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FACULTY OF PSYCHOLOGY AND EDUCATIONAL SCIENCES

The optimization of error signaling in Human-Computer Interaction

- abstract -

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Structure of the thesis

Contents

Key words: error messages, notification systems, psychological effects, meta-analysis, human-computer interaction

Theoretical approach

Specificity of error messages

Error messages are ways to report a defection or a problem that has occurred during work on a personal computer (PC). By their nature, computer error messages are a intrusive event in the computer operating activities, fact that signals the existence of an internal malfunction (system error) or a faulty operation made by the user (user error).

So far, the studies about computer errors have been focused in particular on human errors within Human-Computer Interaction: the synthesis carried out by Iosif and Marhan(2005) on this type of fact presents many possible errors, but all of them is based on the premise of faulty computer usage. In this thesis we are interested in the effects of the messages, not the conditions of their occurrence.

Cognitive effects of error messages

The error message is an event that interrupts the user while he is interacting with the computer. In these types of situations the user must pay attention to the displayed message and ignore his activity, and then return to the initial task. This process of changing the object of attention may lead to variances of cognitive performance and mistakes in computer usage. For example, McFarlane(1999) recounts the case of a plane crash occurred because of the interruption made by the traffic controller during pre-flight checks.

The literature that has examined the effect of interruptions on user performance in the initial task has focused so far on other types of interruptions like pop-up messages, e-mails, experimenter intervention, telephone, etc., but not on error messages. Studies of this type of disruption have identified a phenomenon called by Ballas, Heitmeyer and Perez (1992, p. 129) the *automation deficit*. The automation deficit occurs due to limited user's cognitive resources, in case the user has to handle multiple tasks at the same time. The occurrence of a disruption requires accessing the information needed to solve the secondary task, eliminating from the working memory the information related to the main task, solving the secondary task, eliminating from the working memory the information related to the secondary task and accessing the information need to solve the main task. Experimentally, the existence of the automation deficit can be observed by the delayed response of the user, response which is less precise, the subjective feeling of losing control and the subjective feeling of stress (Ballas et al., 1992).

Research on variables that may lead to increased or decreased negative effects of disruptions focused on several factors: the difficulty of the main task and the type of disruption, the time of disruption, the moment of disruption and the similarity between the main and the secondary task. Experimental studies have concluded that the automation deficit is to the utmost extent when the main task is difficult; the disruption is produced by a complex stimulus, long-term (over 18 seconds) and very different from the main task.

Emotional effects of error messages

Currently, there are several lines of research that analyze the emotional reactions of users at the time they encounter error messages: studies on the effectiveness of training programs, studies on user aggressiveness and studies on interruptions effects.

A first direction is the study of the effectiveness of error management trainings. Error management trainings are used to study new computer applications and are based on encouraging learners to solve the problems that generate errors, and not to avoid the occurrence of errors (Frese, Brodbeck, Heinbokel, Moosser, Schleiffenbaum & Thiemann, 1991). Starting from the idea that errors can not be avoided, this training field focused on improving the way the users react to error messages. The results reported so far indicate the fact that the participants' abilities of controlling their emotions play an important role in predicting the success of these training programs (Frese et al., 1991; Heimbeck, Frese, Sonnentag & Keith, 2003:, Keith, 2005).

The second line of research started with the sociological study conducted by Ipsos MORI for the Compaq European division. Results show that anger and frustration are current emotional reactions that occur due to error messages (Ipsos MORI, 1999). Subsequent research in this line of study has shown that frustration is related to user characteristics (in particular the lack of IT knowledge) and to the used system malfunctions (Ceaparu, Lazar, Bessiere, Robinson & Schneiderman, 2004). The most frequent malfunctions reported by users are about the internet connection, used software applications or the computers' internal components. To solve these types of malfunctions the users spend approximately 40% of their work time, which leads to large decreases in productivity and also to financial losses for the employers (Lazar, Jones, Hackley & Schneiderman, 2006; Ceaparu & Co., 2004).

In an attempt to explain the occurrence of frustration, researchers have considered several mood variables. Previous studies have shown that a high level of frustration is associated with low levels of self-efficacy in computer usage (Bessiere, Ceaparu, Lazar, Robinson, Shneiderman, 2004), emotional instability (Rose, Bennet-Murphy, Byard and Nikzad, 2002) and high computer anxiety (Bessiere and Co. 2004). All these variables affect the frustration intensity, regardless of the specific incident that lead to this emotion (Bessiere and & Co. 2004).

The third direction of research on emotions associated with error messages derives from studying the disruption effects in human computer interaction. In one of the first studies that considered the emotional effects of user interruption (Zijlstra, Roe, Leonova & Krediet, 1999), the authors started on the premise that interruptions are frustrating and annoying because the task can not be achieved. The results reported by the authors cited above indicate a decrease in the positive emotional state in subjects that have been interrupted, compared with subjects in the control group. Moreover, it was found that subjects that were made to solve complex disruptions (text editing) have reported higher levels of anxiety, compared with subjects that had to solve simple disruptions (searching for information in a table).

Unlike the authors mentioned before, Bailey, Konstan and Carlis (2000) provide a theoretical argument for the study of anxiety as a effect of interruptions. The authors cited above start from the idea that in interpersonal interactions, the disruption of a person which is focused on a task represents an act of rudeness. Similarly, user interruption by an automated event (messages from the computer referring to updates or messages of error) represents also an act of rudeness. In the case of state anxiety, it was reported an increase in interrupted subjects, compared to non-interrupted subjects. In a previous study, Bailey and Konstan (2006) studied emotional reactions of users, depending on the moment of the disruption (during the main task or between two tasks). The results have shown an increase in the level of irritation of subjects interrupted during the task, compared with subjects interrupted between tasks (Bailey and Konstan, 2006).

An interesting approach is proposed by Kirsh (2000), which introduces the term *informational anxiety*. According to Kirsh, informational anxiety is the result of cognitive overload, which occurs in the context of a high demand of cognitive resources (the volume or diversity of the information that needs to be processed). Informational anxiety represents an important effect of cognitive overload, defined as "the overwhelming feeling experienced by individuals when confronted with too much information or when he is not capable of finding or interpreting data" (Kirsh, 2000, p.22). In other words, the user feels his ability to complete the current task threatened, and this threat leads to anxiety. The main problem with Kirsh's ideas is represented by the absence of an empirical study that can make the difference between anxiety generated by cognitive overload and anxiety generated by preventing the user to achieve his objective. This difference is very important because simply avoiding cognitive overload does not exclude anxiety installation.

Research on emotional effects of disruptions (Zijlstra and Co., 1999; Bailey and Co., 2000); Bailey and Konstan, 2006) or on error messages have provided strong arguments for further research in this field. However, at this time there is no clear delimitation of these effects: even if state-anxiety seems to be related to interruption appearance or error messages, the relation between these events and other emotional states (irritation, anger) remains not enough studied.

Study 1. Cognitive effects of the error messages

The aim of this study is to highlight the effects of error messages on cognitive performance in post-error tasks. We are interested in comparing the effects of error messages with effects of common interruptions from the computer. As we stated before, interruptions may lead to decreased cognitive efficiency and accuracy. Depending on the moment of interruption, its type and the difficulty of the main task, the effects of interruptions may vary in intensity. Because of these variations, it is important to experimentally control these issues.

The experimental control of these variables was performed by activating the message in a moment in which the impact of disruption is minimal. Thus, the error message appeared after completing a task, and the next task (post-error) appeared on screen only after its disappearance (see Figure 1). In this situation, the message does not interrupt the user because it appeared only after he responded to the previous exercise and before the next exercise appeared on screen.

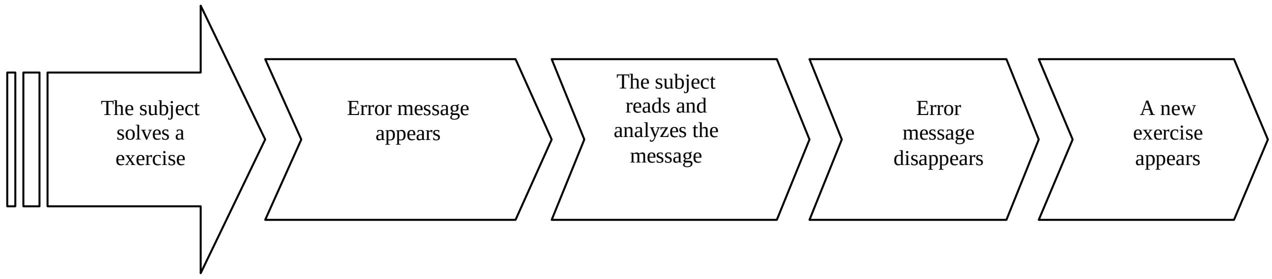


Figure 1. Sequence of events in the experimental situation

An important element in understanding an error message is the ability of the users to understand the semantic content of the message. In a previous study (Maricutoiu, 2006), we found that this was not associated with the anxiety level reported by the user after the occurrence of an error message. In other words, users who understand the meaning of the words that compose the message do not differ of users who do not understand.

