

# A Neuroscience Approach in User Satisfaction Evaluation in Maritime Education

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**ABSTRACT:** The evaluation with the use of neuroscience methods and tools of a student's satisfaction – happiness from using the e-learning system (e-learning platforms, e-games, simulators) poses an important research subject matter. In the present paper, it is presented a research on course conducted in the Marine Training Centre of Piraeus. In particular, this research with the use of a neuroscience tools-gaze tracker and voice recording (lexical analysis), investigates the amount of satisfaction of the students using Engine room simulator (ERS 5L90MCL11, Kongsberg 2003 AS) by monitoring the users' eye movement and speech in combination with the use of qualitative and quantitative methods. The ultimate goal of this research is to find and test the critical factors that influence the educational practice and usability of e-learning marine systems and the ability to conduct full-time system control by the marine crew.

## 1 INTRODUCTION

In Marine Education (ME), the use of non conventional methods and tools (biometric tools) is a useful contribution in its amelioration. ME follows certain education standards (STCW'95) for each specialty (Captain, Engineer) and for each level (A', B', C'). Its scope is the acquisition of basic scientific knowledge, dexterities on execution (navigation, route plotting, administering the engine etc) as well as protecting the ship and crew (safety issues and environment protection issues). Specifically, the STCW'95 standard defines three competency levels: Management, function and support while at the same time it defines related dexterities. Every dexterity level suggests the totality of the learning goals and the goal definition is the basic characteristic of training. The simpler competence make up the more complex ones. This hierarchical increase in the level of dexterity places an austere framework for the educator designer of lessons in each marine school.

The introduction of simulators and other modern training tools constitutes an important research question on what degree it can fulfil all the expectations set forth by the STCW'95 (IMO, 2003, Papachristos et al., 2012, Tsoukalas et al., 2008).

We propose a research framework for educational and usability evaluation of marine e-learning systems that combines a neuroscience approach (biometric tools of gaze tracking & speech recording for measuring emotional user responses-lexical analysis) with usability assessment. Certainly, the proposed approach may require further adaptations to accommodate evaluation of particular interactive e-learning systems. The main elements of the proposed approach include (Papachristos et al., 2012):

- 1 Registration and interpretation of user emotional states
- 2 Gaze tracking and interpretation
- 3 Speech recording and lexical analysis (sentiment processing)

- 4 Usability assessment questionnaires
- 5 Wrap-up interviews.

This procedure is a primary effort to research the educational and usability evaluation with emotion analysis (satisfaction) of the users-students in marine e-learning environments.

## 2 THEORETICAL BACKGROUND

In the investigative field of psychology, the use of the English word *affect* is very popular, which usually covers a plethora of concepts such as emotions, moods and preferences. The term emotion tends to be used for the characterization of rather short but intense experiences, while moods and preferences refer to lower intensity but greater duration experiences. In general, we could note that psychology considers the emotional mechanism as a determinist mechanism that pre-requires a stimulus – cause incited in the brain by use of the neural and endocrine system (hormonal), the response – emotion (Malatesta, 2009, Papachristos et al., 2012).

Modern scientific community suggests different views concerning understanding emotional mechanism. There is the view that emotion is defined by the natural reactions caused in the body (sweating, pulse increase, etc.), while other researchers believe that it is a purely mind process, while there are also hybrid views that define, each one in a varying degree, the participation and the manner where the human functions are involved in the emotional experience (Vosniadou, 2001).

Many psychologists have claimed that the only way to interpret the totality of emotions is to suggest that there is a common evolutionary base in the development of facial emotional expressions. But the biological approach cannot explain all the facets of a human's emotional behavior, (Vosniadou, 2001).

During the last 25 years, psychology focuses again in the sequence of events involved in the creation" of an emotion. Zajonc considers that experiencing an emotion happens often before we have the time to assess it, while contrarily, Lazarous considers that the thought precedes the emotional experience, assessing that instantaneous cognitive assessments of situations can happen at the same time alongside the emotional experience (Lazarous, 1982, Zajonc, 1984). The speed with which we assess a situation is influenced by our previous experiences. The age scale also seems to influence the creation of emotions. It must be noted that there are also emotions that do not require cognitive processes (thought). For example, loud noises or seeing a lion. Such emotional reactions can be important for the survival of the species and are related to certain stereotypical facial expressions which have global meaning (Vosniadou, 2001).

