At The Very Root of The Development Of Interest: Using Human Body Contexts to Improve Women's Emotional Engagement In Introductory Physics

Geneviève Allaire-Duquette

Patrick Charland

*Martin Riopel**

Université du Québec à Montréal, Faculté des sciences de l'éducation

CP.8888 Succ. Centre-ville, Montréal, Québec, Canada, H3C 3P8

**allaire-duquette.genevieve@uqam.ca*

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Abstract
In physics, women find contexts concerning human biology, medical applications, or natural phenomena highly relevant (Hoffmann, 2002), and the rareness or absence of these in physics curricula may make it more difficult for women to develop and maintain their interest in physics. To date, research in physics education addressing student's interest mainly employed subjective or contextual data, mostly questionnaires containing statements about different scientific topics. However, no index has been used to identify the triggering of interest as it is happens in real time and, more importantly, in action. Psychophysiological data, in this case electrodermal activity, allow non-intrusive recordings of student's arousal that serve as a more direct and objective way to observe their interest while they solve physics problems. The onset of interest with arousal must be investigated given that a strong, positive emotional engagement is an essential first step in developing interest in a discipline (Hidi & Renninger, 2006). This study compares the emotional engagement of 13 female college and university students while solving physics problems involving either technical or human body contexts. Results show that the emotional engagement of women in the subject was, in part, significantly greater and more positive when they were solving problems involving the human body context rather than the technical context.
Keywords - development of interest, gender, introductory physics, contextualization

Introduction

Physics classes often involve problems that are technical or presented in purely scientific contexts (Häussler, Hoffmann, Langeheine, Rost, & Sievers, 1998; Holmes, Burns, Marra, Stubbe, & Vine, 2003, Murphy, 1990; Srivastava, 1996) which may explain the gender disparity in the field and women's lack of interest in the subject (Murphy & Whitelegg, 2006). The underrepresentation of women in physics at university (see Figure 1) has been widely addressed in American and international literature (eg. Baram-Tsabari & Yarden, 2008 ; Lavonen, Byman, Juuti, Meisalo, & Uitto, 2005). Although the gender gap in other scientific fields has been bridged in recent years, the gender disparity in physics, in both professional and academic spheres, is yet to be reduced (Ivie & Stowe, 2000 ; Lorenzo, Crouch, & Mazur, 2006). Among all sociological, psychological, and cultural factors affecting the choice of women to pursue studies and careers in physics, there is a consensus that one of the major contributing factors is that women develop significantly lower levels of interest in physics than men (see, for example, related studies in Scotland (Stark & Gray, 1999), Australia (Dawson, 2000), the United States (Jones, Howe, & Rua, 2000), England (Murphy and Whitelegg, 2006), Germany (Hoffmann, 2002), and an international study (Lavonen et al., 2005)).

Although the desire to engage in learning or problem solving is essential in an individual's learning process (Hidi & Harackiewicz, 2000), teachers rarely have a clear understanding of their roles in developing their students' interest toward their discipline (Lipstein & Renninger, 2006), and this seems to be the case with physics.

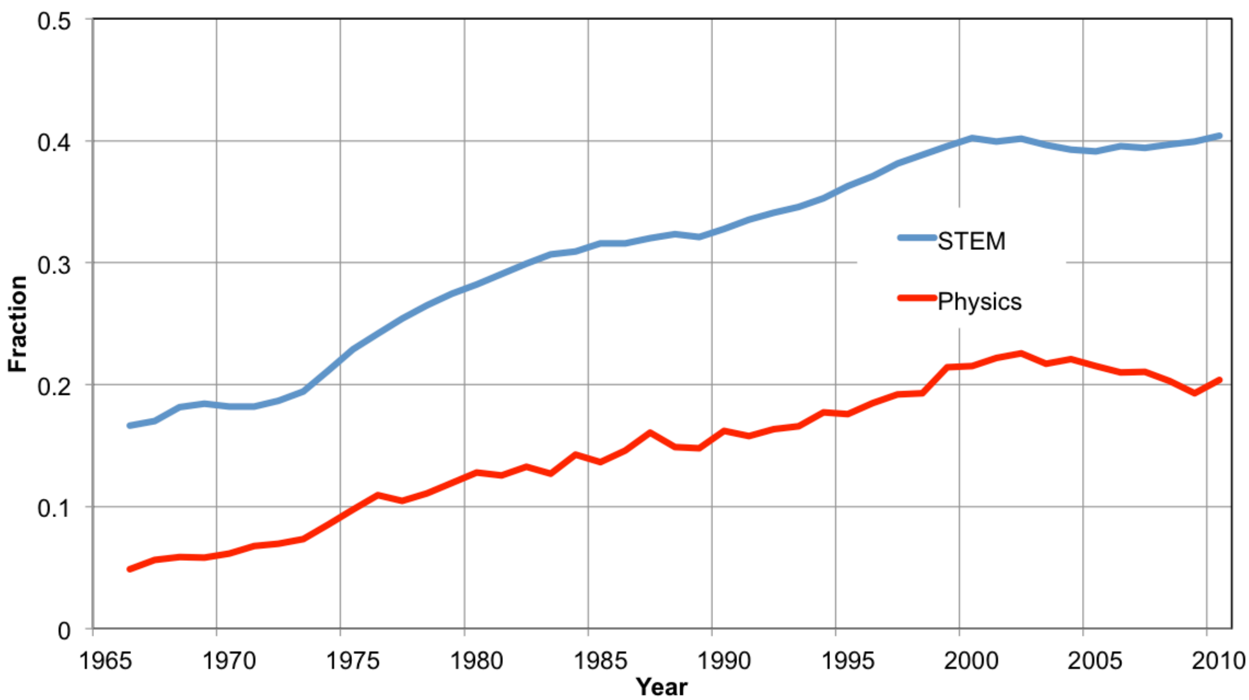

Figure 1. Bachelor's degrees earned by women from 1966 to 2010.[17] *(STEM = Science, Technology, Engineering, & Mathematics) (Source: IPEDS Completion Survey)*

Hoffmann (2002) found that less than 20% of the variance in the interest of men and women in physics was due to content, whereas the remaining 80% was related to the context in which the concepts and activities were presented to the students. For example, classes in mechanics rarely focus on the study of phenomena in context (Murphy and Whitelegg, 2006), but use sports, military, and automotive contexts (Hoffmann, 2002). To stimulate and maintain the interest of an individual in a particular subject matter, a teacher needs to initiate a first critical phase (Hidi & Renninger, 2006) that is accompanied by a sudden change in the emotional and cognitive processes (Hidi & Baird, 1986, 1988, Mitchell, 1993). Stimuli-engaging emotions are then assumed to develop students' interest in physics. Therefore, physics teachers must focus on stimulating the emotions of their students. Certain contexts are suggested to be more effective in stimulating emotions (Duit, Häussler, Lauterbach, Mikelskis, & Walter, 1992, p.109):

> *Physics that arouses emotions in general stimulates interest. [and] Girls' feelings appear to be stimulated especially by natural phenomena. They are*

not as much as boys [for example] interested in « stunning » technical devices or developments.

