THE USE OF A NEUROSCIENCE-BASED METHODOLOGY TO DEMYSTIFY AND TEACH ABOUT THE BENEFITS OF THE NUCLEAR FIELD: NEUROSCIENCE APPLIED TO NUCLEAR ENERGY TEACHING

Roberta de C. Barabás[1] and Gaianê Sabundjian

Instituto de Pesquisas Energéticas e Nucleares (IPEN / CNEN - SP)
Av. Professor Lineu Prestes, 2242
05508-000 São Paulo, SP

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 advance – specially 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. Despite its benefits the nuclear energy is still addressed with prejudice. Accidents in nuclear field have contributed for its negative image. Prejudice against nuclear energy lead to misconceptions on the theme, which interfere with authorities' decision on the development of new nuclear technology. Education is the starting point for public acceptance of nuclear technology. Educational neuroscience is an emerging scientific field that explores the interactions between biological processes and education and helps identify and change implicit associations. This paper aims to demonstrate how the previous knowledge may interfere with the implicit associations towards a source of energy. The first steps of a neuroscience-based methodology in progress are presented in this paper: a) a pretest with specialists of the nuclear field; b) a subsequent test with lay subjects; and c) comparison of the results from the pretest and test. A future step consists of applying neuroscience principles to Brazilian science teachers to identify and modify implicit attitudes towards nuclear technology to promote an assertive teaching-learning process The global educational scenario has demonstrated absence of neuroscience-based methods for the nuclear technology teaching and that represents an opportunity for developing strategic teaching methods that will help demystifying the theme consequently improving public acceptance of this type of technology. Once the real scenario is demystified, the population will have a broad vision of all contributions of the nuclear field.

1. 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 [1].

Despite all benefits that result from the peaceful uses of nuclear technology, it is still addressed with prejudice by the society probably due to an incorrect and limited view of its benefits [2]. Accidents in nuclear field have contributed for its negative image leading to the formation of prejudiced beliefs and attitudes against nuclear technology [3].

[1] Email of the first author: robertabarabas@usp.br

Holding prejudice against nuclear technology will lead to misconceptions and interfere with authorities' decision on the development of new technology. Nevertheless, the literature states that prejudices – either explicit (conscious) or implicit (unconscious) – might be avoidable, reduced and even reversed [4,5].

A key aspect to be considered regarding implicit prejudice is that although it is unconscious it interferes with behavior and automatic responses [6]. The explicit prejudice may be easily recognized by others; however, the implicit ones cannot be recognized except through specific types of implicit memory tests.

The field of educational neuroscience has developed several types of implicit association tests aiming to assess implicit prejudices that individuals are consciously unaware [7-10].

As far as prejudices are reported in the nuclear energy education scenario implicit measurement techniques can be an effective tool to identify and measure prejudices against nuclear technology

This paper aims to demonstrate how the previous knowledge may interfere with the implicit associations towards a source of energy (nuclear and oil). The first steps of a neuroscience-based methodology in progress are presented in this paper: a) a pretest with specialists of the nuclear field; b) a subsequent test with lay subjects; and c) comparison of the results from the pretest and test. This study demonstrates how educational neuroscience helps identify and change implicit associations regarding nuclear technology.

2. MATERIAL AND METHODS

The first step of the methodology consisted of reviewing the literature about nuclear energy education worldwide to have a clear visualization of the global nuclear energy educational scenario and to serve as a reference for the design of the proposed methodology [2].

The second step consisted of selecting a reliable implicit memory test to measure implicit attitudes [11]. Among the various types of tests reported in the literature, the Implicit Association Test (IAT) demonstrated to be widely administered with successful results [12-15].

2.1. The Implicit Association Test (IAT)

The IAT is a chronometric procedure that measures the relative strength of associations by contrasting latencies across conditions. It is designed to reveal the automatic associations subjects hold between concepts (e.g. nuclear and oil) and attributes (e.g. good or bad) by asking the participant to rapidly pair concepts and associated constructs [12].

The *Free*IAT software was used to administer the IAT proposed by this study [16]. 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.

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.

In order to demonstrate the steps of the IAT designed for this research, one example of possible association will be provided in Figures 1 to 4.