Also, another factor that can be investigated in relation to the emotional experience is the language process. The psychological research in the language production, comprehension and development is developed mainly after 1960 as a result of linguist's N. Chomsky research on generative grammar (Pinker, 2005). The psycholinguistic research showed that language comprehension and production is not

influenced only from factors not related to their linguistic complexity but also from the speaker's/listener's existing knowledge for the world around him/her, as well as by the information included in the extra linguistic environment (Vosniadou, 2001).

Investigating the emotional gravity of words spoken by a speaker and defined its emotional state (current or past) constitutes a state of the art issue. Most of the emotional state categorization suggested concern the English language. To overcome this problem, studies have been conducted that approach the matter cross-culturally and study the assignment of the categories to various languages. This assignment has conceptual traps since the manner in which an emotional state is apprehensible; an emotional state is influenced by cultural factors as well. In a rather recent cross-cultural study done by Fontaine et al., (2007), 144 emotional experiences' characteristics were examined, which were then categorized according to the following emotional "components": (a) event assessment (arousal), (b) psycho physiological changes, (c) motor expressions, (d) action tendencies, (e) subjective feelings, and (f) emotion regulation.

International bibliography contains various approaches – techniques (sorting algorithms) concerning linguistic emotional analyses, which are followed and are based mainly in the existence of word lists or dictionaries with labels of emotional gravity along with applications in marketing, cinema, internet, political discourse etc (Lambov et al., 2011, Fotopoulou et al., 2009). There are studies also concerning sorting English verbs and French verbs that state emotions based on conceptual and structural-syntactical characteristics. For the Greek language there is a study on verbs of Greek that state emotions based on the theoretical framework "Lexicon-Grammar" that is quite old and doesn't contain data from real language use; there are also some studies concerning Greek adjectives and verbs that state emotions and comparison with other languages (French – Turkish) under the viewpoint: Structural-syntactical + conceptual characteristics. More recent studies in Greek conducted systematically the noun structures based on the theoretical framework of "Lexicon-Grammar" and the establishment of conceptual & syntactical criteria for the distinction and sorting of nouns based on conceptual-syntactical characteristics of the structures in which they appear (Papachristos et al., 2012).

The observation of eye movement, as well as the pupil movement, is an established method in many years now and the technological developments in both material equipment and software, made it more viable as a practicality measurement approach. The eyes' movements are supposed to depict the level of the cognitive process a screen demands and consequently the level of facility or difficulty of its process. Usually, the optical measurement concentrates on the following: the eyes' focus points, the eyes' movement patterns and the pupil's alterations. The measurement targets are the computer screen areas definition, easy or difficult to understand. In particular the eyes movement measurements focus on attention spots, where the eyes remain steady for a while, and on quick

movement areas, where the eye moves quickly from one point of interest to another. Moreover the research interest is focused in the interaction of gaze tracking during the presentation of information and content (internet) in a natural environment (Dix et al., 2004, Kotzabasis, 2011).

Gaze interaction through eye tracking is an interface technology that has great potential. Eye tracking is a technology that provides analytical insights for studying human behavior and visual attention (Duchowski, 2007). Besides that, it is an intuitive human-computer interface that especially enables users with disabilities to interact with a computer (Nacke et al., 2011). Infrared monitor eye gaze tracking Human-Computer Interaction (HCI), which is limited by restrictions of user's head movement and frequent calibrations etc, is an important HCI method (Cheng et al., 2010, Hansen and Qiang, 2010). This method measuring the effect of personalization could be the relationship of users' actual behaviour in a hypermedia environment with theories that raise the issue of individual preferences and differences (Tsianos et al., 2009). The notion that there are individual differences in eye movement behaviour in information processing has already been supported at a cultural level (Rayner et al., 2007), at the level of gender differences (Mueller et al., 2008), and even in relation to cognitive style (verbal-analytic versus spatial-holistic) (Galín and Ornstein, 1974).

The most common applications for eye tracking today are either in marketing (e.g., Maughan et al., 2007) or in usability research (e.g., Schiessl et al., 2003). Yet, using eye trackers as devices for HCI has started to become a focus of research in recent years and the field is slowly starting to come of age (Cournia, et al., 2003, Jakob, 1990). However, the use of eye tracking in digital games is still new (Isokoski, and Martin, 2006), in the same way it is new for gaze interaction in virtual worlds (Istance et al., 2009) and for gaze visualizations in three-dimensional (3D) environments (Stellmach et al., 2010).