Therefore, strategies for stimulating students' interest and engaging them in physics must be identified, considering that physics, as it is traditionally taught, is perceived by students as irrelevant and demotivating (Murphy & Whitelegg, 2006). In fact,

(…) a promising educational tool could be developed if science teachers were to create and maintain girls' situational interest in science through the introduction of non-scientific contexts and illustrations that are known to activate girls' individual interests (Krapp, 1998; Mitchell, 1993). (Kerger, Martin, & Bruner, 2011, p.608-609)

The effect of a problem's context on student's emotions when answering physics problems has never been investigated. Therefore, the potential of the contextualization of physics problems for generating a sudden change in an individual's affective processes that trigger their interest has never been confirmed. Research results along these lines can justify the development of educational interventions that aim to diversify contexts as well as ways of approaching problems in physics (e.g., studying physics through biological contexts). In recent years, an increasing number of studies are collecting psychophysiological data that provide more direct and objective measures of psychological states. According to the OECD (2007, p.22),

Neuroscience is beginning to provide a detailed account of how human beings– or their human brains–respond to different learning experiences and classroom environments and why they react in the ways they do. This understanding is important for education because so much educational policy and practice is based on only limited information.

Psychophysiological measures allow researchers to observe how students react to changes in their learning environment. In the case of this study, these measures allow us to observe from a neuroscientific perspective how learning conditions can promote the development of women's interest in physics. Psychophysiological measures of emotional engagement can provide new evidence on the role of contexts in generating women's interest in physics. The long-term aim of this study is to improve the development of women's interest in physics and to increase their representation in the field.

Developing interest in physics

Interest is a motivational variable that refers to a psychological state of engagement or predisposition to re-engage in a certain task, event, or idea (Hidi & Renninger, 2006). The affective components of interest include the expression of positive emotions and are neurobiologically based (Hidi, 2003). The human motivational system originates from emotional brain circuits (Panksepp, 2003). Therefore, the interest of individuals would be aroused through interactions in which they are engaged physically, cognitively, and symbolically with the object of their interest (Hidi & Renninger, 2006).

> *Second, both the affective and cognitive components of interest have biological roots (Hidi, 2003). Neuroscientific research on approach circuits in the brain (e.g. Davidson, 2000) and on seeking behavior (e.g., Panksepp, 1998, 2000) indicate that interested activity has a biological foundation in all mammals. Panksepp and his colleagues specifically argued that the seeking system is an evolutionary and genetically ingrained emotional brain system. (Hidi & Renninger, 2006, p.112)*

Although individuals are capable of developing interest on their own, the object and the environment largely define the direction of the interest and the scope of its development (Hidi & Renninger, 2006). In physics education, interest is considered a psychological state that reflects the relationship between a student and the teaching approach of the phenomena of the material world (Hoffmann, 2002). As Kerger *et al.* (2011, p.608-609) report,

> *In the first phase, situational interest is triggered, for example, by environmental conditions such as group work, computers, puzzles, incongruous or surprising information, character identification (...)*

The first phase of the development of interest is known as triggered situational interest. It involves a sudden change in an individual's affective process, which is regarded in this study as emotional engagement. In physics classes, situational interest can be triggered by the classroom climate, teaching strategies, learning activities, or contexts in which the physics lesson is presented (Häussler & Hoffmann, 2002). The learning environment can also generate situational interest among students who have, a priori, low levels of interest in physics (Hoffmann, 2002). Triggered situational interest in physics is seen as a three-dimensional concept (Gardner, 1985), with the dimensions being interest in a subject (e.g., optics), interest in the context in which the subject is presented (e.g., photography), and interest in the type of learning activity (e.g., building a camera). This study focuses on interest in the context in which the subject is presented.

Many studies on student interest in physics argue that the integration of more contexts about natural phenomena, social issues, or students' daily experiences must be prioritized to inspire changes in physics education (Häussler & Hoffman, 2002; Labudde, Herzg, Neuenschwander, Violi, & Gerber, 2000. Murphy & Whitelegg, 2006). Duit *et al.* (1992) summarized the main findings on the relation between the contextualization of physics and the interest of women in the subject:

- The relation between social issues, such as noise pollution and energy consumption, and physics is of particular interest to women, and this interest increases with age.
- Medical and biological applications, such as the magnetic sense of birds and ultrasound emissions by some animals, stimulate women's interest more than technical applications.
- Women perceive contexts relating to the human body as the most significant, such as the prevention of motor vehicle collisions or the effects of electric shocks on the human body.

Other studies confirmed findings reported by Duit et al. (1992) that women are not only particularly interested in human biology, social issues, medical applications, and natural phenomena, among others (Hoffmann, 2002) but that they also appear to be more sensitive to the contexts in which physics content is presented (Häussler et al., 1998). Recent studies (Murphy & Whitelegg, 2006; Skyabina & Reid, 2003) have confirmed such findings, noting that despite substantial evidence, the contexts used in physics classes still reflect examples where physics is studied by itself rather than in relation with social, medical, or human body contexts.

Therefore, this study wishes to further the understanding of how contexts in physics education can influence women's interest in the subject. Using a psychophysiological approach, this study compares the context that triggers women's interest, i.e., the human body context, with the context that is largely perceived as irrelevant for women, i.e., technical context.

This article is organized as follows. The Methodology section discusses the measurement of emotional engagement and describes the study design, including the sample, protocol, and experimental processes. The Results and discussion section presents the findings of this study, relating them to the hypothesis and questions raised in the Introduction section. The Conclusion section summarizes the major findings of this study, highlights their importance, and discusses future areas of research.

Methodology

The early stages of the development of interest depend on the emotional processing and the sudden change in an individual's affective process (Hidi & Renninger, 2006). One way to determine changes in an individual's affective process is to measure their emotional engagement, which is a psychological state that reflects the configuration of their instant reaction (River & Godet, 2003). Bradley, Codispoti, Cuthbert, & Lang (2001, p.276) call it *emotional meaning*, and " Multivariate studies have consistently shown that the principal variance in emotional meaning is accounted for by two predominant factors, pleasure and arousal (...)". Therefore, emotional engagement involves (1) valence, or the appreciation of an experience from negative to positive and (2) arousal, or the intensity of the appreciation.