Figure 1. The concept dimension

Figure 2. The attribute dimension

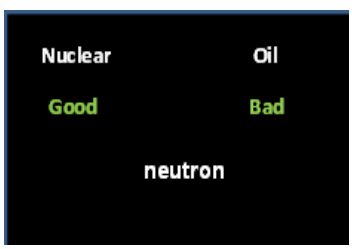

Figure 3. Concept-attribute pairing

Figure 4. The categories are combined in an opposite way

2.1.1. Pretest with specialists

The third step of the methodology consisted of administering a pretest. According to Hair et al., when items of a measurement instrument are developed specifically for a study, a pretest should be taken before the main experiment is carried out [17].

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 Nuclear Engineering Center (CEN) at the Instituto de Pesquisas Energéticas e Nucleares (IPEN). The pretest aimed to check the comprehension and consistency of the selected stimuli.

2.1.2. Test with lay participants

Subsequently, the customized IAT was administered to 29 lay participants and the results were compared to the pretest with specialists. The administration of the IAT to lay participants aimed to identify quantitatively the implicit associations towards nuclear energy and oil. The results from the pretest with specialists and from the test with lay participants were compared.

3. RESULTS AND DISCUSSION

3.1 Pretest Analysis

Aiming to check the comprehension and consistency of the customized IAT a pretest was first administered to 24 specialists from the Nuclear Engineering Center (CEN) at IPEN. 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 [18].

Table 1: Cronbach

Internal	Unacceptable	Poor				Excellent

Consistency						
Cronbach's alpha	$0.5 > \alpha$	$0.6 > \alpha \geq 0.5$	$0.7 > \alpha \geq 0.6$	$0.8 > \alpha \geq 0.7$	$0.9 > \alpha \geq 0.8$	$\alpha \geq 0.9$

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 [19]. The value of alpha was 0.869, suggesting that the items have good internal consistency.

3.2 Comparison of Results of the Pretest and Test

This section presents and discusses the results from the customized IAT administered to the specialists (pretest) and lay participants (test).

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 (Fig. 5).

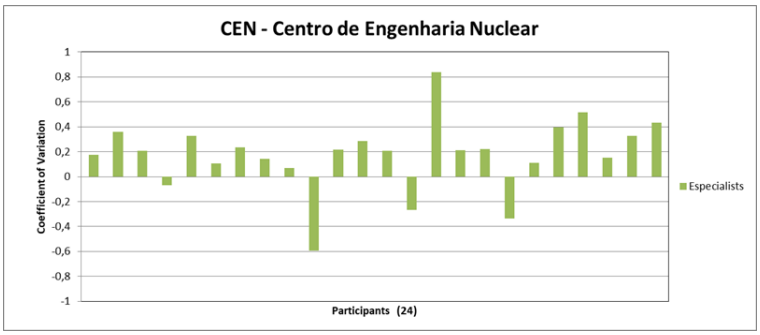

Figure 5. Representation of the scores of the implicit associations towards nuclear energy and oil

Of the 29 lay participants, 15 demonstrated positive automatic associations towards nuclear energy and 14 towards oil. The balanced percentage of positive associations towards nuclear energy and oil may be due to the fact that the lay subjects 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 (Fig. 6). The following items of comparison will contribute to this preliminary conclusion.

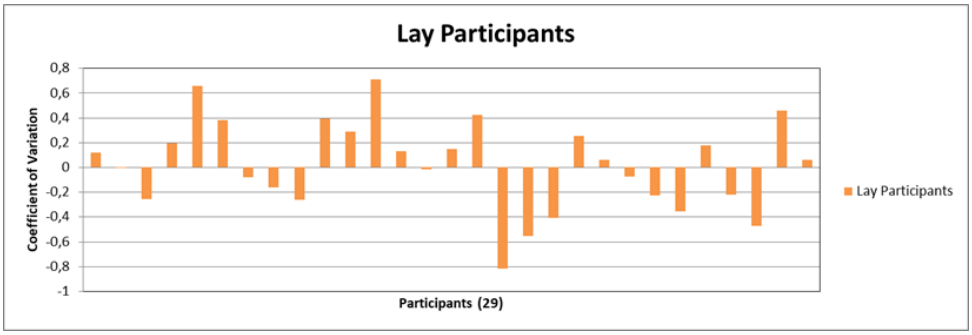

Figure 6. Representation of the scores of the implicit associations towards nuclear energy and oil

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 (Fig. 7).