Because previous research results showed that interruptions have a higher impact on processing efficiency than on processing accuracy, the subjects were instructed to solve the tasks as correctly as they can, regardless of the time they need to do so. We asked for a high accuracy in order to analyze the cognitive efficacy without variations in responses accuracy.

The study aims to test the following hypotheses:

H1: Subjects who receive an error message will have a lower cognitive performance than subjects who receive no message.

H2: The degree of English knowledge will not affect the cognitive performance significantly.

An important factor that explains the decrease in cognitive performance is represented by the duration of the interruption. Based on cognitive science results, studies from the field of interruption in human-computer interaction have shown that the duration of interruptions affects the variance in cognitive performance in post-error tasks. When the message appears we expect that the users will analyze the message, the causes of its appearance and the possibilities of answers available. Regarding the duration of disruptions, we started with the following assumptions:

H3: The time spent by subjects analyzing error messages will be greater than the time spent analyzing the neutral message.
H4: The more time a user spends analyzing the computer generated message, the greater his cognitive performance will decrease in the up-following tasks.
H5: The better the user knows the English language, the faster he will analyze the messages received from the computer.

Method
Participants

In planning this study we estimated the number of subject needed, starting from a expected effect (d = .70) and a statistical power of .80. This estimation indicated that 48 subjects is the minimal number needed to achieve the objectives of this study. The study was conducted in 2007 and involved the voluntary participation of 61 subjects (of which 20% male), students in second year of the Faculty of Sociology and Psychology from the West University of Timisoara. From these, 83,56 % declared that they have a personal computer at home.

Development and pre-testing of experimental equipment

In order to study the effect of error messages, a experimental software was built, that:

- presents cognitive tasks as a intelligence test;
- registers time spent on solving each task;
- records subjects' responses to each task;
- launches in a randomized way a message to the user (neutral message or error message);
- records the time needed to press the "OK" button after the appearance of the message;
- builds a database to store all information recorded (answer at each item, time needed to elaborate the answer and time needed to read the message).

Cognitive tasks were represented by the first two series of Raven Standard Progressive Matrices (series A and series B). Choosing this type of task is supported by the following arguments:

- the test has a high degree of validity;
- being a progressive test, there can be identified cognitive tasks with different degrees of difficulty, which allows experimental manipulation of this specific aspect;
- the cognitive task is a visual one, requiring subjects to identify relations between elements presented on the computer screen.

To assess the difficulty of the items, we conducted a pilot study involving 92 students (30,4 % males) from the West University of Timisoara. Participants went through all 24 items, instructed to answer as fairly as they can, even if this could take a while. These results have become the basis of decisions related to the tasks in which the post-error cognitive performance was measured in Studies 1, 4 and 5.

Experimental manipulation

Experimental manipulation in error messages was performed with the help of the software described previously. Depending on experimental condition, subjects:

- received no message (control condition)
- received one neutral message (“Please adjust your time and date”)
- received one system error message (“Your computer has encountered an unhandled exception and will have to close”)
- one user error message (“One of your actions caused un unhandled exception and as a result your computer will have to close”)

Messages appeared regardless if the answer given for item A12 was right or wrong and did not permit seeing item B1. This strategy allowed decreasing the effects related to the moment of interruption, the message appeared between two cognitive tasks. Subjects were randomly distributed in one of the four experimental conditions.

Study variables

General cognitive performance was measured by the mean time needed for solving the Raven intelligence test (series A), in a computerized version. Since the distribution of the reaction time is asymmetrical and positive (Sava, 2004), this indicator is the average of natural logarithms of the reaction times for items A1-A8.

Time assigned for reading messages sent by the computer was measured with the help of the program built for this thesis and it represents the number of seconds elapsed from the appearance of the message until the user has pressed “OK”. Similarly with the time measures presented in this study, we used the natural logarithm of raw data in order to normalize the distribution of these data.

Post-error cognitive performance was measured by the time needed to solve the task B1. Similarly with the anterior variable, the value for this variable is the natural logarithm of time needed to solve the task. This item appeared after the neutral message or after the error message.

Degree of English knowledge was measured by a self-assessment scale from 1 to 10 for reading, writing, speaking skills in English. Scores from these three assessments were accumulated in a general indicator.

Results

Post-error cognitive performance

Data analysis was performed using analysis of covariance (ANCOVA). Data analysis indicated that there are significant differences in terms of processing between experimental conditions ($F(3,49)=8{,}416$, $p<.001$). The cognitive performance in the pre-message tasks is also a significant predictor for this dependent variable ($F(1,49)=28{,}719$, $p<.001$). A comparative analysis of these two factors indicate the fact that the explanatory power of the experimental manipulation (partial $\eta^2 = .340$) is similar with that of the cognitive performance measured prior to interruption (partial $\eta^2 = .369$).

The absence of a significant relation between the degree of knowing English and the post-error cognitive performance ($F(1,52) = 0{,}352$, $p=.555$) is surprising. This result indicates the fact that the semantic content of the message is not the one that led to the variance in cognitive performance.

Differences between experimental conditions were analyzed by contrast analysis (the reference group was the control group), achieving significant results between the control group and the “system error” condition ($t_{contrast} =.520$, $p<.001$) and between the control group and the “user error” condition ($t_{contrast} = .401$, $p=.008$). There was no significant difference between the control group and the “neutral message” condition (tcontrast = -.035, p = .807).

Time assigned analyzing computer messages

Results obtained confirm Hypothesis 3 of this study. Analysis of variance results indicated that, depending on the message encountered, users needed different time intervals for message analysis ($F(2,37) = 28,803$, $p<.001$). Both error messages needed significantly much more time for analysis from users, when contrasted to the neutral message condition.

The forth hypothesis of this study stipulated a positive relation between time spent on analyzing computer messages and time spent on solving post-message tasks. Data analysis offers support for Hypothesis 4: $r(38) = .470$, $p = .002$ (statistical power = .921 for alfa of .05, one-tailed)

The last hypothesis of this study shows a negative relation between the degree of knowledge of English and the time spent on analyzing computer generated messages. The results obtained refute this hypothesis: $r(38)= -.203$, $p = .172$ (statistical power = .357, for alfa of .05, one-tailed).

Discussions

- this study eliminated the influence of factors that can lead to automation deficit: the appearance of a “common” disruption (neutral message) did not lead to a significant change in cognitive performance;
- under these conditions, the appearance of a error message has led to a significant decrease in cognitive performance. This effect can not be attributed to the known factors so far in the known literature;
- error effects on cognitive performance reported in this experiment can increase in work tasks that are different from the one used in this study. We expect that these effects will be more pronounced if the task is limited by a timeline, if it is more complex or if the message appears as a interruption of the main task;
- the absence of a significant relation between the level of English knowledge and the effect of error messages (cognitive performance and time spent analyzing the message) indicate the fact that we are dealing with a surface processing of these stimuli (which does not require semantic understanding of the error message);
- analysis and decision time for each of the error messages was significantly higher that the time assigned to the neutral message. A possible explanation for this result is the induction of an uncertainty state, demonstrated in our case by postponing the decision of action, even when there are no alternatives;
- subsequent studies will focus on identifying the emotional effects of error messages, the factors underlying these effects and how these emotional effects interact with the cognitive ones.

Study 2. Emotional states associated with error messages

The results of the first study of this thesis indicated the occurrence of decreased user cognitive performance in post-error messages tasks. This decrease can not be attributed to user interruption, because there were no significant differences identified between the control group (uninterrupted) and the neutral message group.

So far, research on emotional reactions in case of user disruptions or error messages (as a form of disruption) indicated the anxiety feeling as a possible effect of these events. However, the absence of a consistent theoretical approach and the existence of some results concerning the induction of irritation states show us that the anxiety feeling may be not the only effect of these events.

Starting from these observations, we aimed in this study to compare the degree of error messages association with the anxiety feeling and with anger. To achieve this, we used the Implicit Association Test (IAT). Although the content of measurement through implicit tests is not yet very clear, James and Rentsch (2004) considered that the test measures semantic associations which are not available to introspection: biological impulses, forgotten learning experiences, automated cognitive processes or cognitive processes related to growing or protecting self-esteem and the subjective state of well-being.

The Implicit Association Test (IAT) was developed by Greenwald, McGhee and Schwartz (1998) in order to measure the intensity of the association between a target-stimulus and a certain trait (attribute). In our study, target-stimuli were represented by different messages from the operating system MS Windows (error messages or informing messages), and the attributes were represented by words that describe states of anger, anxiety or relaxation. Measuring implicit associations with the help of IAT pointed out that these correlate (moderate correlation) with parallel self report measurements: the mean correlation is r = .361, according to a meta-analysis performed by Greenwald, Poehlman, Uhlmann and Banaji (2009).