In the field of learning and instruction, eye tracking used to be applied primarily in reading research with only a few exceptions in other areas such as text and picture comprehension and problem solving (Halsanova et al., 2009, Hannus and Hyona, 1999, Hagerty and Just, 1993, Hyona and Niemi, 1990, Just and Carpenter, 1980, Rayner, 1998, Van Cog and Scheiter, 2010, Verschaffel et al., 1992). However, this has changed over the last years, eye-tracking is starting to be applied more often, especially in studies on multimedia learning (Van Cog and Scheiter, 2010). Because eye tracking provides insights in the allocation of visual attention, it is very suited to study differences in intentional processes evoked by different types of multimedia and multi-representational learning materials (Van Cog and Scheiter, 2010, Halsanova et al., 2009).

### 3 RESEARCH METHODOLOGY

The Research Methodology must fulfill all three requirements of the cognitive neuroscience: (a) experiential verification, (b) operational definition, and (c) repetition.

The main purpose of this research activity is the analysis of emotional state and the investigation of the standards that connect the user's Satisfaction-Happiness by use of the eye-head movement & oral text (as the basis for the situation) in the basic dipole: *happiness (satisfaction) – sad (non satisfaction)*.

We use a research protocol PR-AS. It is defined in detecting, recognizing and interpreting the emotional information in conjunction with other information created during the execution of a scenario in an electronic learning marine system (simulators or training software). The emotional information comes from the user's emotional state before, during, and after the scenario/exercise. Its structure concerns the following sections (Papachristos et al., 2012):

- 1 the mood/emotion before the scenario/exercise (oral text)
- 2 Behavioral action (head movement, gaze) during the scenario and
- 3 the emotional post-experience – satisfaction (oral text).

Measuring the emotional information will be realized using the following processes:

- 1 *Natural parameters' measurement*: Movement parameters (head movement, gaze movement) and oral text as text and
- 2 *Registering* user opinion/viewpoint/view.

The suggested protocol (*Protocol Research of Affect Situation, PR-AS*) is comprised by the following sections (Fig. 1) (Papachristos et al., 2012):

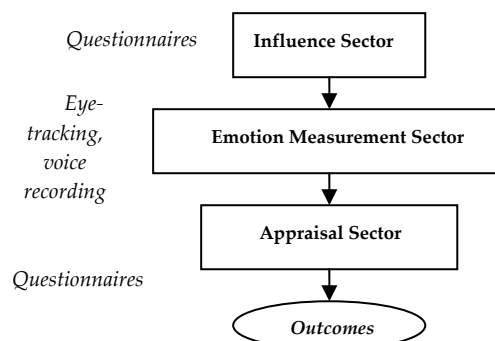


Figure 1. Structure of PR-AS

- *Influence Sector*: it based on Action Tendency Theory (concern view) and on Practical Reasoning Theory. This theoretical processing is characterized as a Framework for User's Innate Stimuli. The influence's department consists of the following measurements that take place before the scenario execution by way of questionnaires: (a) profile (learning-medical), (b) personality, (c) expectations-interesting and (d) personal background (education, professional experience, computer using).
- *Emotion Measurement Sector*: Measurements concerns the happiness-sad (emotion-mood) in combination with the degree of activation-assessment by the user within the framework of this dipole, i.e. the measurement of dynamics in relation to the stimuli (sound, animation, schemas, etc.) received in total by the software-scenario (virtual relationship) considering that the user is

always on a core emotional state (core affect) and the specific satisfaction for the scenario and software (evaluation process of the educational use for the software and scenario/exercise to the degree of satisfaction of the trainee-user) adopted by the Oatley approach that the (personal) goals have been achieved there is a sense of joy, while failures if followed by sadness and despair and is connected with the emotion of satisfaction. At the same time the natural parameters comprising the protocol's core are registered. These are the visual (head movement, gaze tracking with "Face Analysis tool") and voice recording (emotional reasoning) (Astariadis et al., 2009). This is based on the use of tools for recording head movement (distance from the monitor, left-right head movement, left-right head rolling), gaze tracking (x,y coordinates) and voice recording of spoken words (as reasoning of meta-emotional experience – lexicalization of emotional gravity). Additionally, the researcher records observations related to the physiological and non-physiological attitude of the user (mistakes, time of execution, execution success, the user's psychological state).

- *Appraisal sector:* In this section, the Satisfaction recording takes place but also commenting related to the day when measurement is taking place & in total up to that moment, as far as the software tool is concerned, after the experimental conduct of the scenario/exercise (usability), personal self-evaluation, scenario evaluation (benefits) in combination with the weighed usability assessment tool (DEC SUS Tool) (Brooke, 1996).