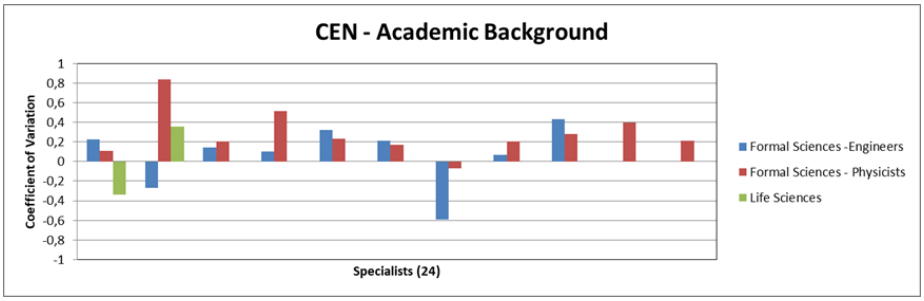

Figure 7. Representation of the scores of the implicit associations towards nuclear energy and oil according to academic background

Regarding the academic background of the 29 lay participants, 19 respondents majored in the field of Social Sciences, 6 in the field of Formal Sciences, and 4 in the field of Life Sciences.

Of the 19 who majored in Social Sciences, 10 demonstrated more positive associations towards nuclear energy, and 9 had more positive associations towards oil. Again, the balanced results may be due to the different academic/professional experiences (Fig. 8).

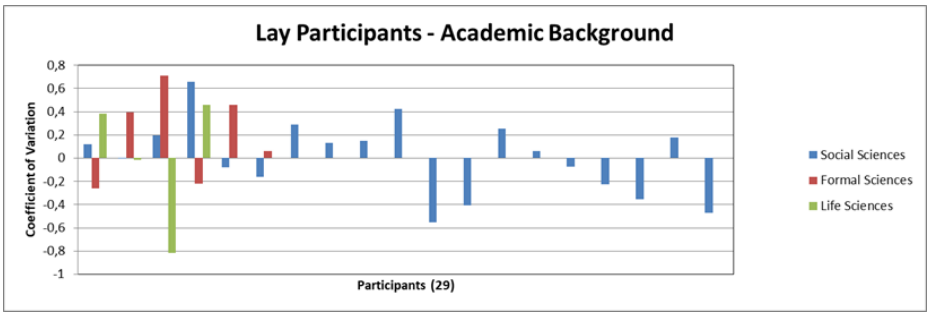

Figure 8. Representation of the scores of the implicit associations towards nuclear energy and oil according to academic background

Regarding gender, 14 specialists 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 (Fig. 9).

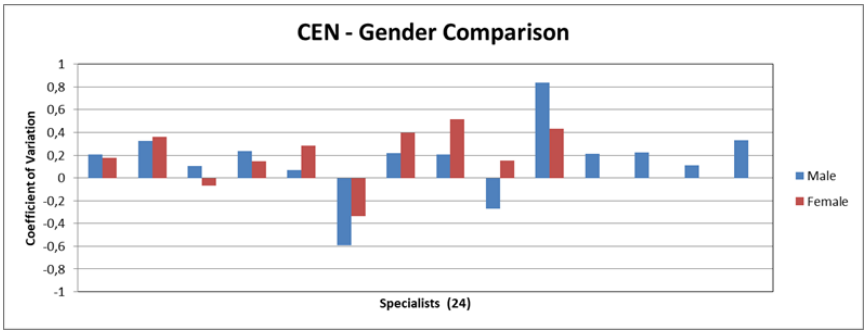

Figure 9. Representation of the scores of the implicit associations towards nuclear energy and oil according to gender

Regarding gender, 16 lay participants were male and 13 female. 43.7% of male lay participants and 61.5% of female demonstrated positive associations towards nuclear energy; moreover, the strength of positive associations held by the female had higher values (Fig. 10).