The followinf arguments sustain our option for the IAT methodology:

- the implicit measure of associations is in a small extent influenced by motivation or social desirability (Hofman et al., 2005;, Tulbure, 2006). This trait is important for our study because it eliminates the limit of previous research related to social desirable responses;
- the implicit measure of associations is in a small extent available to introspection. From our point of view, this feature of IAT's methodology provides us access in an area of the human psychic that is very hard to access only by questionnaire, making it possible to confirm previous research results through alternative ways;
- the implicit measure of associations aims representations automatic activated by an relevant stimulus. The automatism represents a fundamental trait of emotional reactions (Rosca, 1974), fact that confers a high validity to the comparison between the two emotional states (anger and fear). In addition, the IAT usage in the anxiety and personality study domain has shown that behavioral indicators are best predicted by IAT, while self-report measurements have a lower predictive power (Steffens & Shultze-Konig, 2006; Gschwender, Hoffmann & Schmitt, 2008).

Objectives and hypotheses

The main objective of this study is to analyze how error messages associate with two emotional states: fear and anger. After using a common scale to measure these associations, we can launch the following hypothesis:

H1. There are significant differences between implicit association of error messages with the state of fear and implicit association of error messages with the state of anger.

Previous research have shown that the users experience is negative correlated with computer anxiety (Heinssen, Glass and Knight, 1987) and with frustration generated by the computer (Bessiere and Co. 2004). Therefore, we expect:

H2a. The work experience with the computer correlates negatively with implicit association between error messages and anxiety.

H2b. The work experience with the computer correlates negatively with implicit association between error messages and fear.

Previous studies pointed out that neuroticism (or low emotional stability) correlates with high computer anxiety (Pitariu, 2003) and with high levels of user frustration (Rose and Co, 2002). Therefore, we expect:
H3a. Emotional stability correlates with decreased levels of implicit associations between error messages and anxiety.
H3b. Emotional stability correlates with decreased levels of implicit associations between error messages and anger.

In the section devoted to understanding error messages, we have shown that the understanding of English may represent an important variable in the study of emotions associated to error messages. Therefore, we expect that users who understand the content of the error messages will feel less threatened or frustrated. We expect that:
H4a. High levels of English knowledge will correlate with low levels of implicit associations between error messages and anxiety.
H4b. High levels of English knowledge will correlate with low levels of implicit associations between error messages and anger.

Method

Participants

In planning of the present study we estimated the number of subjects needed, starting from a medium expected effect and a statistical power of .80. This estimation indicated that 64 subjects is the minimum number needed for achieving these parameters.

This study took place in November 2008 and involved the voluntary participation of 80 subjects (from which 23,8 % male), students in the second year at the Faculty of Sociology and Psychology from the West University of Timisoara. All subjects reported they have a personal computer at home, acquired 2 to 11 years ago (m=6,95, σ= 2,86).

Methods

Implicit Association Test (IAT). The objective of the study involves going through two IAT designs: one design that measures the association between the error message and anxiety and one design that measures the association between the error message and nervousness. For these designs, we used 5 stimuli for each element:

- 5 error messages
- 5 neutral messages
- 5 words related to fear (apprehension, panic, agitation, uncertainty, fear);
- 5 words related to hostility (fear, hostility, irritation, revolt, vehement);
- 5 word related to relaxation (calm, relaxed, cozy, balanced, still)

Table 1. Design structure for IAT 1 (fear vs. relaxation)

Phase	Number of trials	Stimuli	Left key (E)	Right key (I)
B1 – Adaptation	20	5 error messages + 5 neutral messages	Error message	Information message
B2 – Adaptation	20	5 fear items + 5 relaxation items	Fear	Relaxation
B3 – Adaptation	20	5 error messages + 5 neutral messages + 5 fear items +5 relaxation items	Error message + Fear	Information message + Relaxation
B4 – Critical	40	5 error mesages + 5 neutral messages + 5 fear items +5 relaxation items	Error message + Fear	Information message + Relaxation
B5 – Adaptation	20	5 fear items + 5 relaxation items	Relaxation	Fear
B6 – Adaptation	20	5 error messages + 5 neutral messages + 5 fear items +5 relaxation items	Error message + Relaxation	Information message + Fear
B7 – Critical	40	5 error messages + 5 neutral messages + 5 fear items +5 relaxation items	Error message + Relaxation	Information message + Fear

Because we wanted that the presence of the examiner not to be necessary from a test to another, we used MediaLab (experimental software), that allowed the conduct of the second IAT test in continuation of the first IAT test.

Half of the subjects went firstly through the test that associated error messages with fear, and the other half through the test that associated error messages with hostility. This strategy permitted to counterbalance for a possible order effect.

Personality Inventory DECAS (Sava, 2008) was applied in order to measure the Emotional Stability variable. The test has 95 items with dichotomy answers and it measures 5 major dimensions of the personality (Big Five Model).

Demographic questionnaire. Participants completed a short questionnaire that investigates their experience in working with a computer. We asked for information regarding the first year they interacted with a computer and the year they had a computer at home. At the end, the questionnaire asked the participants to self-assess their abilities in reading, writing, understanding and speaking in English using a scale from 1 to 10. Higher grades indicated a higher level of competence.

Results

Differences between the two implicit measures

The results obtained show that anxiety and anger are differently associated with error messages: t(71) = 4,171, p<.001. Regarding the effect size, the difference between the two means is a moderate one: d (Cohen) = .487. The statistical power of the within-group t test is .98 (for α = .05, two-tailed).

These results sustain hypothesis 1, indicating significant statistical differences between the two implicit measures: anxiety is more frequently associated with error messages (m = 0,656, σ = 0,350) than anger (m = 0,494, σ = 0,331).

Computer experience

Subjects' experience was measured using the number of years past since the first computer interaction.

Table 2. The correlation matrix of the variables included in hypotheses 2, 3 and 4

	1	2	3	4	5
1. IAT anxiety	1				
2. IAT anger	.513*	1			
3. Emotional stability	-.306*	-.161	1		
4. Understanding of the English language	-.307*	-.192	.119	1	
5. Computer work experience (in years)	-.099	.053	.088	.253*	1

Note: N= 73. Correlations marked with a * are statistically significant at p < .05 (one-tailed)

On average, a first contact with the computer occurred 3 to 12 years ago (m=8.34, σ= 2.24). Results presented in Table 2 indicate that relations between the two implicit measures and the computer experience are statistically insignificant.

Emotional stability

Emotional stability (or low neuroticism) was measured by using the Personality Inventory DECAS (Sava, 2008). The results presented in Table 2 sustain Hypothesis 3a: r(73) = -.306, p<.05. The statistical power of this correlation is .843 (for α = .05, one-tailed). The results obtained do not support Hypothesis 3b: r(73) = -.161, p>.05, with a statistical power of .403 (for α = .05, one-tailed).

Knowledge of the English language

For measuring the degree of English knowledge we asked our participants to self-asses their writing, reading, understanding and speaking skills in English, using a scale form 1 to 10. The variable English knowledge represents the average of these self-assessments. The results presented in Table 2 sustain Hypothesis 4a: r(73) = -.307, p <

.05, with a statistical power of .844 (for α = .05, one-tailed test). However, the correlation coefficient that tested Hypothesis 4b is insignificant: $r(73) = -.192$, $p > .05$, with a statistical power of .500 (for α = .05, one-tailed test).

Discussions

- this study used a innovative methodology in the field of human-computer interaction, methodology that allowed comparative analysis of two error messages effect: anxiety and anger;
- results indicated strong associations between error messages and the two fundamental emotions analyzed: fear and anger. For each emotion analyzed, the average association coefficients were over .50;
- comparative analysis of the association coefficients revealed a significant statistical difference, the state of fear is more intensely associated to error messages, as compared to the state of anger;
- the results obtained in this study show us that users are more prone to adopt avoidant and secure behavior when error messages occur;
- results point out a significant relation in implicit association of error messages with anxiety and English knowledge. The users' incapacity to understand the content of the error message correlates with the implicit perception of them as feeling threatened;
- even if the literature in the field reports significant associations between user experience and explicit measures of anxiety and anger, the correlation coefficients obtained in this study are very low. This result can be a cause of the implicit measures used, which are less susceptible to modeling as a result of experience. We can conclude that experience is negatively associated with explicit emotional reactions (due to coping mechanisms improving and to problem solving strategies), but experience does not associate with implicit reactions (tied to early user experience in computer interaction);
- further studies of this thesis will have to answer the following questions: which are predictors for anxiety in the case of error messages and which are the effects of this form of anxiety?

Study 3. Computer anxiety. A meta-analysis of its predictors.

Because the past study demonstrates that anxiety represents the most powerful emotional effect of error messages, we aim to investigate the relation between computer anxiety and its main predictors and effects. Since the number of hypotheses of this study is rather large, we preferred to synthesize them in Table 3.

