

*LVA Computerized Global Stress Readings as a Function of Task
Induced Stress*

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1. Introduction

It is well established that the speech signal carries, in addition to linguistic content, information about the speaker's intentions and emotional state, and that listeners are capable of perceiving this information. The nature of speech production and the human vocal apparatus allow for the encoding of emotional and other nonlinguistic information in several ways. Previous studies have found correlations with speaker mood or style and with the fundamental frequency of phonation (F_0), its prosodic patterns, glottal source characteristics, as well as articulatory details^{1,2}.

The ability to detect stress in speech has many applications in voice communications such as increasing the robustness of speech recognition algorithms, military voice applications and law enforcement, acoustic measures of speech that permit automatic and unobtrusive on-line monitoring of the effects of stress and neurological impairment on an astronaut's ability to perform in extended deep-space missions³, industrial quality control^{4,5}, mental health applications, e.g., prediction of suicide⁶.

Scherer⁷, reviewing acoustic–phonetic findings on vocal affect, proposed a “sequence theory of emotional differentiation,” rooted in the physiology of speech production and taking into account the physiological effects of emotional status. According to Scherer's theory, stimuli are evaluated according to functionally defined criteria, such as “novelty,” “need,” “coping potential,” etc. The net result of the outcomes of all evaluation checks affects the nervous

¹ Murray, I. R., and Arnott, J. L. (1993). “Toward the simulation of emotion in synthetic speech: A review of the literature on human vocal emotion,” *J. Acoust. Soc. Am.* **93**, 1097–1108.

² Scherer, K. R. (1986) “Vocal affect expression: a review and a model for future research,” *Psychol. Bull.* **99**, 143–165.

³ Ongoing NSBRI-NASA research project. National Space Biomedical Research Institute. One Baylor Plaza, NA-425, Houston, TX 77030.

⁴ Wilson G.M. and Sasse M.A. (2000) “Listen to your heart rate: counting the cost of media quality”. In *Affective interactions to-wards a new generation of computer interfaces*. Edited by Paiva A.M. Springer, Berlin, DE. pp 9-20.

⁵ Wilson G.M. and Sasse M.A. (2000) “Do users always know what's good for them? Utilizing psychological responses to assess media quality”. In *People and Computers XIV - Usability or Else! Proceedings of HCI2000*. Edited by McDonald S., Waern Y. and Cockton G. Springer-Verlag, London, UK. pp 327-341.

⁶ Ozdas, A. Shiavi, R.G. Silverman, S.E. Silverman, M.K. Wilkes, D.M. (2004) “Investigation of vocal jitter and glottal flow spectrum as possible cues for depression and near-term suicidal risk”, *Biomedical Engineering, IEEE Transactions*, 51(9), 1530- 1540.

⁷ Scherer, K. R. (1986) “Vocal affect expression: a review and a model for future research,” *Psychol. Bull.* **99**, 143–165.

system and, in turn, the physiological consequences of the nervous system's response define the changes in voice characteristics that carry the emotional information. For example, unpleasant stimuli cause "faucal and pharyngeal constriction and tensing as well as shortening of the vocal tract," leading to stronger high-frequency resonances, a rise in the first formant, a fall in the second formant, narrow formant bandwidths, etc⁸.

Workload (or task-induced) stress and its vocal consequences have been investigated^{9, 10, 11}. Extreme levels of stress, in particular those of pilots during in-flight emergencies have also been examined, and several *F0*-related parameters have been identified as good correlates of stress level^{12, 13}. *F0*-related parameters, including short-term perturbations, long-term variability, and mean value, are among the measures often reported to correlate with elevated levels of speaker emotional stress, either task-induced or in real-life emergencies. However, in all of the aforementioned studies it was evident that the acoustic correlates of emotions in the human voice are subject to large individual differences (i.e., among speakers). However, there appears to be some regularity in the *perception* of the speakers' emotions based on acoustic parameters, such as *F0*. More recently, Scherer et al¹⁴ used speech degraded by filtering, splicing, or time-reversal and found that *F0* and voice quality "can convey affective information independently of the verbal context." They recommended distinguishing "linguistic" and "paralinguistic" *F0* features by manipulating acoustic stimuli in a systematic way.