Valence, the first variable of emotional engagement, is the subjective appreciation of an experience that reflects the type of motivational system instinctively activated, appetitive (positive) or aversive (negative). Arousal is a measurable physiological change that reflects the predisposition of the organism to react (Lang, Greenwald, Bradley, & Hamm, 1993). Generally, an organism demonstrates an increase in arousal when there is a relative increase in the response intensity of its sympathetic nervous system.

Electrodermal activity (EDA) (or galvanic skin conductance) is the most widely used psychophysiological indicator and the most validated measure of arousal. The changes in skin conductance can provide information about bodily states of activation during emotional, cognitive, and physical behaviors; these changes are identified by measuring the activity of cholinergic sympathetic neurons in the eccrine glands located in the dermis (Venables & Christie, 1980). Thus, EDA has become a tool for studying the most common affective processes given the significance of the autonomic nervous system in expressing emotions and inspiring motivation (Figner & Murphy, 2011).

Valence was measured based on participants' response when asked about the degree to which a task was pleasant, similar to Häussler *et al.* (1998) and Kerger *et al.* (2011) who asked students to rate their interest toward certain topics in physics. Arousal, the second variable, is measured by EDA given its minimal invasiveness. Several studies have used emotional biosensors to measure arousal levels. A pioneering study conducted by Tranel, Fowles, and Damasio (1985) confirms that EDA is a reliable measure of arousal. They found that the average level of EDA is significantly higher when participants are experiencing stimuli with affective connotations compared to more neutral stimuli. Figure 2 summarizes the main elements of the methodology.

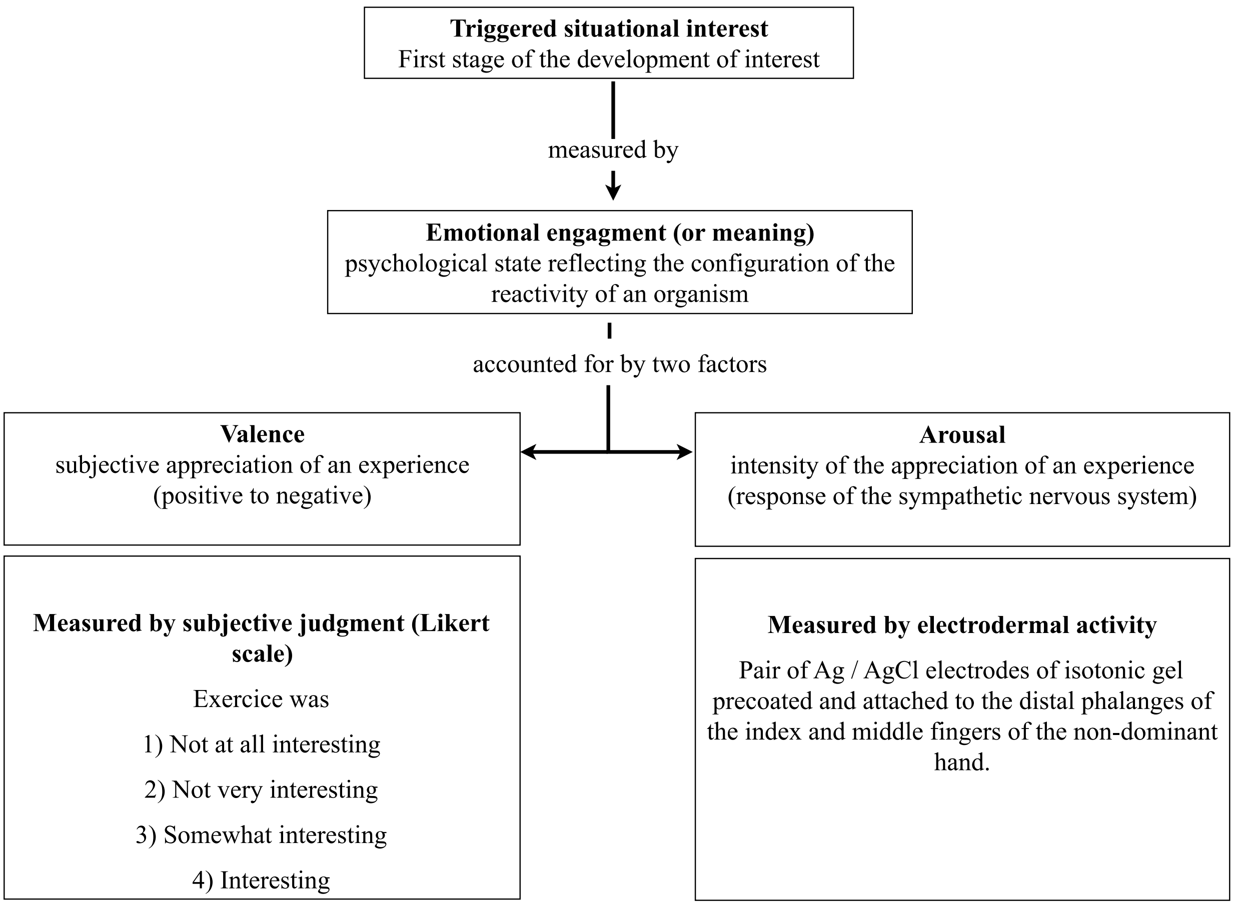

Figure 2. *Main elements of the methodology*

In accordance with the literature review presented in the Introduction, this study proposes the hypothesis that women's interest in physics can be, in terms of valence and arousal, triggered more by human body contexts than technical contexts. Consequently, arousal should be greater and valence more positive while women answer physics problems concerning the human body compared to problems involving technical issues.

For the study, 13 women who had taken an introductory physics course as part of a general natural sciences CEGEP[i] program with no specified major except for two participants who took a problem-based and computer-assisted option. They were recruited from a college and a university (mean age: 20.1 years). Their arousal levels were measured by EDA with a pair of Ag/AgCl electrodes precoated with isotonic gel (*Biopac Systems Inc)*. Electrodes were attached to the distal phalanges of the index and middle fingers of the participants' non-dominant hand. Data were recorded, amplified, and digitized by BSL Pro software (Biopac Systems, Inc.). The mean and variance were computed from the raw logged signal, wherein variance was dependent on both the number and amplitude of the fluctuations in the skin conductance level (Doberenz, Roth, Maslowski, Wollburg, & Sunyoung, 2011).

The level of EDA is a sensitive measure of the changes in the activity of the sympathetic nervous system related to emotions (Critchley, 2002). It was clearly demonstrated that the level of EDA informs on the level of arousal by its sensitivity to the significance of a stimulus (Dawson, Schell, & Filion, 2007). The level of EDA is a measure of the activity of the eccrine sweat glands that are innervated by the sympathetic nervous system. Consequently, any stimulus accompanied by emotion causes variations in the galvanometer in proportion to the liveliness of the emotion. In sum, the level of EDA increases in proportion to the general arousal level of an individual (Nakasone, Prendinger, & Ishizuka, 2005). This relation has also been confirmed by Lang et al. (1993) who noted a significant covariance between the magnitude of EDA and self-declared arousal and interest levels in relation to a stimulus.