Table 3. Study hypotheses

Variable type	Variable	Expected Relation
Predictor of computer anxiety	Trait anxiety	+
	Extraversion	0
	Agreeableness	0
	Neuroticism	+
	Openness	-
	Conscientiousness	0
Effect of computer anxiety	Personal efficiency in the interaction with the computer	-
	Degree of innovation in using technology	-
	Intention of using the computer	-
	Computer utility perception	-
	Perceived ease of use	-
	Performance in use	-

Procedure

The meta-analysis was conducted in accordance with Hunter and Schmidt's (2004) recommendations and it aims the calculation of average correlation coefficients and their confidence interval, after eliminating the influences of sampling error.

From the studies identified as helpful for the meta-analysis, we retained the following information: characteristics of the used sample (N, gender distribution, age mean, participant nationality), correlation coefficients between computer anxiety and the variables presented in the introductive part of this chapter and the instruments that were used to measure these variables.

Results

After analyzing the literature in the field, we identified 38 studies that present sufficient data to include them in the meta-analysis. We identified 79 correlation coefficients that are useful for our research. The obtained results are presented in Table 4.

Table 4. Meta-analysis results.

Correlated Variable	N total	k	Z score	Obs. Var.	Resid. Var.	Z min	Z max	% sa.	Q-Test	*N*
Trait-anxiety	2452	10	.246	0,073	0,055	.137	.355	42,95	Q(9) = 13,099, p = . 158	39
Extraversion	672	4	-.106	0,068	0	-.106	-.106	100	Q(3) = 3,096, p = . 377	5
Neuroticism	781	5	.238	0,081	0,053	.134	.343	56,89	Q(4) = 5,027, p = .284	19
Openness	667	4	-.251	0,012	0	-.251	-.251	100	Q(3) = 0,098, p = .992	16
Conscientiousness	insufficient studies									
Agreeableness	Insufficient studies									
Personal efficiency in computer interaction	2776	13	-.422	0,230	0,208	-.831	-.013	17,95	Q(12 = 145,11, p<.001	96
Degree of innovation in using technology	725	5	-.149	0,177	0,149	-.442	.143	29,11	Q(4) = 22.37, p<.001	10
Intention of using the computer	1824	8	-.263	0,135	0,106	-.471	-.055	38,48	Q(7) = 32,89, p < .001	34
Computer utility perception	2248	10	-.159	0,264	0,253	-.655	.337	8,5	Q(9) = 155,63, p<.001	22
Perceived ease of use	973	5	-.390	0,145	0,105	-.596	-.183	47,43	Q(4) = 20,15, p<.001	34
Performance in use	694	6	-.172	0.144	0.094	-.358	.013	57,12	Q(5) = 14,18, p = .014	14

Legend: N total = total number of subjects for which the average effect was calculated; k = number of independent samples; Z score= average effect; Obs.Var. = observed variance of the average effect; Rezid.Var. = rezidual variance of the average effect; Z min = the lower margin of the confidence interval for the average effect; Z max = the higher margin of the confidence interval for the average effect; % eş. = percent of variance explained by sampling error; Q-test = homogeneity test; *N* = failsafe N.

Discussions

- Personality variables which significantly associate with computer anxiety are: trait-anxiety, neuroticism and openness (negative correlation);
- Users that are prone to anxiety in computer interaction belong to the avoiding type: such people prefer established ways of working and avoid change (specific to a low openness) in order to decrease intense emotional reactions (specific to neuroticism);
- People that experience anxiety while interacting with the computer will have negative expectations about their own capacity of solving potential problems or about their performance in computer use;
- An interesting result is represented by the non-significant relation between computer anxiety and the degree of innovation in using technology. The obtained result can be explained by the specificity of computer activities, which do not allow the same level of innovation using technology. In other words, the type of computer activities can moderate the analyzed relation : this correlation can be higher in

activities that allow an increased level of innovation and it can be very low in activities that do not allow real variations of innovation;

- The results of the meta-analysis point out significant relations (from the statistic point of view) between computer anxiety and the perceived ease of use in computer usage (Zscore =-.390. k=8) and between computer anxiety and the intention of using the computer (Zscore = -.263, k = 8);
- A surprising result is the one obtained concerning the relation between computer anxiety and the perceived utility of the computer (Zscore = -.159, k = 10). The result from this meta-analysis can be explained by the dispersion degree of computers in human activity: since computers have become indispensable in the majority of fields (if not in all of them), the perceived utility is generalized.
- The relation between computer anxiety and performance in computer use has a low intensity (Zscore = -.172, k = 6) and it is not significant from the statistical point of view. This result can be explained by the nature of the experimental tasks which are the basis of the performance measurement of computer use. In these experimental tasks, the performance was measured by the number of correctly executed tasks. All the tasks involved rather computer operating skills then cognitive performance in use, because the named studies did not take into account the time the participants needed to solve the tasks.

Study 4. The interference between emotional and cognitive effects of the error messages

As shown in the first two studies of this thesis, error messages lead to the inexplicable (until this point) decrease of the cognitive performance in post-error tasks and to induction of negative emotional states (Maricuţoiu, 2006, Bessiere et al. 2004). Regarding the emotional reaction, the results obtained in Study 2 have shown that error messages are implicitly associated with the state of fear and the state of nervousness, but the first one is significantly stronger associated with the error messages.

However, studies so far have failed to confirm a relation between the emotional effects and the cognitive effects of error messages. This relation is theorized by Eysenck, Derakshan, Santos and Calvo (2007) in *The Attentional Control Theory* and by Smith and Caputi (2007) in *The Model of cognitive interference of computer anxiety.*

The attentional control theory (Eysenck et al., 2007) describes the relation between the anxiety experience and cognitive performance. According to this theory, the anxiety experience influences the two sides of cognitive performance: efficacy and efficiency. First of all, the accuracy of the cognitive processes (their efficacy) is affected by the interference of information generating anxiety in content processing, by excluding the relevant but threatening information for the task. Second of all, cognitive performance is affected by limited resources of the cognitive processing system related to experience anxiety: the threat of an objective leads to cognitive resources allocated for the purpose of detecting the source and the purpose of formulating the future action (Eysenck et al., 2007, p.338).

The cognitive interference model of computer anxiety proposed by Smith and Caputi (2007) is a theoretical model which aims to explain the relation between computer anxiety and the user cognitive performance during computer use. The theory wants to explain the variables which can distort the computer-based evaluation of cognitive abilities. According to this model, computer anxiety leads to the occurrence of several effects, classified as followed: emotional effects (subjective events of emotional activation and objective physiological events), behavioral effects (physical retreat or task avoidance , attentional instability) and cognitive effects (concern about the use of a computer, uncertainty, uncontrollable thoughts).

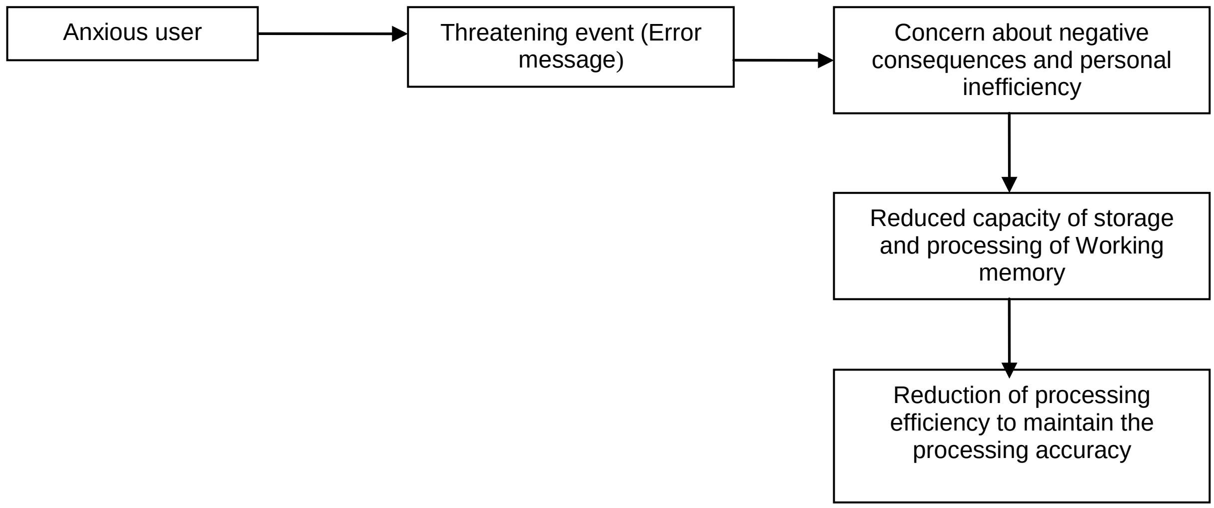


Figure 2. The effect of computer anxiety on cognitive performance
(adapted from Smith and Caputi, 2007, p. 1487)

Objective and hypotheses of the study

This research has as objective the study of the interference between the cognitive and emotional effects of error messages. As we found out from the first study of this thesis, the occurrence of an error message can lead to decreased cognitive performance in a post-error task. With this study we aim to investigate the relation between cognitive and emotional effects of the error messages, but also the investigation of potential explicative variables of this phenomenon.