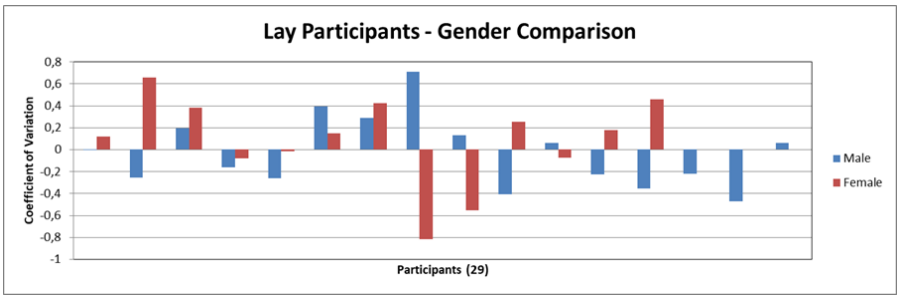

Figure 10. Representation of the scores of the implicit associations towards nuclear energy and oil according to gender

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 (Fig. 11).

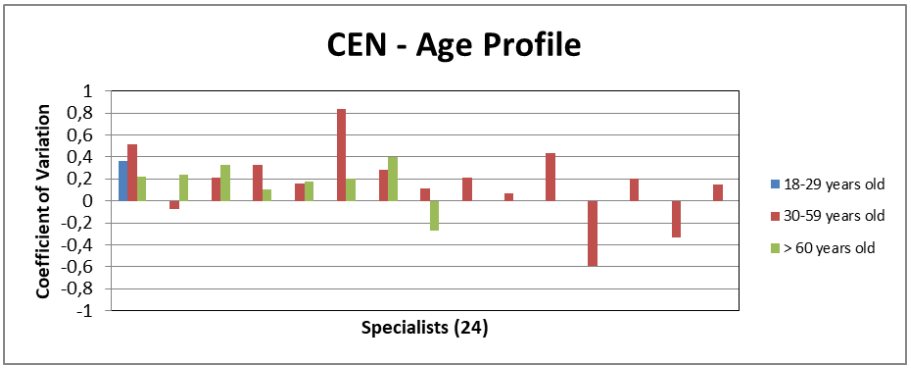

Figure 11. Representation of the scores of the implicit associations towards nuclear energy and oil according to age

Regarding age profile, of the 16 young lay respondents, aged 18-29, 9 had more positive associations towards nuclear energy and 7 towards oil. Of the adults aged over 30 years, 7 had positive associations towards nuclear technology and 6 towards oil (Fig. 12). Once again, the balanced results demonstrate the experiences of life and academic/professional background interfere with the concepts and associations towards a theme.

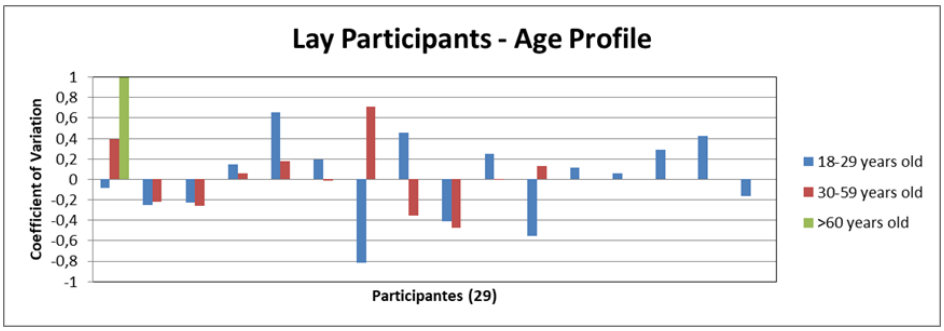

Figure 12. Representation of the scores of the implicit associations towards nuclear energy and oil according to age

The results presented above demonstrated that the specialists tend to have more positive associations towards the use of nuclear energy than towards oil. However, the lay subjects had 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 lay public is 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 [4,5].

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.

4. CONCLUSIONS

The present study concluded that: a) the IAT pretest administered to the specialists demonstrated good internal consistency (Cronbach`s alpha reliability coefficient was 0.869); b) the IAT comparison between the pretest with specialists and the test with lay participants demonstrated that the previous knowledge interferes with the implicit associations towards a source energy.

The steps of the methodology in progress presented in this paper have provided reliable data for the next steps of the doctoral research.