Valence was measured by subjective judgment. After answering each problem, participants had to declare if it was 1) not at all interesting, 2) not very interesting, 3) somewhat interesting, or 4) interesting. Such four-point Likert scales were used with a pair mode to avoid ambiguity in the interpretation of the central level(Gable and Wolf, 1993).

The experiment took place in two semi-isolated rooms. The task consisted of five physics problems that were designed into two equivalent versions focusing either on human body and technical contexts (see example in Appendix 1). These problems were based on textbooks and online teaching materials. Particular attention was given to maintaining equivalence between the pairs of exercises so that only the context differed between the two versions. Therefore, the similarity of the problems in terms their degree of idealization, number of steps, unit conversion, and graphic presentation, were ensured. These problems were presented to participants in random order using the E-prime software (*Psychology Software Tools*, Inc., 2014).

The study used a within-subjects design where there is less variance caused by participant dispositions. Consequently, the variability is more likely due to differences in the conditions of the study than to behavioral differences between subjects (if between-subject was used). In a within-subject design, missing data are less likely to affect the validity of the results. Also, since there were only two conditions to test, the design could be more adequately described as a counterbalanced measured design. A complete analysis of the random sequences used showed that "human body context" condition has been presented between 3 and 9 times at each possible position and "technical context" condition has been presented between 4 and 8 times at each possible position. For example, the first problem presented was of a "human body context" type for 8 participants and of "technical context" type for the 5 other participants.

Before computing the mean and variance, the raw signal of EDA was pretreated at intervals of 0.005 seconds. First, a logarithmic transformation of the plot was performed to normalize the distribution. Venables and Christie (1980) suggested transforming the raw data level of EDA (microsiemens) to reduce the indexes of skewness and kurtosis of the dataset.[38] Then, to ensure that the level of EDA was not overvalued by electrodermal responses (oscillations), the plot was smoothed over 10 seconds,[41] meaning that average conductance was calculated at intervals of 10 seconds.

Statistically, the assumption that human body contexts generate greater arousal levels and more positive valence than technical contexts will only be supported if the means of arousal and valence are larger while solving problems with human body contexts than problems with technical contexts. Therefore, the test contains a directional hypothesis that would be confirmed if the observed differences point in the same direction. To compare valence and arousal levels for human body and technical contexts, a one-sample unilateral Student t-test and the Wilcoxon signed rank unilateral test were used.

As arousal is compared using two means (human body and technical contexts), the p-value must be adjusted. When the same variable is compared from multiple tests, the level of significance of the results must be adjusted to reduce the risk of incorrect conclusion of the significance of the differences. The correction used by Bonferroni, Sidak, and Dunn is very conservative and uses the same overall error rate for all comparisons. Holm (1979) and Larzelere and Mulaik (1977) proposed the adjustment of the p-value based on the number of compared means by arranging the observed mean differences in a descending order and calculating the adjusted p-value for each comparison (see appendix 2). Thus, the p-value for each comparison decreases to become equal to the initial value (0.05 in this study). The effect size for each comparison was obtained by computing Cohen's (1969) coefficient, which is commonly used when comparing means (Rosenthal, 1994, 1991). Cohen's d is calculated as follows:

$$d = t / n^{1/2}$$

where t is the statistic obtained from the Student one-sample t-test and n is the sample size.

Results and discussion

With regard to valence, 14 means were missing (11%) from a potential set of 130 means (13 participants and 10 problems). Incomplete observations were excluded from the statistical analysis. Valence for human body contexts ($D(13) = 0.255$, $p = 0.02$) had a larger deviation than that for technical contexts ($D(13) = 0.241$, $p = 0.04$). Figure 3 shows that means of the valence for human body and technical contexts differ significantly as the error bars do not overlap.

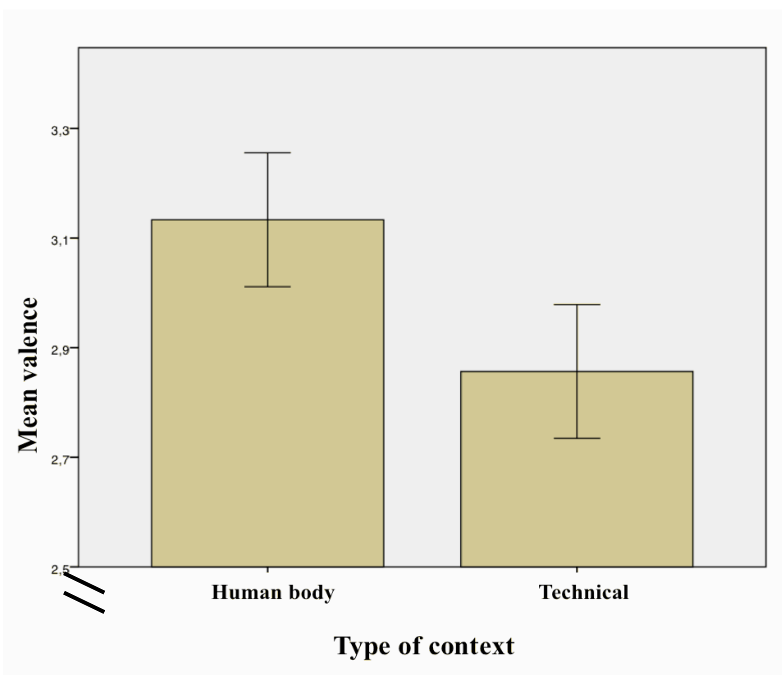

Figure 3. *Average valence of the human body and technical contexts (at 95% confidence interval)*

On average, human body contexts (mean = 3.1; sd = 0.4) generated a more positive valence than technical contexts (mean = 2.9; sd = 0.5). This difference is statistically significant ($t(13) = 2.469$; $p_{unilateral} = 0.015$) and ($Z(13) = -2.081$, $p = 0.02$), and the effect size ($d = .68$) is large (Cohen, 1969).

With regard to arousal, 41 means were missing (32%) from a potential set of 130. Incomplete observations were again excluded from the statistical analysis. This large proportion of missing data was due to unmanageable experimental conditions. Given their school commitments, the participants were allowed to leave the experiment after 60 minutes irrespective of the status of completion. Technical problems prevented adequate data recording for three of the participants. According to Erath, El-Sheikh, Hinnant, and Cummings (2011), it is common in psychophysiological research for 8%–9% of the participants to not have an interpretable plot EDA due to technical failures. Data missing due to technical issues can be ignored as their value is random and no model can explain missing data in a data matrix. Missing data is missing at random since the probability that a value of EDA or Likert scale is missing is independent of the value of the two variables. Thus, missing data might be dependent on the confidence or competence level of the participants in physics as it might affect the number of exercises they could perform within the given time frame (60 minutes). However, this study does not measure competence or confidence levels of the participants; thus missing data should not influence the results of valence or arousal levels for both contexts.