To highlight the relation between cognitive and emotional effects of error messages, the user will first interact with an error message and subsequently with a neutral message. If an interference between the cognitive and the emotional effects exists, we expect to observe decreased cognitive performance in the case of neutral message. In other words, once the user has encountered an error message, he will react in a similar way at any other message from the computer. Therefore, we propose as first hypothesis:

H1: Subjects who have met a neutral message will experience decreased cognitive performance in case he previously encountered an error message.

The findings obtained in Study 2 of this thesis have indicated a powerful implicit association between error messages and anxiety experience. By integrating these results in the cognitive interference model of computer anxiety we expect that, at the occurrence of an error message, the user cognitive performance will decrease in case of association between the error message and anxiety. In the absence of an error message, we expect to obtain a statistically insignificant relation between cognitive performance and the association of error messages with anxiety. Therefore, we propose the next hypothesis:

H2: The relation between the implicit association of error message with anxiety and cognitive performance is moderated by the presence/absence of error messages.

The obtained results from the study of implicit associations indicated the fact that emotional stability is significantly negatively correlated with the degree of association between the error messages and anxiety. This result is supported also by the meta-analysis presented in the previous chapter, which identified a significantly positive and homogenous relation between neuroticism (or low emotional stability) and computer anxiety. In this research, we expect that the relation between the cognitive performance in post-error tasks and emotional stability to be more intense in the situation in which the user encounters an error message. In other words, we expect that the presence or absence of the error message will moderate the relation between emotional stability and cognitive performance. Therefore, we propose the next hypothesis:

H3: The relation between *emotional stability* and *cognitive performance* is moderated by the occurrence of error messages.

Methodology

Participants

While planning the research we conducted a previous estimation of the number of needed subjects, starting from a medium expected effect, mixed 3X3 design and a statistical power of .80. This estimation indicated a minimum of 53 subjects for every intergroup experimental condition.

The research was conducted in December 2008 and involved the voluntary participation of 100 students (of which 38% male). All the participants are second year students at the Faculty of Sociology and Psychology of West University of Timisoara. Regarding the experience of computer interaction, the majority have a personal computer at home (90%), acquired 1 to 15 years ago (m = 6,42, σ = 3,68);

Experimental manipulation

The participants have been randomly divided into 3 experimental conditions: control, information+error and error+information. In the control condition, the participants worked on the computer without receiving any message from it. In the information+error condition, the participants received an informational message (*Please adjust your date and time)* followed by an error message (*Your computer has encountered an error).* In the error+information condition, the participants received the same two messages but in reversed order.

The experimental design is a mixed one, type 3X3. The intra-group variable is represented by the moment of the measurement (the three problems), and the inter-group variable is the order in which the messages appear (no message, information+error, error+information).

Table 5. The experimental design of Study 4.

	First problem	Second problem	Third problem
Control group	No message	No message	No message
Experimental group 1	Information	No message	Error
Experimental group 2	Error	No message	Information

The variables of the study

The error messages were generated by the same software described in Study 1 of this thesis. With the help of this software, the following variables were measured:

- *Cognitive performance of item A8* – time needed for solving the task from the moment of its appearance until the moment of the solution selection
- *Cognitive performance of item B5* – time needed for solving the task from the moment of its appearance until the moment of the solution selection
- *Cognitive performance of item B10* – time needed for solving the task from the moment of its appearance until the moment of the solution selection
- *General Cognitive performance* – measured by the medium time of solving the items of the intelligence questionnaire *Raven Progressive Matrices* (series A, items A1-A7);

In addition to these measures, we used the following instruments:

- The Personality Inventory DECAS (Sava, 2008) – measures the big five dimensions of the personality described by the Big Five Model;
- The demographic questionnaire used in Study 2 of this thesis;
- An IAT design which measures the degree of implicit association of the error messages with fear, described in Study 2 of this thesis.

Results

Cognitive and emotional reactions interference

As it was expected, the within-group analysis did not indicate the existence of significant results between the three moments of the measurement. The equivalence of the three selected problems for this experiment is confirmed by the absence of significant differences between the measurements: $F(1,178) = 3,044$, $p = .052$.

The results of the within-group analysis confirmed the hypothesis of the research: the interaction effect is statistically significant, underlining a different evolution of the cognitive performance related to the manner in which the experimentally manipulated messages appeared ($F(4,178) = 2,640$, $p = .035$). The interaction effect ($\eta^2 = .056$) is medium-low (Sava şi Maricuţoiu, 2008) and the statistical power (.73) is acceptable.

The relation between implicit associations and cognitive performance in post-error tasks

In order to test Hypothesis 2 of this research we calculated the correlation coefficients between the implicit associations of the error messages with anxiety experience and cognitive performance, for the subjects from the control-group but also for the subjects from the “error+information” group.

Results show a great difference between the two correlation coefficients: $q = .520$, $\Delta r^2 =.166$. This result has a moderate statistical power ($\beta = .628$), that indicates that the result was not a random one. Based on these results we can state that the relation between implicit association of error messages and cognitive performance is moderated by the occurrence of error messages.

The relation between Emotional stability and Cognitive performance in post–error tasks

In order to test Hypothesis 3, we calculated the correlation coefficients between Emotional Stability and Cognitive performance in post error-task, for the group control (no error) and also for the subjects in the “error + information” group.

Results show a mean difference between the two correlation coefficients: $q = .323$, $\Delta r^2 = .070$. This result has a low statistical power ($\beta = .342$), which points out great chances that the result obtained is a random one.

Discussion

- Subjects which encountered an error message followed by a neutral message experienced the highest decrease of cognitive performance in the post-message tasks. The average time for solving the first item increases when the error message occurs from 1,842 to 1,973. The same tendency can be observed in the third situation if we compare the results of the control-group (m=1,868) with the ones of the “information+error”-group (m=2,099);
- The occurrence of the neutral message after the error message leads to an increase of the time needed for solving the next item. This effect is similar to the effect of an error message.
- The occurrence of the error message leads to a change in the manner the user interprets other types of messages from the computer. We can say that the participants from the “error+information” condition reacted in a similar way to the neutral message as to the error message. The obtained results from the second

problem show that, in the case of the "error+information"-group, the average time for solving is not very different from the mean of the other two experimental groups. A possible interpretation of this variation of the cognitive performance is offered by the attentional control theory (Eysenck &colab., 2007): the occurrence of the error message led to a preferential processing of the irrelevant stimulus for the task (neutral message).

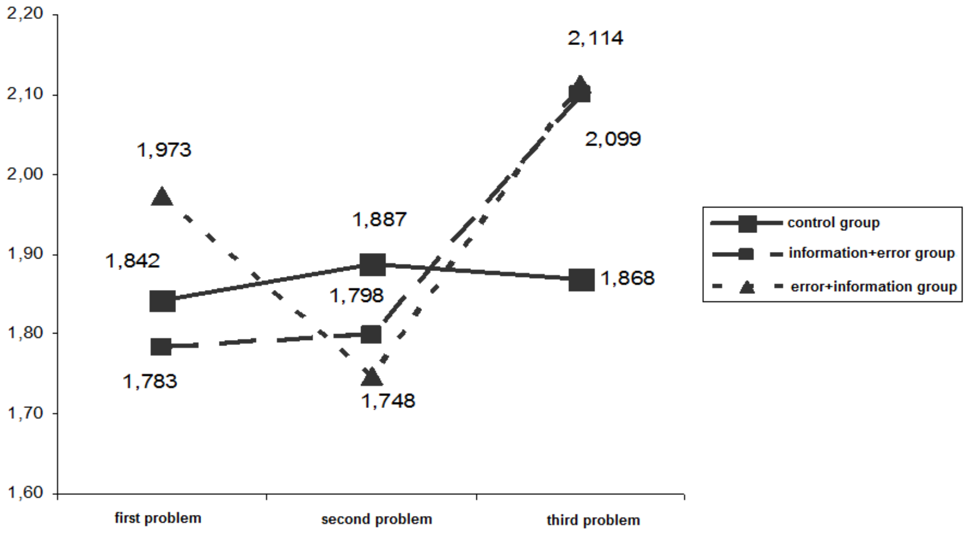


Figure 3. Average time for solving in the 9 experimental conditions

- The appearance of the error message has a very powerful moderation effect on the relation between the implicit association of the messages with the anxiety and the cognitive performance in the post-error tasks. In the control group, the relation between these two variables is negative and statistically non-significant. In the experimental group, the relation between these two variables is positive and statistically significant. The difference between these two correlation coefficients points out a moderation effect. Since this relation was not significant for the control group, we can attribute it exclusively to the occurrence of the error message.
- The research did not identify a significant relation between *emotional stability* and *cognitive performance in the post-error task* .In both experimental conditions, the results show a non-significant relation between these two variables. Regarding the difference between the correlation coefficients obtained from the two experimental condition, it is one of low intensity ($q = .323$, $\Delta r^2 = .07$). We consider that this result has two possible explanations:
    - aside from the implicit association of the error messages with anxiety variable, the emotional stability represents a more general psychological variable. This level of generality can explain the fact that the association is poor in intensity;
    - from the size effect point of view, the correlation is of medium intensity, but the number of available subjects did not assure a sufficiently strong statistical power in order to make the result significant;
- In conclusion, the obtained results indicated the existence of interference between cognitive effects and emotional effects of the error messages.

