asphalt, pre-salt, platform, Petrobrás, pipeline, drilling, diesel,* and *fossil.*

The IAT procedure has five steps, with steps 3 and 5 providing critical data. Typically, there are 40 trials within each critical block. The participants see the stimuli (words) that are presented sequentially in the center of the computer screen and are asked to respond as fast as possible by pressing the "E" key if the word belongs to the category on the left and the" I" key if the word belongs to the category on the right. Participants perform this categorization task until all stimuli have been presented several times. When a respondent presses the wrong key in response to a stimulus item, the task presents a red X and waits for the correct response to be made. In the IAT, Greenwald *et al*. found that error responses provide useful information for measuring the intended construct (Greenwald *et al*., 1998). During each trial, information is stored regarding the current stage, what stimulus was administered, how long (in milliseconds) until a correct response was entered, and whether an incorrect response was given. Two output files are created: the 'AllData.txt', containing raw data from all trials and the 'ScoresOnly.txt', containing the most relevant "final" scores. The IAT effect is calculated by using latency data from steps 3 and 5. According to Nosek *et al*., the interpretation of the IAT effect consists of the following values: lower or equal to 0.15 (= neutral); between 0.16 and 0.35 (= slight); between 0.36 and 0.65 (= moderate); greater than 0.65 (= strong). Those values are valid for both positive and negative values [21]. In order to demonstrate the steps of the IAT designed for this study, one example of possible association will be provided in Figures 1 to 4.

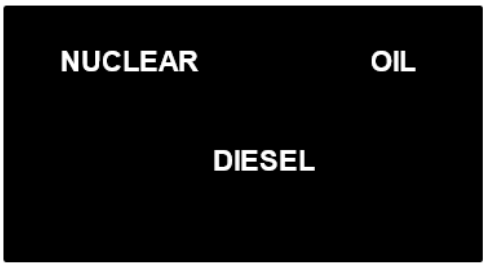

Figure 1. The concept dimension

Figure 2. The attribute dimension

Figure 3. Concept- attribute pairing

Figure 4. The categories are combined in an opposite way

Pretest with Specialists: After customizing the IAT for the study, a pretest with specialists on the nuclear field was administered. According to Hair *et al*. (2006), when items of a measurement instrument are developed specifically for a study, a pretest should be taken before the main experiment is carried out (George and Mallery, 2003). To measure the strength of implicit associations towards nuclear energy and oil a pretest using the customized IAT was first administered to 24 specialists from the *Centro de Engenharia Nuclear* (CEN) at the *Instituto de Pesquisas Energéticas e Nucleares* (IPEN). The pretest aimed to check the comprehension and consistency of the selected stimuli.

Pretest results: Of the 24 specialists, 87.5% demonstrated positive automatic associations towards nuclear energy and 12.5% towards oil. The high percentage of positive associations towards nuclear energy was an expected result since the subjects have deep knowledge about the applications of nuclear energy as shown in Figure 5.

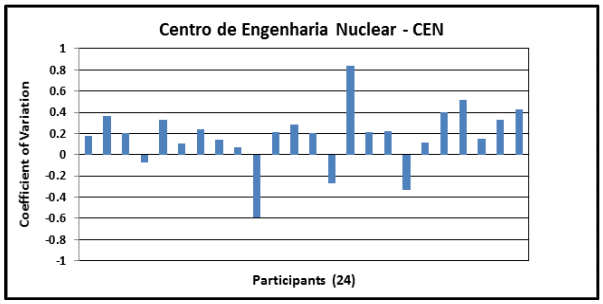

Figure 5. Representation of the scores of the implicit associations towards nuclear energy and oil

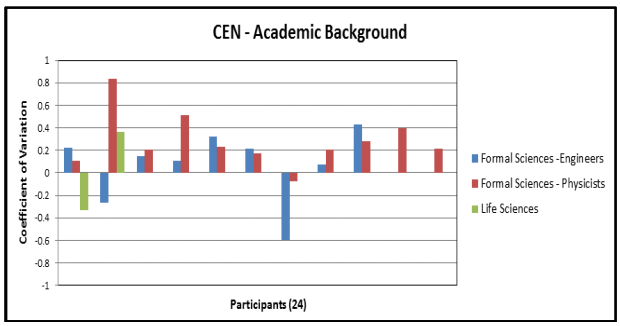

Figure 6. Representation of the scoresof the implicit associations towards nucear energy and oil according to academic background

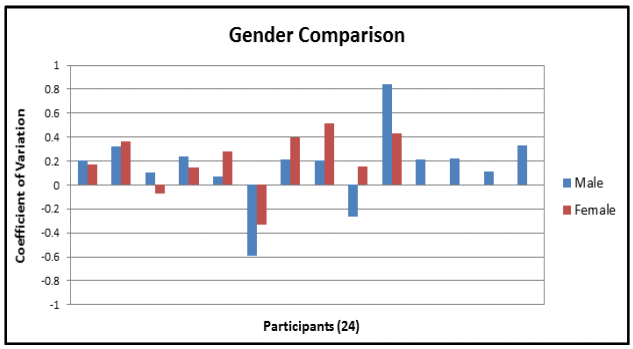

Figure 7. Representation of the scores of the implicit associations towards nuclear energy and oil according to gender