⁸ Ibid.

⁹Ruiz, R., Legros, C., and Guell, A. (1990). "Voice analysis to predict the psychological or physical state of a speaker," *Aviat. Space Environ. Med.* **61**, 266–271.

¹⁰Hecker, M. H. L., Stevens, K. N., von Bismark, G., and Williams, C. E.(1968). "Manifestations of task-induced stress in the acoustic speech signal," *J. Acoust. Soc. Am.* **44**, 993–1001.

¹¹Streeter, L. A., Macdonald, N. H., Apple, W., Krauss, R. M., and Galotti, K. M. (1983). "Acoustic and perceptual indicators of emotional stress," *J. Acoust. Soc. Am.* **73**, 1354–1360.

¹² Williams, C. E., and Stevens, K. N. (1969). "On determining the emotional state of pilots during flight: an exploratory study," *Aerospace Med.* **40**, 1369–1372.

¹³Kuroda, I., Fujiwara, O., Okamura, N., and Utsuki, N. (1976). "Method for determining pilot stress through analysis of voice communication," *Aviat. Space Environ. Med.* **47**, 528–533.

¹⁴Scherer, K. R., Ladd, D. R., and Silverman, K. A. (1984). "Vocal cues to speaker affect: testing two models," *J. Acoust. Soc. Am.* **76**, 1346–1356.

Detecting stress in “real world” speech has been investigated in a number of studies^{15, 16, 17}.

Still, reliable detection of stress, even in clean speech, continues to be tricky. It requires that a speaker change his neutral speech production process in a consistent manner so that extracted features can detect and perhaps quantify the change. However, speakers are seldom consistent in how they convey stress or emotion in speech, and therefore reliable detection typically requires a multi-dimensional solution. In the past, a variety of approaches was used to detect stress in speech based on pitch structure, duration, intensity, glottal characteristics, and vocal tract spectral structure¹⁸. A number of multidimensional features were introduced, such as analyzing a sub-band structure with a number of novel nonlinear based features using properties of the Teager Energy Operator, also a new neural network algorithm which classifies speech under stress using the susas stress database by utilizing five spectral parameter representations (Mel, Δ -Mel, Δ^2 -Mel, Auto-Corr-Mel, and Cross-Corr-Mel cepstral), that are considered as potential stressed speech relayers¹⁹.

Layered Voice Analysis (LVA) is a recently developed voice analysis technology utilizing numerous mathematical algorithms to detect and measure a wide range of emotions, stress levels, and cognitive processes. Commercially, this technology is employed to verify truthfulness and identify deception. The LVA technology was developed by Nemesysco, Ltd.

(1)

This current study focuses on the Global Stress Level (JQ) parameter and how it is affected by task- induced stress.

¹⁵G.Zhou, J.H.L. Hansen, and J.F. Kaiser, (2001), “Nonlinear Feature Based Classification of Speech under Stress”, *IEEE Trans. Speech & Audio Process.*, **9** (3):201-216.

¹⁶ J. H. L. Hansen, B. D. Womack, (1996) “Feature Analysis and Neural Network Based Classification of Speech Under Stress” *IEEE Trans. Speech Audio Process.*, **4**(4):307-313.

¹⁷D. A. Cairns, J. H. L. Hansen, (1994) “Nonlinear Analysis and Detection of Speech Under Stressed Conditions”, *J. Acoust. Soc. Am.*, **96**(6):3392-3400,

¹⁸ *ibid.*

¹⁹ B. Womack, J.H.L. Hansen, (1994) "Speech Stress Classification and Feature Analysis using a Neural Network Classifier," *Journal of the Acoustical Society of America*, 96 (5) Pt. 2: 3351.

1.1 *Hypotheses*

- a) Global Stress vocal indicator (JQ) will increase as a function of increased stress during the completion of a timed exercise.
- b) Assumption that stress increases or decreases along with the subjects' announcement of having found a solution and subsequently drops sharply or increases immediately afterwards.