Study 5. The optimization of error signal in human-computer interaction

The present study has two objectives. Firstly, we propose solutions that can lead to the decrease of emotional and cognitive effects of the error messages. Secondly, we are interested in studying the relation between user *emotional stability* and emotional reactions to the occurrence of error messages.

In order to identify the solutions which lead to decreased emotional and cognitive effects of error messages, we start from the premise of surface processing of these messages. This premise is supported by the absence of correlations between the user capacity to understand English and the cognitive effects (highlighted in Study 1 of this thesis) or the emotional effects (Maricuţoiu, 2006) of error messages. Surface processing of error messages implies recognizing the problem only after the message visual analysis, without the need of message meaning analysis. From our point of view, visual elements that are relevant for inducing negative emotional states and a decline in cognitive performance are: graphic elements specific to error messages (the icon), the presence of the word *error* in the text message or in the descriptive text of the error message.

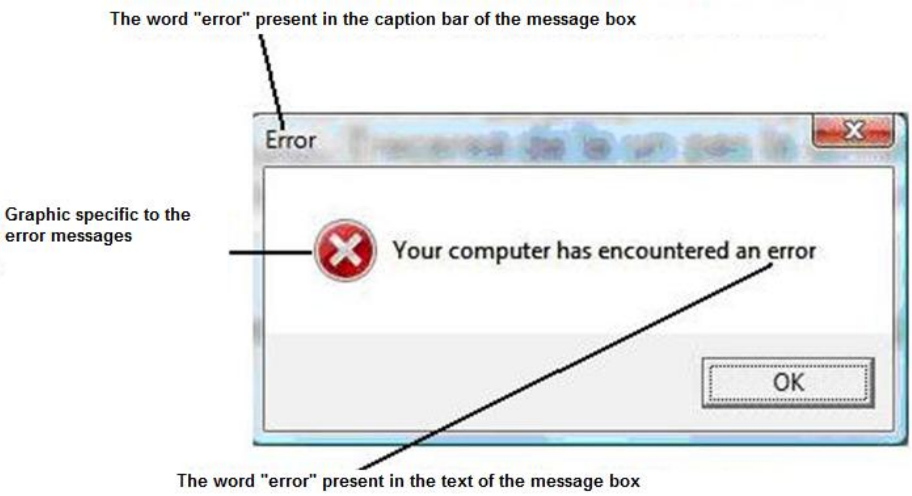


Figure 4. The elements of the error message which are taken into account in this study

In order to achieve the first objective of this thesis, we will manipulate each of these three elements specific to the error messages. The manipulation will take place according to an experimental design type 2X2X2, described further. Therefore, we propose the following hypotheses:

H1a. The absence of graphic elements specific to error messages (the icon) will lead to a decrease of physiological effects of the error messages.

H1b. The absence of graphic elements specific to error messages (the icon) will lead to a decrease in the subjective experience of anxiety.

H1c. The absence of graphic elements specific to error messages (the icon) will lead to an increased user cognitive performance in the post-error task.

H2a. The absence of the word *error* from the descriptive text of the message will lead to a decrease of physiological effects of the error messages.

H2b. The absence of the word *error* from the descriptive text of the message will lead to a decrease in the subjective experience of anxiety.

H2c. The absence of the word *error* from the descriptive text of the message will lead to an increased user cognitive performance in the post-error task.

H3a. = The absence of the word *error* from the text of the message will lead to a decrease of physiological effects of the error messages.

H3b. = The absence of the word *error* from the text of the message will lead to a decrease in the subjective experience of anxiety
H3c. = The absence of the word *error* from the descriptive text of the message will lead to an increased user cognitive performance in the post-error task.

In order to achieve the second objective of this thesis we introduced the *emotional stability* variable in a covariance analysis. To have a more complete image of the emotional effects of the error messages we will use both specific negative emotions physiological parameters measurement (heart rate) and an assessment of the subjective experience of anxiety. In this regard, we propose the following hypotheses:

H4a. Emotional stability will correlate negatively with the user's heart rate, measured after the occurrence of the error message.
H4b. Emotional stability will correlate negatively with the level of subjective experiencing, measured after the encounter with the error message.

Methodology

Participants

To decide on the number of subjects necessary for this study, we conducted an estimation of the sample volume needed in order to obtain a significant result at α = .05, with a statistical power of .80, while the expected effect size is medium (f=.25) and the study will have a design type 2x2x2 inter-group. This estimation brought out a number of 16 subjects for every experimental condition, a total of 128 subjects.

At this research 110 students participated (48% male). All subjects declared that they possess a personal computer, which they daily use.

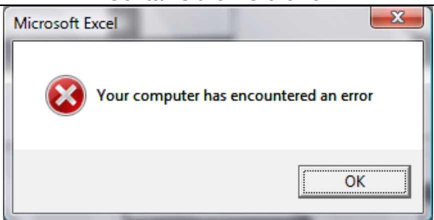
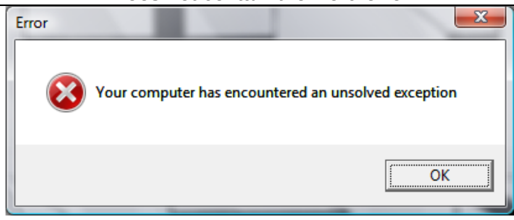
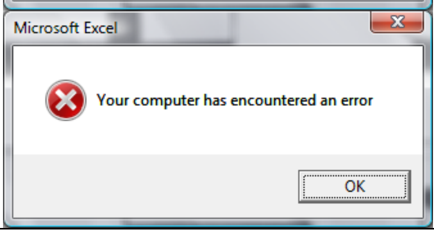
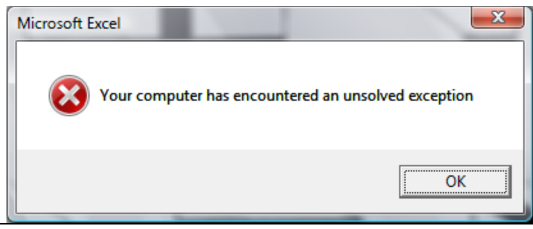
Experimental manipulations

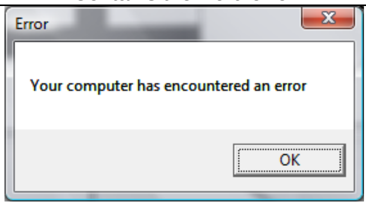
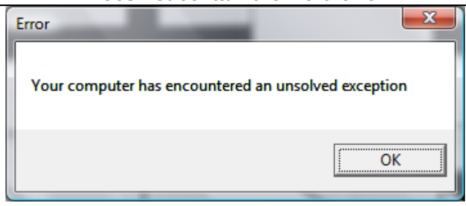
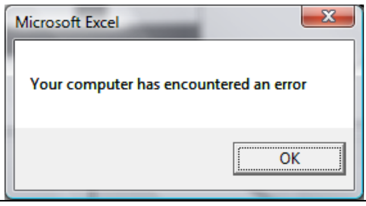
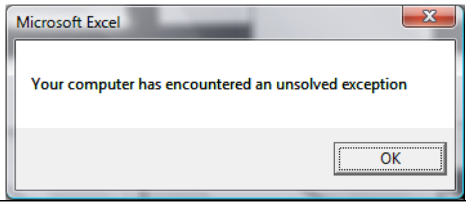
To test the previous mentioned hypotheses, we will manipulate the following independent variables:

- Presence/absence of graphic elements
- Presence/absence of the word "error" in the descriptive text of the message
- Presence/absence of the word "error" in the text of the message

The experimental design will be inter-group 2X2X2, structured as in the following sketch:

Table 6. Experimental design of study 4.

Graphic element	Descriptive text	The text of the message	
		Contains the word error	Does not contain the word error
Present	The word "error" present		
	The word "error" absent		

Graphic element	Descriptive text	The text of the message	
		Contains the word error	Does not contain the word error
Absent	The word "error" present		
	The word "error" absent		

The variables of the study

The dependent variables of this study are: cognitive performance in the post-error task (the time for solving the task from the first plate after the occurrence of the message) and the emotional state of the user. The emotional state was measured at the end of the experimental task. Two aspects of the emotional state were measured: the subjective experience of anxiety at the end of the experimental task (measured by the Fear scale from the list of adjectives PANAS-X – Watson and Clarck, 1992) and the organic reaction at the end of the experimental task (users pulse, measured by an Omron automated appliance, model R7)

Aside from the experimental manipulations, we expect to observe significant effect of the next covariate variables: general cognitive performance (the average of the time for solving the plates previous to the error message) and emotional stability (measured with the personality inventory DECAS).