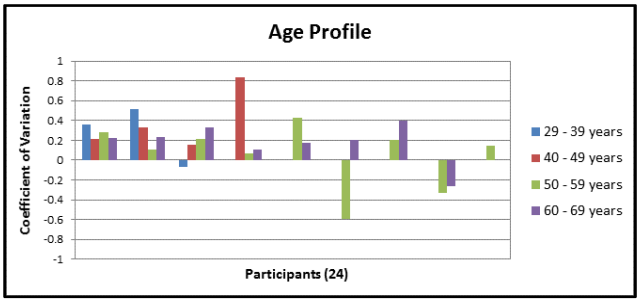

Figure 8. Representation of the scores of the implicit associations towards nuclear energy and oil according to age

Regarding the academic background of the specialists, 100% of the physicists, 80% of the engineers, 50% of the environmental experts demonstrated more positive associations towards nuclear energy than to oil as illustrated in Figure6. Of the 24 specialists, 14 were male and 10 female. 85.7% of male subjects and 90% of female demonstrated positive associations towards nuclear energy; however, the strength of positive associations held by the female had higher values as demonstrated in Figure 7.

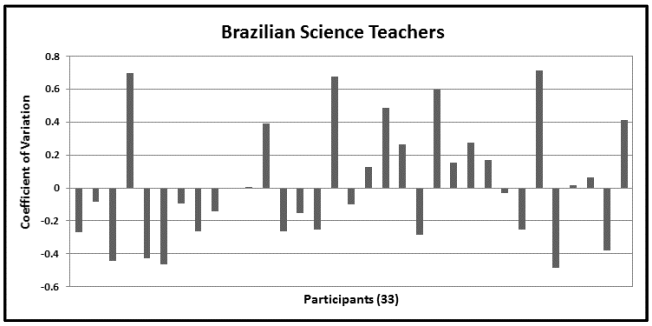

Figure 9. Representation of the scores of the science teachers' implicit associations towards nuclear energy and oil

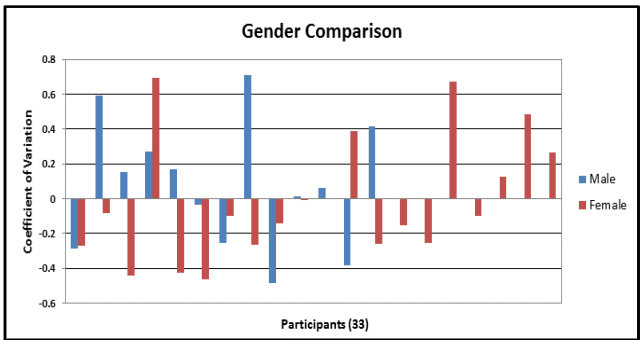

Figure 10. Representation of the scores of the science teachers' implicit associations towards nuclear energy and oil according to gender

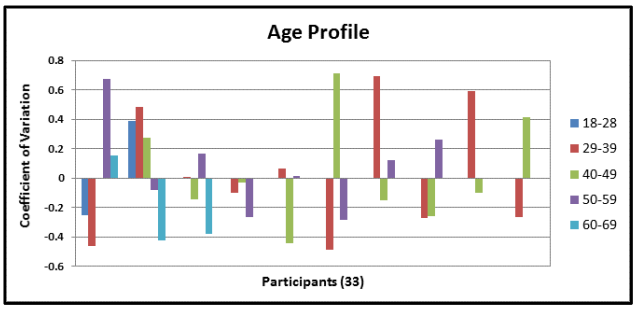

Figure 11. Representation of the scores of the science teachers' implicit associations towards nuclear energy and oil according to age

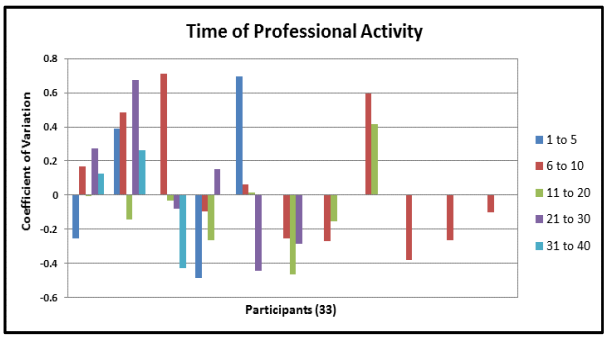

Figure 12. Representation of the scores of the science teachers' implicit associations towards nuclear energy and oil according to time of professional activity

Regarding age profile, 12.5% of the specialists who demonstrated more positive associations towards oil were over the age of 50 years. Younger respondents tended to demonstrate more positive associations to nuclear technology as shown in Figure8.