2. Methods

2.1 Participants

Thirty subjects (N=30) were volunteers randomly selected from the Netanya, Israel industrial park. The subjects ranged in age from 18 to 50. There were 15 males and 15 females.

Each subject was told that an experiment was being conducted and that it would require approximately 10 minutes of their time. They were also told that they would be paid 30 Israeli Shekels for their participation. All subjects signed a consent form (Appendix 1) which outlined the parameters of the experiment. It was also mentioned to the subjects that they could earn an additional sum of money, as a bonus, if they were successful in the task. No amount was mentioned.

2.2 Procedures

The experiment involved solving arithmetic problems (Appendix 2). There were three sets of problems to solve. Time limits were set for each set of problems and the times were 60 seconds, 45 seconds, and 30 seconds, respectively.

Voice stress parameters were measured by having the subjects verbalize their activities. All of the audio material was recorded using the Audacity²⁰ recording application. The subjects were instructed to solve “out loud” the various problems. All the subjects were also video recorded for possible further analysis by impartial judges as to their perceived levels of stress (this material has not been used in the present analysis).

Two recording audio formats were used simultaneously. The two formats were:

11,025 Hz 16 bit stereo and 8,000 Hz 16 bit stereo.

In order to facilitate this, two microphones were used.

²⁰<http://audacity.sourceforge.net/>

The subjects were additionally attached to a GSR which transmitted its frequencies to a PC in a 8,000 Hz 16 bit mono recording audio format.

2.3 Motivation Manipulation

The subjects were all told individually, that the task at hand was also presented to 9th graders and 80% were successful. It needs to be mentioned that the subjects were not expected to succeed given the time limitation.

The monetary bonus was also discussed and an additional 50 Shekels was offered if they were successful. The cash money was always on the table within sight of the subject. The subjects were not told that that they need to succeed in all three phases of the task in order to receive the bonus.

2.4 The Experiment

- a. All subjects were greeted and seated, then two neck microphones were attached to the garment collar and they were attached to the GSR.
- b. The details of the arithmetic problems were detailed and as well as the financial rewards and time limitations.
- c. The recording commenced and the subject was asked to state his subject number and name (the number being the one he received when he/she first signed the consent form). The recording of this initial bio-data was necessary for the establishment of the base line (calibration).

As soon as the calibration was completed, the subject was asked to solve three sets of arithmetic problems “out loud” without using pencil and paper. He was then asked to verbalize all his activities. He was also aware of the time limitations.

- d. The subject was recorded with two microphones connected to two computers using the Audacity recording application.
- e. The subject was also connected to a GSR unit.
- f. At the conclusion the subject was presented with the correct answers and told if he succeeded or not and paid accordingly.

2.5 Automated Analyses

All material was saved in wave files. For each subject, there were 3 wave files for the arithmetic section (11,025 Hz, 8,000 Hz, and the GSR). In total, there were 3 wave files for each of the 30 participants. The total number of wave files used for the experiment was 90. All the wave files were analyzed with a Stress Analyzer application developed by Nemesysco, Ltd., especially for this experiment. Mean JQ scores were calculated for each wave file. These scores were compared to the calibration scores received. The calibration scores were calculated from 6 verbal segments that were neutral or non-emotional in content. This calibration was done for each of the 90 wave files used.

2.6 Materials and Equipment

- a. Three (3) Audacity applications on three (3) separate PCs.

All Audacity applications are installed on PCs, with a minimum of Pentium III.

- b. One (1) GSR.

GSR Model GSR2 specification: Manufacturer: Thought Tech.LTD

INTL.PAT/DES.PEN

Cable length: Approx 2.5m

Plug Type: 1.5mm Stereo

- c. Two (2) neck mikes for optimal recording.

Neck Mikes Model: OV100M specification:

Manufacturer: OVANN

Multi-Functional Microphone & Extension Cable

Microphone Unit: 6x5mm Dielectret condenser

Microphone Directivity: Omni Direction

Sensitivity: $-58\text{dB} \pm 3\text{dB}$

Impedance: Low

Frequency Response: 30Hz to 16,000Hz

Standard Operation Voltage: 3V

Cable Length: Approx 2.5m

Plug Type: 3.5mm Stereo

d. One (1) video recorder.