Results

Factors which influence the post-experiment pulse

Statistical analysis pointed out significant effects of the independent variable "Icon" (F(1,99) = 5,037, p = .027) and of its covariate emotional stability (F(1,99) = 4,224, p = .042). The absence of the icon in the structure of the error message leads to a decrease in user heart rate, from an average of 87,09 beats per minute (in the condition in which the message contained the icon) to an average of 80,58 beats per minute. Regarding the significant relation between heart rate and emotional stability, this correlation is negative: r(106) = -.206, p = .033.

Factors which influence state anxiety

The results of the statistical analysis confirm the obtained results from the past analysis. The variation of state anxiety is significantly influenced by the presence or absence of the icon specific to error messages F(1,100) = 5,201, p = .025) and the variation of emotional stability F(1,100) = 4,714, p = .032, the correlation between emotional stability and state anxiety is r(103) = -.230, p = .007).

Factors which influence the cognitive performance in the post-error task

The obtained results indicated several factors which influence the variation of the cognitive performance in the post-error task. Thereby, the dependent variable is influenced by the general cognitive performance (F(1,96) = 19,916, p < .001), the presence of the word *error* in the text of the message (F(1,96) = 5,822) and the interaction between the three independent variables of this study (F(1,96) = 8,016, p = .006).

By analyzing the means of all the 8 experimental groups, we can observe that the presence of the word *error* in the text of the message led to an increase of the time needed for solving the post-experiment problem. It can be observed that the highest mean (2,226) was registered at the experimental group which encountered the “classical” error message, and the lowest mean (1,909) was registered at the message which differed mostly from the error message (no icon and no “error” in the text of the message or the descriptive text of the message).

Discussion

- Different elements of the error message have different effects;
- The graphic elements of the error messages (icon) significantly influence the emotional reaction of the user. In the case of the physiological measurements (heart rate), but also in the case of the objective self-assessment, we obtained results which show the fact that the absence of the graphic element leads to a significant decrease of these parameters. Moreover, this result was obtained in the context in which the emotional stability was maintained constant (because it was introduced as a covariate);
- The variations of the cognitive performance in the post-error task can be caused by the general cognitive performance (measured before the occurrence of the error message), but also by the elements of the error message. The presence or the absence of the word *error* in the error message significantly influenced the time needed for solving the next cognitive task. Also, significant variations of the cognitive performance were registered, depending on the combination of all the elements which form the graphic interface of the error message.

Conclusions, limitations and applicability of the thesis results

Conclusions on the effect of error messages

The present thesis approached the error messages effects and how these effects can be diminished. Starting from research findings on interruption effects in the human-computer interaction, we have built an experimental design that minimizes these effects. Thus, we believe that our findings represent minimal effects, which may have higher intensities in a context where the messages occur in different situations.

Using the experimental design, we concluded that error messages lead to decreased cognitive performance in post-error tasks (result obtained in Study 1 and replicated in Study 4 of this thesis) and to the anxiety state installation (result obtained in Study 2 and Study 5 of this thesis, which confirms the conclusions of Maricuţoiu, 2006).

In the present thesis, Study 1 and Study 4 showed that error messages have significant effects even in the case of a usual disruption which does not lead to the automation deficit. Furthermore, findings of Study 1 have showed that users spend more time analyzing the error message itself, whether they do or do not understand the semantic content of these messages. Based on these results, we can say that the error messages appearance in these work situations may lead to higher cognitive effects than other types of interruptions.

The present thesis has shown that the occurrence of an error message produces two types of cognitive effects: immediate effects and subsequent effects. The immediate effects refer to a decrease in the cognitive task performance, task following the error message. Subsequent effects refer to the user tendency to react of any other message from the computer, as it was an error one. Results obtained in Study 4 have shown that the error message occurrence may lead to an artificial decrease in cognitive performance for subsequent messages.

A first result which explains the error messages effects indicates that the user reaction to error messages is a result of surface processing. Thus users' ability to understand the English language does not correlate with variations in cognitive performance during post-experimental task (Study 1 of his thesis) or with state-anxiety variations (Maricuţoiu, 2006). In other words, users do not need to understand the semantic context of the error message to have reactions identified in this thesis.

Regarding interpersonal differences that affect the reaction to error messages, we can say that they are specific to each type of reaction.

The general cognitive performance is a constant predictor of cognitive performance in post-error tasks (results obtained in Study 1, Study 5 and Study 5). Also, the Study 4 results have showed that in the context of error messages occurrence, the cognitive performance in post-error tasks correlates with the degree of the implicit association between error messages and anxiety. This result, together with the rest of Study 4 results, indicates that cognitive performance in post-error tasks correlates with interpersonal cognitive differences and also with interpersonal differences in implicit associations. These findings confirm the theorized effects by the Cognitive interference computer anxiety model (Smith & Caputi, 2007). However, our studies focused on confirming these effects and not on testing the psychological mechanisms theorized of this model.

Regarding the emotional effects of the error messages, the results of Study 5 indicated Emotional stability as a main personality variable responsible for state anxiety variation. Although the meta-analysis presented in Study 3 of this thesis identified several interpersonal differences which explain the computer anxiety variation, these relations were not indentified in our studies. This difference can be explained by the fact that the anxiety caused by error messages is a specific manifestation form of computer anxiety, and its predictors can be slightly different from the predictors of computer anxiety.

In Study 5 we identified several elements of the error message interface, which are relevant for decreased cognitive and emotional effects. Although the message itself did not modify its meaning, the simple exclusion of the word "error" led to a decrease in the cognitive effects' intensity of the message. At the same time, the simple exclusion of the graphic element specific to error messages (the icon) led to a significant decrease of the user emotional reaction, both from physiological and subjective experiencing point of view.

By using the meta-analysis method, we could identify a series of computer anxiety effects. From the practical point of view, the most important are the *intention of use* and the *perceived ease of use*. These two variables are relevant for the prediction of interactions number (intention of use) and the quality of these interactions (perceived ease of use).

Limits of the studies presented in this thesis

Like every research approach, the studies presented in this thesis have a series of limitations. These limits can be classified in the following categories: limits regarding the experimental limits and limits regarding the type and number of subjects selected for the study.

The experimental method used in this thesis has a number of limitations, as it follows (Virga, 2004): artificial conditions in which these are taking place, participant perceptions and the experimenter expectations, convenience sampling.

From these limits, we consider the most important the artificial nature of the tasks. The desire to seek an experimental task that does not require computer knowledge, the subjects' task was to solve a series of abstract problems. This decision may limit our conclusions by the fact that users rarely encounter these types of tasks in their computer interaction.

To limit the chances that participants will anticipate the tested hypothesis, they were told that the purpose of the study is to test the possibility of applying cognitive tests on computer. Furthermore, the location where research was conducted did not allow interaction between subjects that have completed all the tasks and subjects that have not. To eliminate the effect of experimental learning we did not use the same participants for different studies. After completing each study we conducted a meeting in which we revealed the real purpose of the study and the experimental manipulations used. However, these precautions were limited by the fact that each study was conducted over several days and participants were students in the same year. Therefore it is difficult to assess to what extent the subjects did not communicate their colleagues what happened during the study. From the feed-back received during post-experimental sessions, the majority of participants declared that they did not guess the real purpose of the study, even if some declared that when they arrived at the research they knew which are its fazes and how long it takes.

A possible limit of the studies presented in this study is the participant selection, who were students while we were conducting our research. Our choice is justified by easy access to this population, but it may raise question-marks regarding to the possibility of findings extrapolation. However, to limit the effect of poor sampling, we used subject groups relatively balanced in terms of gender. Also, the overwhelming majority of participants stated that they own a personal computer.

A possible limit that needs to be analyzed in this section is the number of participants in each study. Even if at first sight the participants number may be perceived as too small, our findings have a statistical power sufficiently high (over .70) to consider that the number of subjects is sufficient not to commit a Type II error (not rejecting the null hypothesis when it should have been rejected).

Recommendations

Starting from these thesis conclusions, we can make recommendations on human resources management from the view of human-computer interaction and on redesigning the interface error message.

Our results points out that interpersonal difference between users predict computer anxiety. Based on this we can make more recommendations on human resources management from the view of human-computer interaction.

The meta-analysis results indicated an ideal employee profile, ideal for implementing new computer applications. This profile describes an emotionally-stable person and willing to experience new ideas (in our case, new technologies), who has a rich experience in computer working. Based on these results, we consider that selecting this type of person for implementing new technologies at the work place will lead to a decrease in the period of time needed for embracing and improving these technologies in the organizational processes.

The same profile of the anxious user allows us to select the employees who should benefit more from training programs in computer usage. In other words, we consider that emotionally-instable employees should benefit of more training programs to reach the same level of performance in using new technologies.

To redesign the interface error message there should be considered Shneiderman's(1986) recommendations regarding to the phrasing of the message and to the graphic elements of the message (which are important for user emotional reaction). In addition, we consider that a significant improvement of the user reactions could be attained simply by applying the principles of politeness in the human-computer interaction (Whitworth, 2005).