The first trial of arousal measure, the variance of EDA level, was normally distributed for both human body contexts ($D(10) = 0.213$, $p = 0.20$) and technical contexts ($D(10) = 0.213$, $p = 0.20$). Figure 4 shows that means of the variance of EDA for the human body and technical contexts significantly differs as the error bars do not overlap.

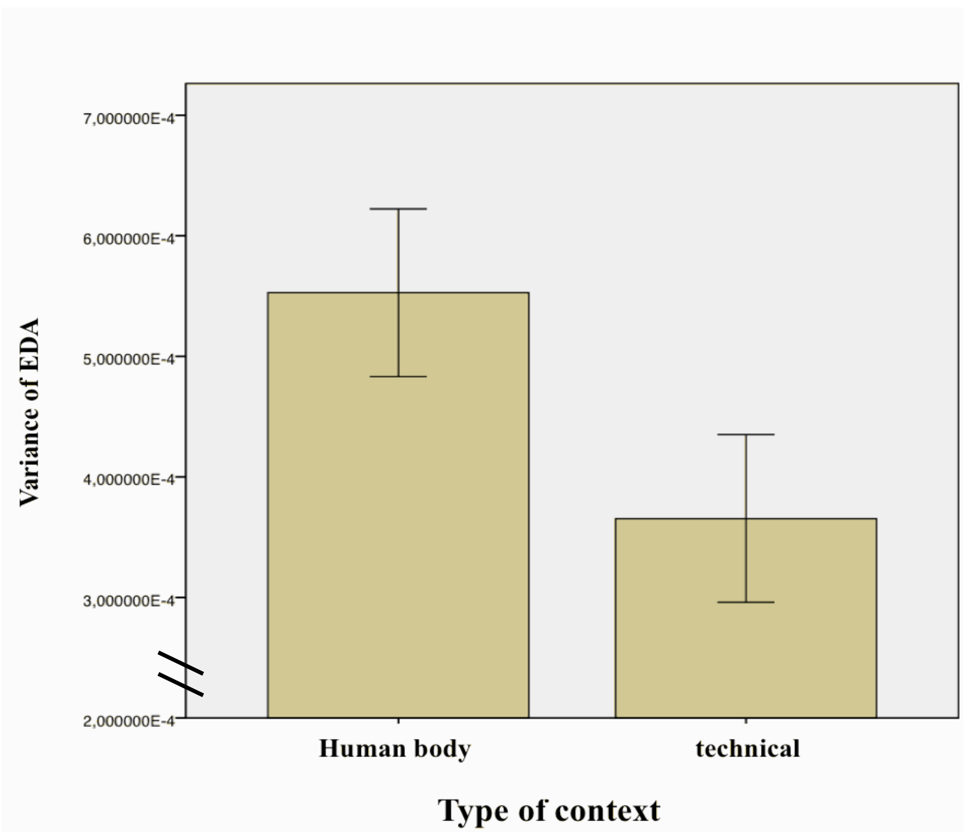

Figure 4. *Average variance of EDA (at 95% confidence interval)*

On average, human body contexts (mean = 0.00055; sd = 0.00047) generated greater arousal than technical contexts (mean = 0.00037; sd = 0.00048). This difference is statistically significant ($p < 0.025$) ($t(10) = 3.044$; $p_{unilateral} = 0.005$) and ($Z(10) = -2.191$, $p = 0.015$), and the effect size ($d = .96$) is large.[44].

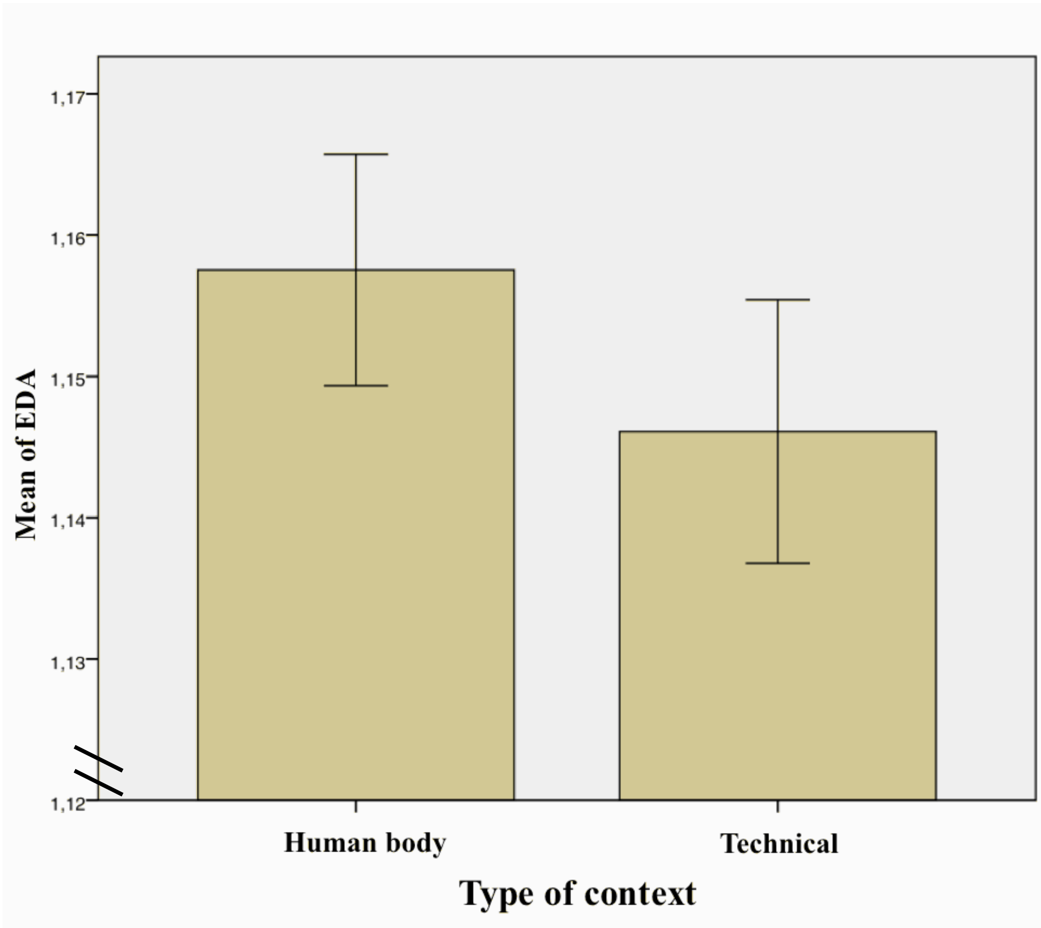

Figure 5. *Average mean of EDA (at 95% confidence interval)*

The second trial of arousal measure, the mean of EDA amplitude, was normally distributed for both human body contexts ($D(10) = 0.160$, $p = 0.20$) and technical contexts ($D(9) = 0.160$, $p = 0.20$). Figure 5 shows no significant difference between the human body and technical contexts in terms of the mean of EDA amplitude as the error bars do overlap.