Data processing concerns the composition of all the above sectors of PR-AS, so that patterns of the natural parameters in relation to emotional states (happiness) and Satisfaction Scale can be found.

#### 4 PARTICIPANTS

The first (random) sampling was carried out between May and June 2012, in the Marine Engine System Simulator (MESS) Laboratory of the Marine Training Centre of Piraeus. The samples consisted of 13 professional (Merchant Marine officers) that were subjected to a specific experimental procedure in engine room simulator ERS 5L90MCL11, (video recording ~23 minutes per student), completed the questionnaires and gave interviews (research methodology).

#### 5 DATA ANALYSIS

The data of experiment come from three sources:

- questionnaires,
- optical data and
- interviews (voice recording).

The samples consisted of 13 professional (Merchant Marine officers, Male) that were subjected to a specific experimental procedure (Tab.1).

Table 1. Structure of Sample

Merchant Marine Officer Order	A' (%)	B' (%)
Officers	38.5 (5)*	61.5 (8)*
Experience		
Sum (total of years)	37	46
Mean (years)	7.4	5.75
Max (years)	9	15
Min (years)	6	4

\*(frequency)

The sample's age profile as shown in Table 2, prevail the younger (12-35 age).

Table 2. Sample's age profile

Age's scale	24-35 (%)	36-45 (%)	>45 (%)
Merchant Marine Officers	53.8 (7)*	30.8 (4)*	15.3(2)*

\*(frequency)

The sample's medical and personality profile (5 Factor model) as shown in Table 3 and Table 4. The personality profile presents homogeneity (high – medium) and the medical profile has a proportional of the sample having diseases of eye (myopia, astigmatism, etc.).

Table 3. Medical profile

Medical Profile	Eye diseases (%)	Eye operation (%)
Merchant Marine Officers	46.1 (6)*	7.6 (1)*

\*(frequency)

Table 4. Personality profile

Merchant Marine Officers (13 male)	very high (%)	high (%)	medium (%)	low (%)	very low (%)
Extraversion	-	23	61.5	-	7.7
Agreeableness	23	46.1	30.7	-	-
Conscientiousness	15.4	76.9	-	7.7	-
Neuroticism	-	7.7	38.4	7.7	23
Openness	15.4	38.4	30.7	15.4	-

The next table shows the educational and simulation background (Tab.5).

Table 5. Educational and Simulation background

Merchant Marine Officers (13 male)	Positive (%)	Negative (%)
Education in Computers	54	46
Simulation experience		
Education	61.5	38.5
Home	15.4	74.6
Job	54	46

The next table shows the results of model motivation (based Vroom model) (Tab. 6).

Table 6. Motivation model Results

Merchant Marine Officers (13 male)		
	Positive (%)	Negative (%)
Performance-Outcome Expectance		
<i>Job search</i>	69	21
<i>Payment</i>	38.5	61.5
<i>Professional development</i>	84.7	15.3
Valence		
<i>Professional value</i>	84.7	15.3
<i>Social value</i>	7.6	92.4
Effort-Performance Expectance		
<i>Professional performance</i>	77	23
<i>Job Security</i>	100	
Interesting		
<i>New technologies</i>	100	
<i>Educational benefits</i>	100	
<i>Personal needs</i>	7.6	92.4

The next table shows the results of evaluation of training program (marine engine system simulator training) and Simulator as software tool (Tab.7).

Table 7. Training program evaluation

Merchant Marine Officers (13 male)					
	very high (%)	high (%)	medium (%)	low (%)	very low (%)
Training Program					
Educational goal	23	54	23	-	-
Time schedule	38.5	30.7	23.1	7.7	-
Total assessment	15.4	38.6	23	23	-
Simulator					
Navigation	38.5	46.1	15.4	-	-
Interface	23	61.6	15.4	-	-
Multimedia	23	53.9	15.4	7.7	-

The next table shows the gradation of the satisfaction in 5<sup>th</sup> scale about the scenario and Marine Simulator (Sat\_Scen, Sat\_Sim) by the users in their answers (Tab.8).