PAL MV500 specification:

Manufacturer: Canon

Digital Video Camcorder

DC 7.4V

Cassettes: Panasonic DV cassettes

Model: Linear Plus

3. Findings

Significant findings were as follows for 25 out of the 30 subjects. Five (5) subjects were disqualified for technical reasons (sub standard recordings and volume control difficulties).

- a. Global Stress vocal indicator (JQ) was found to increase during the completion of a timed exercise.
- b. The average JQ value rose steadily from phase to phase of the test. See figure 1 below.

Figure 1: The average JQ value of 26.71 was zeroed for the sake of simplicity. An Analysis of Variance was generated with a 97% (α 0.03) level of significance.

Phase	Mean	Std	P
1	0.015	0.14	
2	0.559	0.36	
3	1.09	0.319	<0.03

- c. JQ levels varied dramatically shortly before, during, and slightly after the subject's announcement of the solutions (average JQ: 26.71 ± 12.78). This was in contrast to the relatively constant JQ levels during the computation process.
- d. Below are three (3) graphs depicting the three different phases. Each graph illustrates the JQ level for the computation process and the JQ level for the announcement of the solution (figures 2-4).

Figure 2: Phase 1

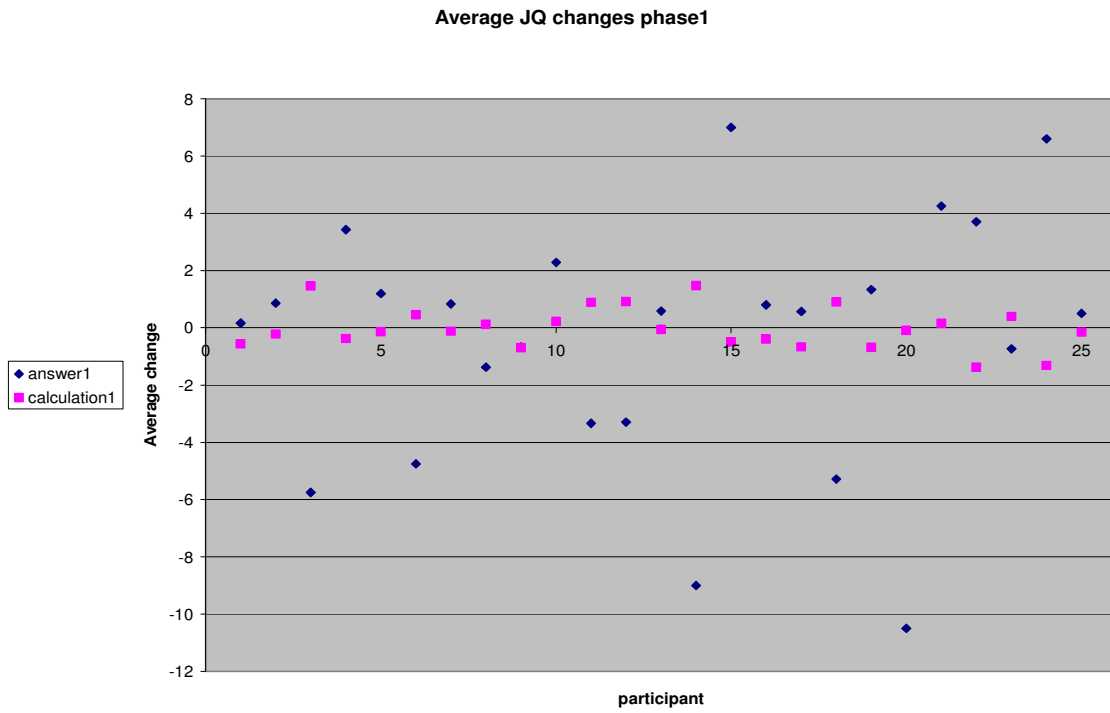


Figure 3: Phase 2

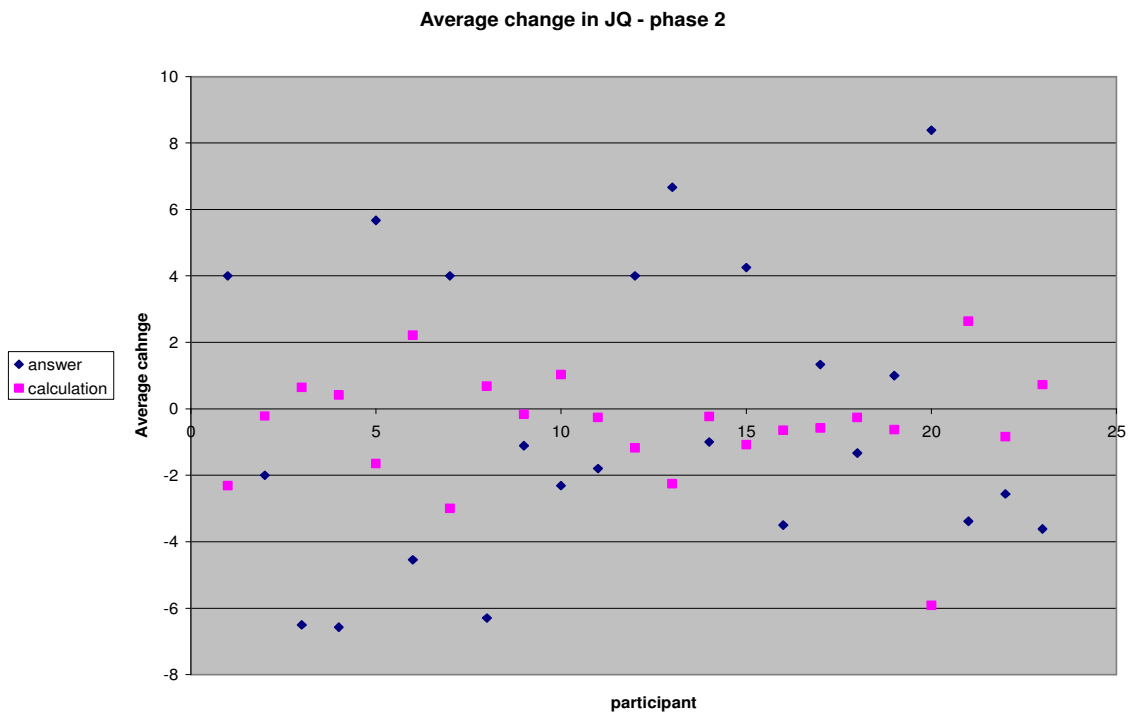
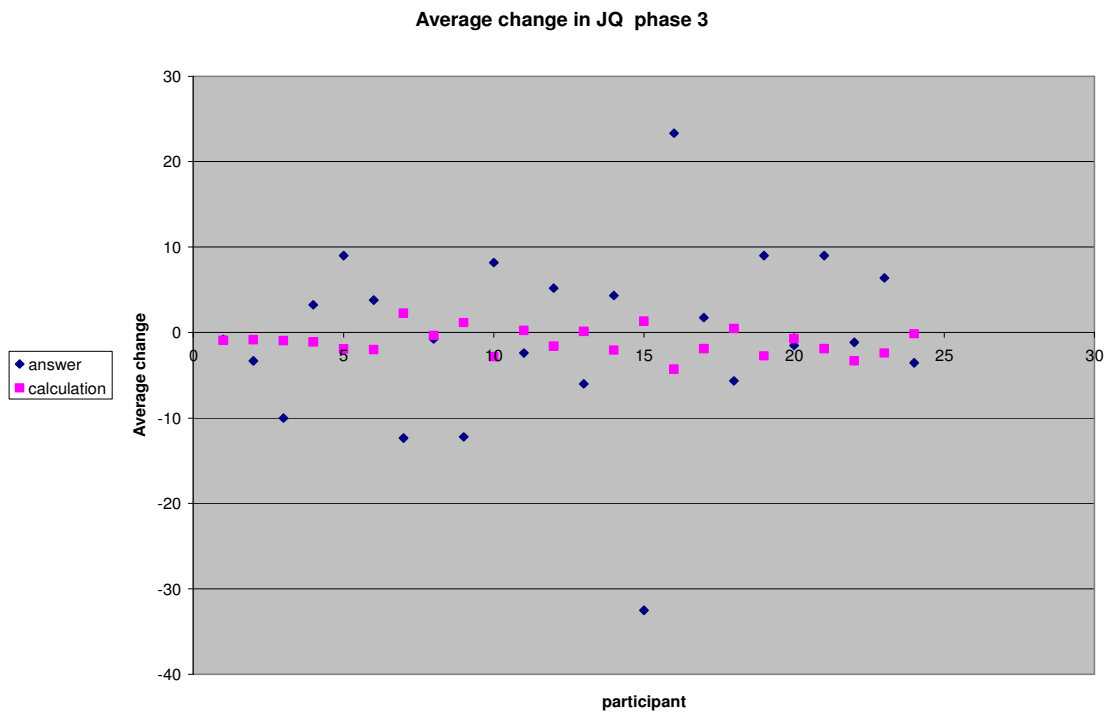