On average, human body contexts (mean = 1.16; sd = 0.16) generated a greater arousal than technical contexts (mean = 1.15; sd = 0.16). However, the difference is not statistically significant ($p < 0.05$) ($t(9) = 1.1585$; $p_{unilateral} = 0.074$) and ($Z(10) = -1.326$, $p = 0.093$).

Interpretation and Limits

Results suggest that women's interest is not triggered in the same manner when the context of physics problems refers to the human body and technical issues. When answering physics problems, women declare to be significantly more interested when the contexts concern the human body, and their arousal, measured by the variance of their EDA, was significantly higher while they solved these problems. This result confirms the findings of Häussler et al. (1998) that women are particularly interested in learning how physics is related to the human body. This result also confirms the recent findings of Kerger & Poncelet (2009) showing the significant effect of context to generate women's interest for scientific topics, particularly in physics.

This result also corresponds with that of Labudde et al. (2000) who suggest that women develop a more positive attitude toward physics when it relates to their everyday experiences. In addition, this result confirms the findings of Murphy and Whitelegg (2006) on the disengagement of women from the traditional teaching method of physics.

Among the two measures of arousal (mean and variance of EDA), only variance appeared to be significantly higher. Therefore, when detecting real-time arousal, one must focus on detecting the sensitivity of EDA rather than its level. This persistent sensitivity can be regarded as an index of emotional arousal that extends over time and can contribute to triggering and maintaining women's interest in physics. Hoffmann (2002) found that women are more sensitive than men to the type of context used for studying physics. However, this study has no equivalent in terms of applying a psychophysiological measure to the study of emotional engagement in education; thus, it is not yet possible to compare these results with those of previous research. Nevertheless, these initial results in a promising area suggest that further research on a larger scale could achieve even more significant results.

The exploratory nature of this research and its small scale inevitably limit the interpretation and generalization of its findings. First, the design of the experimental task wherein the same physics problem was presented twice to each participant, once related to the human body and then to a technical issue, allowed for better control of the dependent variable (i.e., the context). However, during informal interviews after the experiment, two participants said that they felt they addressed the problem more quickly and were more eager to seek the answer the second time a problem was presented to them. Consequently, it is possible that they did pay less attention to the second problem despite changes in its context, values, and choice of answers. By using a larger sample, this limitation can be overcome by presenting only one version of the problem to the participants. This can also eliminate the test–retest effect that may have been produced by the experimental design. A larger pool of exercises can be created, and a fraction of such problems can be presented randomly to each participant. However, with a sample of 13 students, the equivalence of the tasks may have been questionable.

Moreover, the interpretation of these results is challenged given the small sample size. By using limited data, the first level analyses become sensitive to outliers and tend to exaggerate the differences, which produce high variations in the results. The missing values also complicate the interpretation of the results, as information of all variables for a participant must be available to be included in the statistical analysis (Rousseau, 2006).

In the design of the experiment, 15-second pauses were randomly inserted to allow EDA to return to baseline. However, it would have been more optimal to have systematically inserted breaks between each exercise to infer a more precise measure of arousal, calculated by subtracting the average level of EDA during the interval or break before a stimulus from the average level of EDA during a stimulus. Measure of changes in the level of EDA help reduce bias owing to the gradual increase in the average level of EDA as participants move from repeated to new stimuli, as in problem solving.[47] The systematic insertion of pauses also helps mitigate the effect of priming, which is the persistence of emotional arousal generated by the previous problem that influences the problem presented right after it.

In sum, acknowledging the limits associated with the design of experimentation and small sample size, the results are still interesting and promising to the community of physics educators. This study clearly suggests that the contextualization of physics can play a significant role in triggering the interest of women in the subject. The emotional engagement of the participants was significantly more positive when solving physics problems related to human body contexts as opposed to technical contexts.

Future Research Areas

This study focused on women's lack of interest in physics with a specific purpose. The study compared the immediate and direct effects of the type of context of physics problem on the emotional engagement of women, which served as an index of the triggered interest. This study shows how psychophysiological measures can provide an additional level of analysis for certain educational issues. In this case, it resulted in increasingly detailed observations, in real time and in action, of emotional engagement, an essential first step in the development of interest. Thus, these data support the validity of existing research results showing, with more subjective measures, how women's interest can be triggered by contexts used in physics education.

Further research on interventions that can improve women's interest in physics should be conducted in an educational environment and the long-term effects of such interventions not only on the development of interest but also on learning outcomes and self-confidence should be documented. Eventually, in continuity with Häussler and Hoffmann's (2002) major study, the effort of integrating contexts that consider the interest of women should be combined with other educational changes to evaluate the effect of interactions among different possible interventions, such as teaching style, mathematical approach, and organization of class time.

Conclusion

Women's underrepresentation and poor interest in physics pose major problems for scientists and educators in industrialized countries. The effect of contexts used in physics studies on women's interest has been the focus of many researchers (eg. Häussler and Hoffmann, 2002; Kerger et Poncelet, 2009 ; Kerger et al., 2011). It has been recognized that physics is usually presented as a purely scientific or technical context without considering its social utility. As emotional engagement represents the first essential step in developing an individual's interest in a particular subject matter (Hidi & Renninger, 2006), researchers have called for studies to identify pedagogical approaches in physics that can stimulate students' emotions (Duit et al., 1992).

Our quasi-experimental study empirically supports our proposed hypotheses as well as previous findings (eg., Haussler *et al.*, 1998). From a psychophysiological perspective, this research precisely demonstrates that using human body contexts to illustrate physics concepts is a promising educational change because it triggers the situational interest of women more effectively than the technical contexts traditionally used.

From a wider perspective, questioning the contexts used in physics education raises questions about the influence of the choice of contexts on the transmission of knowledge. Beyond the reorganization of teaching material, adapting contexts raise questions on the current teaching approaches in physics (Murphy & Whitelegg, 2006). However researchers must recognize that, to a certain extent, masculinity and physics have influenced each other over time and today, adapting the curriculum to more diverse interests represents a challenge to this coevolution.