Adherence to these principles should also consider the user cognitive effects minimization, effects caused by error messages. Even if in the experiments presented in this thesis we minimized the variable influence that can affect the cognitive user performance, in real life, the error messages effects combine with interruptions effects identified in this study. A possible solution to avoid user interruption is offered by McFarlane's (1999,2002) research, that suggests three solutions:

- the user is interrupted, but can negotiate the moment he will handle the secondary task (negotiated solution);
- the user installs a software to monitor his activity and to allow interruptions only in the preset conditions by the user
- the user plans the moments of interruption (for example, from 15 to 15 minutes).

In conclusion, to optimize the ways of reporting errors in human-computer interaction, the following must be considered:

- redesigning the interface error message – waiver specific icon error messages;
- removal of the word "error" from the body text and from the descriptive error text message;
- identifying a technical solution that will not allow user interruption from his main task, only if the error is regarding strictly the program used at that moment;
- constructing error messages that take into account the user knowledge level, so that the user can identify viable behavioral options.

Refferences

Bailey B. P., Konstan J. A. & Carlis J. V. (2001). The effects of interruptions on task performance, annoyance, and anxiety in the user interface. In: M. Hirose (coord.), *Human-Computer Interaction – INTERACT 2001 Conference Proceedings* (pp.593-601). Amsterdam: IOS Press.

Bailey, B. P. & Konstan, J. A. (2006). On the need for attention-aware systems: Measuring effects of interruption on task performance, error rate, and affective state. *Computers in Human Behavior*, 22 (4), 685-708.

Ballas, J. A., Heitmeyer, C. L. & Pérez, M. A. (1992). Evaluating two aspects of direct manipulation in advanced cockpits. În: P. Bauersfeld, J. Bennett & G. Lynch (Eds.) *Proceedings of CHI'92 Conference on Human Factors in Computing Systems* (pp. 127-134), New York: ACM Press.

Bessiere, K., Ceaparu, I., Lazar, J., Robinson, J.P., & Shneiderman, B. (2004). Social and Psychological Influences on Computer User Frustration. În Bucy, E. and Newhagen, J. (eds.) *Media Access: Social and Psychological Dimensions of New Technology Use* (pp.169-192). Mahwah, NJ: Lawrence Erlbaum Associates.

Ceaparu, I., Lazar, J., Bessiere, K., Robinson, J. & Shneiderman, B. (2004). Determining Causes and Severity of End-User Frustration. *International Journal of Human-Computer Interaction*. 17(3), 333-356.

Eysenck, M.W., Derakshan, N., Santos R. & Calvo M.G. (2007). Anxiety and Cognitive Performance: Attentional Control Theory. *Emotion*, 7, 336-353.

Frese, M., Brodbeck, F., Heinbokel, T., Mooser, C., Schleiffenbaum, E. & Thiemann, P. (1991). Errors in Training Computer Skills: On the Positive Function of Errors. *Human-Computer Interaction*, 6, 77-93.

Greenwald, A.G., McGhee, D.E. & Schwartz, J.L. (1998). Measuring Individual Differences in Implicit Cognition: The Implicit Association Test. *Journal of Personality and Social Psychology*, 74, 1464-1480.

Greenwald, A.G., Poehlmann, T.A., Uhlmann, E.L. & Banaji, M.R. (2009). Understanding and Using the Implicit Association Test: III. Meta-analysis of Predictive Validity. *Journal of Personality and Social Psychology*, 97, 17-41.

Gschwendner, T., Hoffmann, W. & Schmitt, M. (2008). Convergent and Predictive Validity of Implicit and Explicit Anxiety Measures as a Function of Specificity Similarity and Content Similarity. *European Journal of Psychological Assessment*, 24, 254-262.

Heimbeck, D., Frese, M., Sonnentag, S. & Keith, N. (2003). Integrating errors into the training process: the function of error management instructions and the role of goal orientation. *Personnel Psychology*, 56, 333-361.

Heinssen, R.K., Glass, C.R. & Knight, L.A. (1987). Assessing Computer Anxiety: Development and Validation of the Computer Anxiety Rating Scale. *Computers in Human Behavior*, 3, 49-59.

Hofman, W., Gawronski, B., Gschwendner, T., Le, H. & Schmitt, M. (2005). A MetaAnalysis an the Correlation Between the Implicit Association Test and Explicit Self-Report Measures. *Personality and Social Psychology Bulletin*, 31, 1369-1385.

Hunter, J.E. & Schmidt, F.L. (2004). *Methods of Meta-Analysis. Correcting Error and Bias in Research Findings*, Thousand Oaks: Sage Publishers.

Iosif, Gh. & Marhan, A.M. (2005). Analiza şi managementul erorilor în interacţiunea om-calculator. În Iosif, Gh. & Marhan, A.M. (coord.) *Ergonomie cognitivă şi interacţiune om-calculator* (pp. 79-112), Bucureşti: Editura Matrix Rom.

Ipsos MORI (2009). *Employees Get 'It' Out Of Their Systems*. Material găsit online la http://www.ipsos-mori.com/content/employees-get-it-out-of-their-systems.ashx.

James, L.R., & Rentsch, J.R. (2004). J-U-S-T-I-F-Y to Explain the Reasons Why: A Conditional Reasoning Approach to Understand Motivated Behavior. In Schneider, B. and Smith, D.B (eds.). *Personality and Organizations* (pp. 223-250). New Jersey: Lawrence Erlbaum Associates, Inc.

Keith, N. (2005). *Self-Regulatory Processes In Error Management Training*, Inaugural-Dissertation zur Erlangung des Doktorgrades der Philosophie des Fachbereiches 06 psychologie und Sportwissenschaft der Justus-Liebig-Universität Gießen, Frankfurt.

Kirsh, D. (2000). A few Thoughts on Cognitive Overload, *Intellectica*, 30(1), 19-51.

Lazar, J., Jones, A., Hackley, M. & Shneiderman, B. (2006). Severity and Impact of Computer User Frustration: A Comparison of Student and Workplace Users**.** *Interacting with Computers,* 18(2), 187-207.

Maricuţoiu, L.P. (2006). Emotional response to computer error messages. *Psihologia Resurselor Umane*, 4(2), 46-53.

McFarlane, D. C. (1999) Coordinating the interruption of people in human-computer interaction. În Sasse, A., Johnson, C. (Eds.) *Proceedings of Human-Computer Interaction (INTERACT'99)*, Amsterdam: IOS Press, 295-303.

McFarlane, D. C. (2002) Comparison of four primary methods for coordinating the interruption of people in human-computer interaction. *Human-Computer Interaction*, 17 (1), 63-139.

Pitariu, H. (2003). The Influence of Personality Traits Upon Human-Computer Interaction. *Creier, Cognitie, Comportament / Cognition, Brain, Behavior*, 7, 277-294.

Rose, C.L., Bennett-Murphy, L., Byard, L., and Nikzad, L. (2002). The Role of the Big Five Personality Factors in Vigilance Performance and Workload. *European Journal of Personality*, 16, 185:200.

Roşca, Al. (1974). Afectivitatea. În Roşca, Al. (coord). *Psihologie generală*. Bucureşti: E.D.P., p. 400-418.

Sava, F. & Maricuţoiu, L.P. (2007). *PowerStaTim. Manualul utilizatorului*. Timişoara: Editura U.V.T.

Sava, F. (2004). *Analiza datelor în cercetarea psihologică. Metode statistice complementare*. Cluj Napoca: A.S.C.R.

Sava, F. (coord.)(2008). *Inventarul de personalitate DECAS. Manualul de utilizare.* Timişoara: Editura ArtPress.

Shneiderman, B. (1986). Designing Computer System Messages. *Communications of the ACM*, 25, 610-611.

Smith, B. & Caputi, P. (2007). Cognitive interference model of computer anxiety: Implications for computer-based assessment. *Computers in Human Behavior*, 23, 1481-1498.

Steffens, M.C. & Shulze-Konig, S. (2006). Predicting Spontaneous Big Five Behavior with Implicit Association Tests. *European Journal of Psychological Assessment*, 22(1), 13-20.

Tulbure, B.T. (2006). Dissimulating Anxiety in Front of The Implicit Association Test (IAT)*. Cognitie, Creier, Comportament / Cognition, Brain, Behavior*, 10, 559-579.

Vîrgă. D.M. (2004). *Psihologia experimentală de la teorie la practică*. Timişoara: Editura Mirton.

Watson, D. & Clark, L.A. (1992). On Traits and Temperament: General and Specific Factors of Emotional Experience and Their Relation to the Five Factor Model. *Journal of Personality*, 60(2), 441-476.

Whitworth, B. (2005). Polite Computing. *Behaviour & Information Technology*, 24, 353-363.

Zijlstra, F. R. H., Roe, R. A., Leonova, A. B. & Krediet, I. (1999). Temporal factors in mental work: Effects of interrupted activities. *Journal of Occupational and Organizational Psychology*, 72, 163-190.