As expected, the results presented above demonstrated that the specialists tend to have more positive associations towards the use of nuclear energy than towards oil. Those results confirm that the experiences of life and academic/professional background interfere with the concepts and associations towards a theme.

Pretest analysis – internal consistency: The Cronbach´s alpha was applied to measure the reliability of the test. The value of *alpha* ranges from zero (unreliable) to one (perfect reliability), with a value of 0.70 or greater considered acceptable for most purposes. Internal consistency should be determined before a test can be employed for research or examination purposes to ensure validity. Table 1 shows the rule for describing internal consistency using Cronbach's alpha provided by George and Mallery (2003). The Statistical Package for the Social Sciences - SPSS version 17.0 released in 2008 was the software program used in this study to run a Cronbach`s alpha test (SPSS, 2008). The value of alpha was 0.869, suggesting that the items have good internal consistency.

The administration of the IAT to science teachers

Subsequently the customized test was administered to a group of 33 Brazilian science teachers, being 20 female and 13 male. Of the 33science teachers, 36.4% were neutral, that is, they demonstrated no clear preference for any of the categories.30, 3% demonstrated positive automatic associations towards nuclear energy and 33.3% towards oil as illustrated in Figure 9.

RESULTS AND DISCUSSION

The balanced percentage of positive associations towards nuclear energy and oil as well as a neutral preference may be due to the fact that the science teachers have different degrees of knowledge about the applications of nuclear energy from diverse points of view according to their academic/ professional background and life experience. Of the 20 female teachers, 40% of were neutral (no clear preference). 25% of the females demonstrated positive associations towards nuclear energy and 35% towards oil.

Table 1. Cronbach´s alpha reliability coefficients

Internal Consistency	Unacceptable	Poor	Questionable	Acceptable	Good	Excellent
Cronbach's alpha (α)	0.5 > α	0.6 > α ≥ 0.5	0.7 > α ≥ 0.6	0.8 > α ≥ 0.7	0.9 > α ≥ 0.8	α ≥ 0.9

Of the 13 male teachers, 30.8% were neutral, 38.4% demonstrated positive associations towards nuclear energy and 30.8% towards oil. Although the percentage of male preference for nuclear energy was higher, the strength of positive associations held by the female had higher values as demonstrated in Figure10. Regarding age profile participants aged between 18 and 28 had balanced results: 50% demonstrated positive associations towards nuclear energy and 50% towards oil. 40% of the teachers aged between 29 and 39 demonstrated more positive associations towards oil, 30% had positive associations towards nuclear energy and 30% were neutral. 44.4% of the middle-aged teachers, between 40 and 59 were neutral, 33.4% had positive associations towards nuclear e 22.2% towards oilas illustrated in Figure 11. 66.7% of the teachers who demonstrated more positive associations towards

oil were over the age of 60 years. One possible explanation for the higher percentage of negative associations towards nuclear energy among elderly participants may be the fact that they witnessed nuclear accidents such as the Three Mile Island accident (1979), the Chernobyl accident (1986), the crash of the cesium-137 in *Goiânia*, Brazil (1987), and the recent accident in Fukushima (2011). Those events may have been responsible for the negative image of nuclear energy. Regarding the time of professional activity, the results were quite balanced except for the teachers who have between 11 to 20 years of teaching practice. Only 12.5% had positive associations towards nuclear energy. Since these experienced teachers are older, these results agree with the age profile data as demonstrated in Figure 12.

Conclusion

Based on the results presented above we can conclude that specialists tend to have more positive associations towards the use of nuclear energy than towards oil. The science teachers had more balanced results concerning the positive associations towards both sources of energy. The balanced results may be due to the different degrees of knowledge about the peaceful applications of the nuclear technology. Thus, if the science teachers are provided with assertive knowledge about the use of nuclear energy their strength of positive implicit associations towards nuclear energy may increase, since the literature states that implicit associations may be reduced or even reversed 9 rudman *et al*., 2005; Bargh, 1999; Devine, 1989; Dovidio, 1997). The results presented in this paper consisted of the first steps of a doctoral research in progress, which aims to demonstrate how educational neuroscience helps identify and change implicit associations of Brazilian science teachers regarding nuclear technology. The use of neuroscience-based methods may enhance the teaching of physics, together with the technologies related to this science.

Ethics statement: The study was approved by the Ethics Committee of CEFAC – Saúde e Educação, under the number 65557317.0.0000.5538.

Future research: The body of research discussed above demonstrates that principles of neuroscience may be a helpful tool in education. Future studies will include the proposal of a neuroscience-based program aiming to change the implicit associations towards nuclear technology of Brazilian science teachers. The results obtained from the future administration of the methodology will contribute with relevant data for international cognition research.

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