Table 8. Simulator and Scenario Satisfaction

Merchant Marine Officer (13 male)					
<i>Satisfaction scale</i>	very high (%)	high (%)	medium (%)	low (%)	very low (%)
Scenario in Engine room	30.7	61.5	7.7	-	-
Simulator ERS	46.1	46.1	7.7	-	-

The following tables are observed the statistical measures of optical data (face analysis tool) for Gaze (vertical-y), Dist (distance from monitor) and Head roll per satisfaction (simulator & scenario):

Table 9. Gaze tracking parameter (satisfaction simulator)

Merchant Marine Officers (13 male)			
	very high (4 male)	high (8 male)	medium (1 male)
<i>Satisfaction Simulator</i>			
Mean	6.75	7.8	2.73
Max	225.06	332.6	137.7
Min	-252.2	-144.07	-84.1
STDEV	5.2	4.1	17.9

Table 10. Dist parameter (satisfaction simulator)

Merchant Marine Officers (13 male)			
	very high (4 male)	high (8 male)	medium (1 male)
<i>Satisfaction Simulator</i>			
Mean	1.11	1.06	1.03
Max	22.8	5.26	2.14
Min	0.05	0.13	0.32
STDEV	0.1	0.04	0.12

Table 11. Head Roll parameter (satisfaction simulator)

Merchant Marine Officers (13 male)			
	very high (4 male)	high (8 male)	medium (1 male)
<i>Satisfaction Simulator</i>			
Mean	0.58	1.45	-2.4
Max	89.1	88.9	55.2
Min	-86.1	-89.08	-28.0
STDEV	1.7	3.5	7.42

Table 12. Gaze tracking parameter (satisfaction scenario)

Merchant Marine Officers (13 male)			
	very high (4 male)	high (8 male)	medium (1 male)
<i>Satisfaction Scenario</i>			
Mean	8.28	7.09	0.21
Max	225.06	332.6	-203.4
Min	-252.2	-131.4	-144.07
STDEV	6.6	2.95	20.8

Table 13. Dist parameter (satisfaction scenario)

Merchant Marine Officers (13 male)			
	very high (4 male)	high (8 male)	medium (1 male)
<i>Satisfaction Scenario</i>			
Mean	1.12	1.07	0.99
Max	22.8	17.04	2.47
Min	0.09	0.05	0.17
STDEV	0.02	0.09	0.16

Table 14. Head Roll parameter (satisfaction scenario)

Merchant Marine Officers (13 male)			
	very high (4 male)	high (8 male)	medium (1 male)
<i>Satisfaction Scenario</i>			
Mean	1.9	0.49	-2.16
Max	89.1	82.9	88.9
Min	-83.6	-86.1	-89.08
STDEV	3.4	2.44	6.68

The following table is observed the measures of lexical data (sentiment & opinion analysis):

Table 15. Lexical Analysis

Merchant Marine Officers (13 answers-text)		
	very high	high
<i>Satisfaction Simulator</i>		
Using Modifier <sup>1</sup>	83.3%	66.6%
Using Comparison degree <sup>2</sup>	-	16.6%
P <sub>top</sub> <sup>3</sup>	1-16.6%	1-16.6%
	2-0%	2-16.6%
	0-83.4%	0-66.8%
Total words (all texts), TotN <sub>w</sub>	250	129
Mean (all texts)	41.6	21.5
IndexWord <sub>Satisf</sub> <sup>4</sup>	0.19	0.12
IndexWord <sub>NonSatisf</sub> <sup>5</sup>	0.02	0.1
<i>Satisfaction Scenario</i>		
Using Modifier <sup>1</sup>	75%	75%
Using Comparison degree <sup>2</sup>	-	25%
P <sub>top</sub> <sup>3</sup>	1-25%	1-37.5%
	2-25%	2-12.5%
	0-50%	0-50%
Total words (all texts)	181	236
Mean (all texts)	45.25	29.5
IndexWord <sub>Satisf</sub> <sup>4</sup>	0.16	0.17
IndexWord <sub>NonSatisf</sub> <sup>5</sup>	-	0.02

<sup>1</sup>Lexical phrase or word with sentiment volume

<sup>2</sup>Positive, Comparative, Superlative

<sup>3</sup>Topology of sentiment phrases in text:1 in first 1/2 of text, 2 in second 1/2 of text, 0 homogeneity in all text

<sup>4</sup>IndexWord<sub>Satisf</sub> =  $\sum (W_{S+} / N_w)_{\text{text-i}} / \text{TotN}_w$

<sup>5</sup>IndexWord<sub>nonSatisf</sub> =  $\sum (W_{S-} / N_w)_{\text{text-i}} / \text{TotN}_w$   
for W<sub>S+</sub>, W<sub>S-</sub>:  $\sum$  Word with sentiment or opinion load per text (positive polarity+ or negative polarity-)

These results based a Greek Lexicon of Emotions (Vostantzoglou, 1998 2<sup>nd</sup> edition revised).