Opening physics teaching to contexts more appropriate for women, in this case the human body, is a matter of acknowledging that not all students are intrinsically interested in physics (Zohar & Bronshtein, 2005) and emphasizing the importance of diversifying scientific practices. Therefore, the disengagement of women from physics may be overcome by encouraging teachers to demonstrate their commitment to different pedagogical methods of accessing physics knowledge. As Nair and Mejetich (1995, p.29) suggest,

> *In the long term, we may be better off with fewer highly trained physicists but a large number of people with a general technical background, and the teaching style in introductory courses should be adjusted accordingly.*

Acknowledgments

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References

Baram-Tsabari, Ayelet, & Yarden, Anat. (2008). Girls' biology, boys' physics: evidence from free choice science learning settings. *Research in Science and Technological Education, 26*(1), 75-92.

Biopac Systems Inc. (s.d.). Education, Transducers, Electrodermal, EDA LEAD, BSL - SS57L. Retrieved 25 avril, 2013, from http://www.biopac.com/electrodermal-activity-lead-bsl

Bradley, M.M., Codispoti, M., Cuthbert, B.N., & Lang, P.J. (2001). Emotion and Motivation I: defensive and appetitive reactions in picture processing. *Emotion 1*, 276-298.

Cohen, J. (1969). *Statistical power analysis for the behavioral sciences*. New York: Academic Press.

Colicchia, G. (2005). Sit up straight! It's good physics. *Physics Education, 40*(4), 365-369.

Critchley, H.D. (2002). Electrodermal Responses: What Happens in the Brain. *The Neuroscientist, 8*(2), 132-140.

Davidson, R. J. (2000) The neuroscience of affective style. In M. Gazzaniga (Ed.), The new cognitive neurosciences (pp. 1149–1162). Cambridge, MA: MIT Press.

Dawson, C. (2000). Upper primary boys' and girls' interests in science: Have they changed since 1980? *International Journal of Science Education, 22*(6), 557-570.

Dawson, M.E., Schell, A.M., & Filion, D.L. (2007). The Electrodermal System. In J. T. Cacioppo, L. G. Tassinary & G. G. Berntson (Eds.), *Handbook of Psychophysiology* Cambridge, UK: Cambridge University Press.

Doberenz, S., Roth, W.T., Maslowski, N.I., Wollburg, E., & Sunyoung, K.. (2011). Methodological Considerations in Ambulatory Skin Conductance Monitoring. *International Journal of Psychophysiology, 80*(2), 87-95.

Duit, R., Häussler, P., Lauterbach, R., Mikelskis, H., & Westphal, W. (1992). Combining issues of girl-suited science teaching, STS and constructivism in a physics textbook. *Research in science education, 22*(1), 106-113.

Erath, S.A., El-Sheikh, M., Hinnant, J.B., & Cummings, E.M. (2011). Skin Conductance Level Reactivity Moderates the Association Between Harsh Parenting and Growth in Child Externalizing Behavior. *Developmental Psychology, 47*(3), 693-706.

Figner, B., & Murphy, R. O. (2011). Using skin conductance in judgment and decision making research. In M. Schulte-Mecklenbeck, A. Kuehberger & R. Ranyard (Eds.), *A handbook of process tracing methods for decision research*. New York: Psychology Press.

Gardner, P.L. (1985). *Interests in science and technology education.* Paper presented at the Paper presented at the 12th IPN symposium, University of Kiel.

Haussler, P., Hoffmann, Lore, Langeheine, Rolf, Rost, Jurgen, & Sievers, Knud. (1998). A Typology of Students' Interest in Physics and the Distribution of Gender and Age within Each Type. *International Journal of Science Education, 20*(2), 223-238.

Haussler, P., & Hoffmann, L. (2002). An Intervention Study To Enhance Girls' Interest, Self-Concept, and Achievement in Physics Classes. *Journal of Research in Science Teaching, 39*(9), 870-888.

Hebb, D.O. (1949). *The organization of Behavior: A Neuropsychological Theory*. New York: Wiley.

Hidi, S. (2003). *Interest: A motivational variable with a difference*. Paper presented at the 10th Biennial Meeting of the European Association for Learning and Instruction, Padova, Italy.

Hidi, S., & Baird, W. (1986). Interestingness — A neglected variable in discourse processing. *Cognitive Science, 10*, 179-194.

Hidi, S., & Baird, W. (1988). Strategies for increasing text-based interest and students' recall of expository texts. *Reading Research Quaterly, 23*, 465-483.

Hidi, S., & Harackiewicz, J. (2000). Motivating the academically unmoti- vated: A critical issue for the 21st century. *Review of Educational Research, 70*, 151-179.

Hidi, S., & Renninger, A.K. (2006). The Four-Phase Model of Interest Development. *Educational Psychologist, 41*(2), 111-127.

Hoffmann, L. (2002). Promoting girls' interest and achievement in physics classes for beginners. *Learning and Instruction, 12*, 447-465.

Holmes, J., Burns, L., Marra, M., Stubbe, M., & Vine, B. (2003). Women managing discourse in the workplace. *Women in Management Review, 18*(8), 414-425.

Ivie, R., & Stowe, K. (2000). Women in Physics, 2000. *AIP Report R-430, College Park, MD.*

Jones, M.G., Howe, A, & Rua, M.J. (2000). Gender differences in students' experiences, interests, and attitudes toward science and scientists. *Science Education, 84*(2), 180-192.

Kerger, Sylvie, Martin, Romain, & Brunner, Martin. (2011). How can we enhance girls' interest in scientific topics? *British Journal of Educational Psychology, 81*(4), 606-628.

Kerger, Sylvie, & Poncelet, Débora. (2009). Étude de l'influence de l'environnement scolaire – mono-éducatif versus co-éducatif – sur l'intérêt des filles pour les sciences. *Recherches & éducations, 2*, 73-91.

Labudde, P., Herzg, W., Neuenschwander, M.P., Violi, E., & Gerber, C. (2000). Girls and physics: teaching and learning strategies tested by classroom interventions in grade 11'. *International Journal of Science Education, 22*(2), 143-157.

Lang, P.J., Greenwald, M.K., Bradley, M.M., & Hamm, A.O. (1993). Looking at pictures: Affective, facial, visceral, and behavioral reactions. *Psychophysiology, 30*(3), 261-273.

Lavonen, J., Byman, R., Juuti, K., Meisalo, V., & Uitto, A. (2005). Pupil Interest in Physics: A Survey in Finland. *Nordina*, 72-85.

Lipstein, R., & Renninger, K. A. (2006). "Putting things into words":12–15-year-old students' interest for writing. In P. Boscolo & S. Hidi (Eds.), *Motivation and writing: Research and school practice*. New York: Kluwer Academic/Plenum.