A future step consists of administering the IAT to Brazilian science teachers to measure the implicit associations towards nuclear energy and the results will be presented in future works.

ACKNOWLEDGMENTS

The authors would like to thank IPEN for the financial support provided for this work.

5. REFERENCES

1. "Apostila educativa: aplicações da energia nuclear", http://www.cnen.gov.br/apostilas/aplicação.pdf (2015)
2. Barabás, R; Sabundjian, G. "Nuclear Energy Education Scenario around the World", *Proceedings of the International Nuclear Atlantic Conference*, Recife, Pernambuco, November 24-29 (2013)
3. Visschers, V. H. M.; Siegrist,M. "How a nuclear power plant accident influences acceptance of nuclear power: results of a longitudinal study before and after the Fukushima disaster", *Risk Analysis*, **v. 33**, pp. 333-346 (2012).
4. Lowery, B.;. Hardin, C.D; Sinclair, S. "Social influence effects on automatic racial prejudice", *Journal of Personality and Social Psychology*, **v. 81**, pp. 842-855 (2001).
5. Rudman, Ashmore, Gary, " 'Unlearning' automatic biases: the malleability of implicit prejudice and stereotypes", *J Pers Soc Psychol,* **v.81**, 5, pp.856-68 (2001).
6. Schacter, D.L; Tulving, E. *What are the Memory Systems of 1994?* In: Schacter DL, Tulving E, Editors. Memory Systems 1994. Cambridge: MIT Press (1994).
7. Banaji, M. R. "Implicit attitudes can be measured". In H. I. Roediger and J. S. Nairne (Eds.), The nature of remembering: Essays in honor of Robert G. Crowder, *American Psychological Association*, pp. 117-150, Washington, D. C. (2001).
8. Greenwald, A. G.; Banaji, M. R. "Implicit social cognition: Attitudes, selfesteem, and stereotypes*", Psychological Review*, **v. 102**, pp.4-27 (1995).
9. Greenwald, A. G.; McGhee, D. E.; Schwartz J. L. K.. "Measuring individual differences in implicit cognition: The implicit association test"**,** *Journal of Personality and Social Psychology*, **v. 74,** pp. 1464-1480 (1998).

10. Egloff, B.; Schmukle, S.C. “Predictive validity of an implicit association test for assessing anxiety”, *Journal of Personality and Social Psychology*, **v.83**, pp. 1441–1455 (2002).
11. Barabás, R.; Sabundjian, G. “The development of a neuroscience-based methodology for the nuclear energy learning/teaching process”, *Proceedings of the International Nuclear Atlantic Conference*, São Paulo, São Paulo, October 4-9 (2015)
12. Greenwald, A.G.; McGhee, D.E.;. Schwartz, J.K.L. “Measuring individual differences in implicit cognition: The Implicit Association Test”, *Journal of Personality and Social Psychology*, **v.74**, pp.1464-1480 (1998).
13. Egloff, S.C. Schmukle. “Predictive validity of an implicit association test for assessing anxiety”, *Journal of Personality and Social Psychology*, **v.83**, pp. 1441–1455 (2002).
14. Brunel, F.F.; Tietje, B.C.; Greenwald, A.G. “Is the Implicit Association Test a valid and valuable measure of implicit consumer social cognition?”, *Journal of Consumer Psychology*, **v. 14**, pp. 385–404 (2004).
15. Victoria, M.S. et al. *“S*election of visual stimuli for the Implicit Association Test for the Obsessive-Compulsive Disorder (IAT-OCD)”, *Rev Psiq Clín.*, **v.38**,*.3*, pp.102-5 (2011).
16. Meade, A.W. “Free*I*AT: An open-source program to administer the implicit association test”, *Applied Psychological Measurement*, **v.33**, p. 643 (2009).
17. Hair, J.F.et al. *Multivariate Data Analysis*. 6. ed. Upper Saddle River: Prentice Hall (2006).
18. George, D.; Mallery, P. *SPSS for Windows step by step: A simple guide and reference. 11.0 update*. 4th ed. Boston: Allyn & Bacon (2003).
19. SPSS Inc. Released 2008. SPSS Statistics for Windows, version 17.0. Chicago: SPSS Inc.