The following table is observed the results from System Usability Scale (DEC SUS) usability assessment Tool:

Table 16. SUS score results<sup>1</sup>

Merchant Marine Officers (13 male)			
	full sample	very high	high
<i>Satisfaction Simulator</i>			
Mean	73.2	79.1	69.1
Max	92.5	92.5	82.5
Min	62.5	62.5	62.5
STDEV	10.3	10.8	7.3
Mode	62.5	-	62.5

<sup>1</sup>100-80 high score, 80-60 satisfactory rating, <60 low usability

The Total Satisfaction Index (TSI) is calculated as follow:

$$TSI = [\text{Sat\_Sim} + \text{Sat\_Scen}] / 2 \quad (1)$$

The climax with weights of Total Satisfaction Index (TSI) of users shown below:

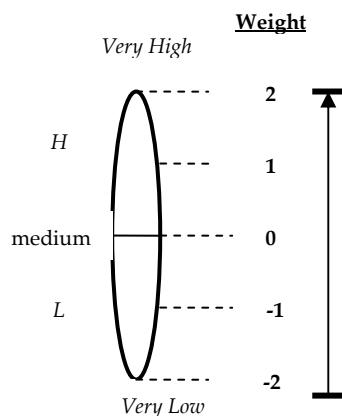


Figure 2. Climax of Total Satisfaction Index

The following table is observed the results from Total Satisfaction Index (TSI):

Table 16. Results of TSI

Merchant Marine Officers (13 users)			
	Mean	STD	Mode
TSI	1.3	0.5	1.5

Finally the next figure is observed the TSI range in sample:

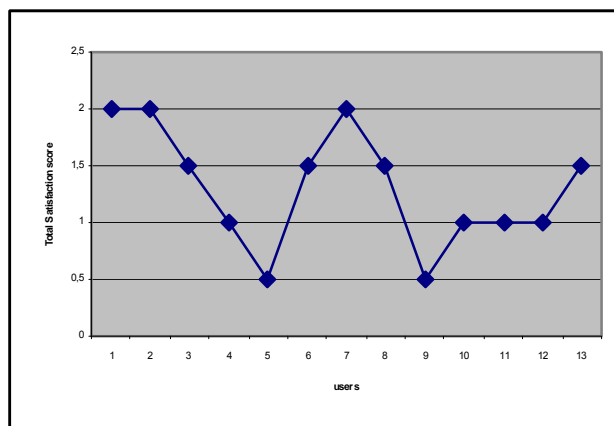


Figure 3. Total Satisfaction Index range in sample

## 6 CONCLUSIONS

From the processing of the experimental data so far it is established that:

- Visual attention (VA) from the "Face Analysis tool" shows
  - growing the attention as satisfaction scenario increase (mean grow high → very high) in dist parameter (distance from monitor, >1 close to the screen)
  - growing the attention as satisfaction scenario increase (mean grow high → very high) in Head Roll parameter (rolling of the head – eye angle from horizontal level, <10 attention depending on the scenario, >10 high mobility)

- growing the attention as satisfaction scenario increase (mean grow high → very high) in Gaze tracking parameter (Gaze vertical parameter >1 view the screen).
- The Engine room Simulator training grows the job security and performance, has professional value and help to professional development (motivation model).
- In lexical analysis, we observe the total word of answer's users depending from satisfaction (growing the mean of Total words from high → very high satisfaction) and the  $\text{IndexWord}_{\text{nonSatisf}} < \text{IndexWord}_{\text{Satisf}}$  (from high → very high satisfaction).
- In the SUS score has satisfactory rating and growing the score from high → very high satisfaction.
- High usability (easy to use, easy to learn).
- Finally, the Total Satisfaction Index (TSI) is high in sample (mean TSI: 1.3 ~ characterization of 'high').

The connection between all above elements resulted from the processing of the optical registration data and the users' interview & questionnaires.

The approach is general in the sense that it can be applied in various types of e-learning marine systems. It is also pluralistic in the sense that it provides the evaluator with complementary sources of data that can reveal important aspects of the user experience during ship control. Certainly, the proposed approach may require further adaptations to accommodate evaluation of particular interactive systems.

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