Lorenzo, M., Crouch, C.H., & Mazur, E. (2006). Reducing the gender gap in the physics classroom. *American Journal of Physics, 74*(2), 118-122.

Mitchell, M. (1993). Situational interest: Its multifaceted structure in the secondary school mathematics classroom. *Journal of Educational Psychology, 85*, 424-436.

Murphy, P. (1990). Gender gap in the National Curriculum *Physics World, 3*(1), 11.

Murphy, P., & Whitelegg, E. (2006). Girls and Physics: continuing barriers to "belonging". *Curriculum Journal, 17*(3), 281-305.

Nair, I., & Majetich, S. (1995). Physics and engineering in the classroom. In S. V. Rosser (Ed.), *Teaching the majority: Breaking the gender barrier in science, mathematics, and engineering*. New York: Teacher College Press.

Nakasone, A., Prendinger, H., & Ishizuka, M. (2005). *Emotion Recognition from Electromyography and Skin Conductance.* Paper presented at the The Fifth International Workshop on Biosignal Interpretation, Tokyo, Japan.

OECD. (2007). Comprendre le cerveau: naissance d'une science de l'apprentissage: Centre pour la recherche et l'innovation dans l'enseignement (CERI).

Panksepp, J. (2003). At the interface of the affective, behavioral and cogni- tive neurosciences: Decoding the emotional feelings of the brain. *Brain and Cognition, 52*, 4-14.

Panksepp, J. (2000). Emotions as natural kinds within the mammalian brain. In M. Lewis & J. M. Haviland-Jones (Eds.), Handbook of emotions (2nd ed., pp. 137–156). New York: Guilford.

Panksepp, J. (1998). Affective neuroscience: The foundations of human and animal emotion. New York: Oxford University Press.

Psychology Software Tools Inc. (2014). *E-prime 2.0*. Retreived June 12th 2014 from: http://www.pstnet.com/.

Rosenthal, R. (1991). *Meta-Analytic Procedures for Social Research*. Newbury Park, CA: Sage.

Rosenthal, R. (1994). Parametric measures of effect size. In H. Cooper & L. V. Hedges (Eds.), *The Handbook of Research Synthesis* (pp. 231-244). New York: Russel Sage Foundation.

American Physical Society. (2013). Fraction of Bachelor's Degrees in STEM Disciplines Earned by Women 1966-2010. Retrieved August 2, 2013, from http://www.aps.org.proxy.bibliotheques.uqam.ca:2048/programs/education/statistics/womenstem.cfm

Srivastava, A.K. (1996). *Widening Access: Women in Construction Higher Education.* (Ph.D. thesis), Leeds Metropolitan University.

Stark, R, & Gray, D. (1999). Gender preferences in learning science. *International Journal of Science Education, 21*(6), 633-643.

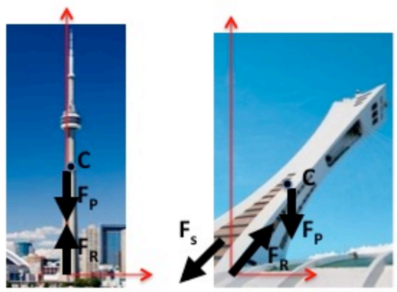
Tranel, D., Fowles, D.C., & Damasio, A.R. (1985). Electrodermal discrimination of familiar and unfamiliar faces: A methodology. *Psychophysiology, 22*, 403-408.

Venables, P.H., & Christie, M.J. (1980). Electrodermal activity. In I. Martin & P. H. Venables (Eds.), *Techniques in psychophysiology* (pp. 3-67). Chichester: Wiley.

Zohar, Anat, & Bronshtein, Boaz. (2005). Physics Teachers' Knowledge and Beliefs Regarding Girls' Low Participation Rates in Advanced Physics Classes. *International Journal of Science Education, 27*(1), 61-77.

Appendix 1 – Sample pair of exercices (Adapted from Colicchia (2005))

Building a leaning tower represents an additional challenge because of the compression force resulting at the base of the structure.

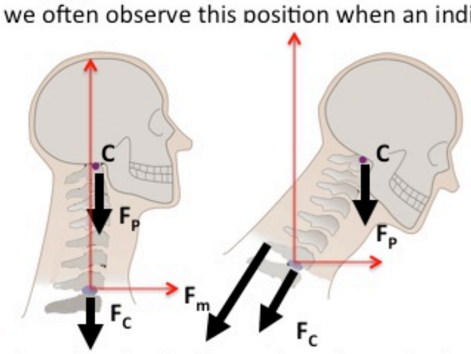


- Center of mass (C)
- Weight (F_P)
- Tension exerted by the structure (F_s)
- Force in reaction to compression (F_R).

According to the figure, how do mechanics principles explain that on a leaning tower, the force reacting to compression (F_R) at the base of the structure increases several times the weight of the tower? (Assuming that the two towers are identical except for their inclination, not the case in the figure)

Choices of answers
1. The center of mass (C) of the tower changes place.
2. On an leaning tower, the tension exerted by the structure (Fs) is smaller
3. The weight of a leaning tower is greater
4. On a leaning tower, the horizontal distance between the center of mass (C) of the tower and the base of the tower increases

Keeping the head tilted represents a risk factor for the development of neck injuries and we often observe this position when an individual works at the computer.



- weight of the head and neck (F_P)
- tension in the muscles (F_m)
- the resulting compression force (F_C).

Under static conditions the summation of all the components of the forces must be equal to zero: ($\sum F_i = 0$ and $\sum F_i d_i = 0$).

According to the figure, how do mechanics principles explain that a position where the head is tilted increases the compression force (Fc) of the vertebra at the base of the neck several times the weight of the head and neck relatively to a straight posture?

Choices of answers
1. The center of mass (C) of the weight of the head and neck (Fp) is not located at the same place according to whether one is in a vertical position or tilting the neck
2. In an tilted position, the activity of the neck muscles (Fm) is reduced
3. In an tilted position, the horizontal distance between the center of mass (C) of the head and neck and the vertebrae at the base of the neck increases
4. In an inclined position, the weight of the head and neck is greater

Appendix 2 – Holm (1979) and Larzelere et Maluaik (1977)'correction

2 means compared

Mean differences (descending)	**t-score (unilateral)**	**Critic P-value**	**Interpretation**
Variance of EDA	$t = 3.044$ $p = 0.005$	$\alpha_c = \alpha_e / n$ $\alpha_c = 0.025$	Significantly different
Mean of EDA	$t = 1.585$ $p = 0.074$	$\alpha_c = \alpha_e / (n - 1)$ $\alpha_c = 0.05$	No significant difference

End of document notes

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[i] Junior general and vocational colleges (in french Collège d'enseignement général et professionnel, a unique concept established by Quebec's (Canada) government in 1967.