Figure 4: Phase 3



- e. As opposed to the hypothesis, the JQ levels did not increase after the announcement of the time left for completion of the task.
- f. While GSR measurements did show some correlation to the expected JQ levels (increases and decreases), no statistical significance could be established. It should be noted that each phase time line is less than the actual task time allotment due to the fact that the subject did not verbalize during the entire task. The first phase was recorded for 47 seconds out of a total of 60 seconds; the second phase was recorded for 37 seconds out of a total of 45 seconds and the third phase was recorded for 25 seconds out of a total of 30 seconds (see figures 5-7 below).

Figure 5: Phase 1

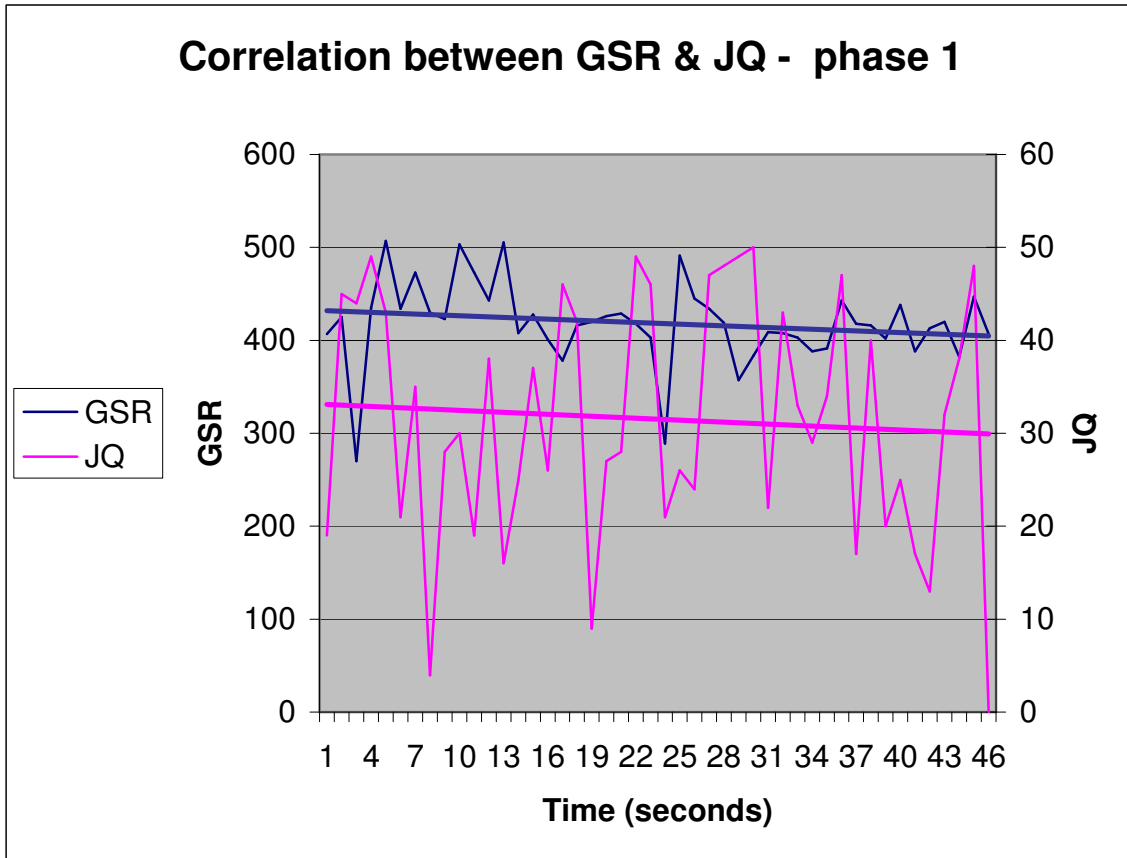


Figure 6: Phase 2

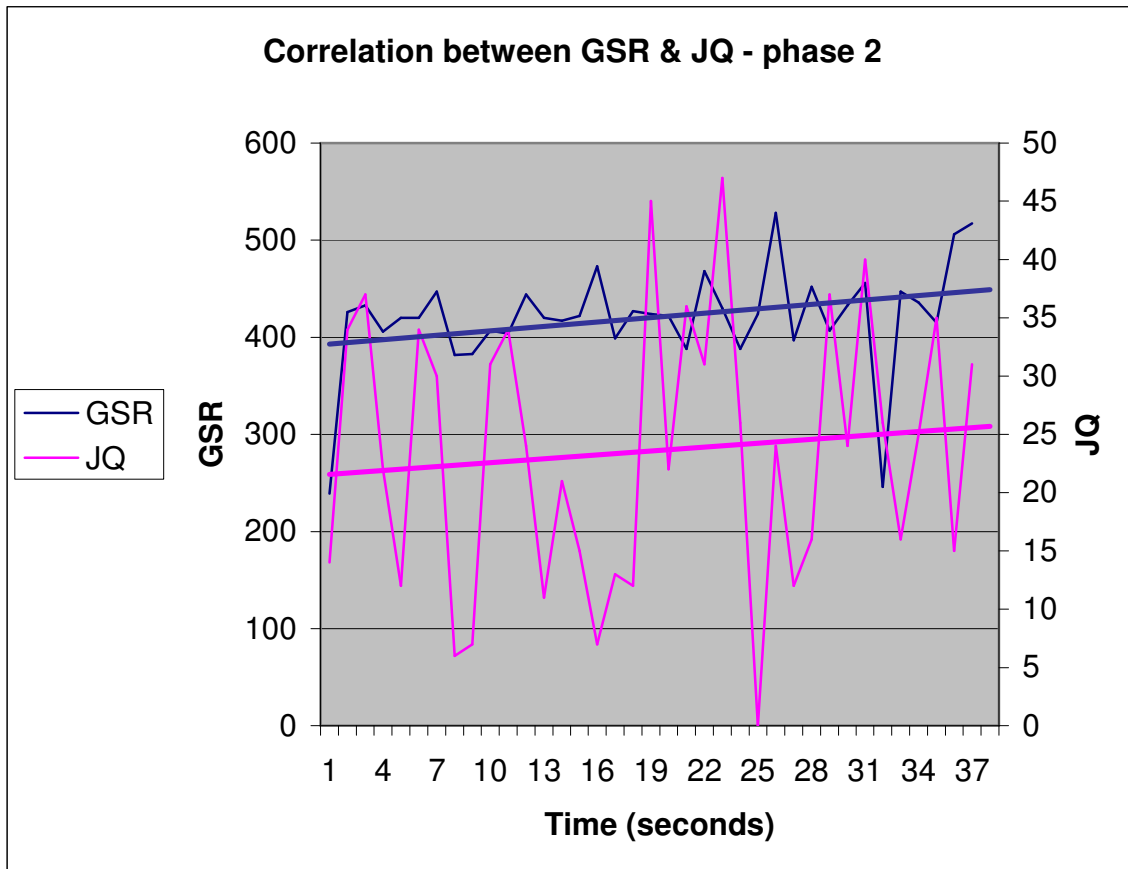
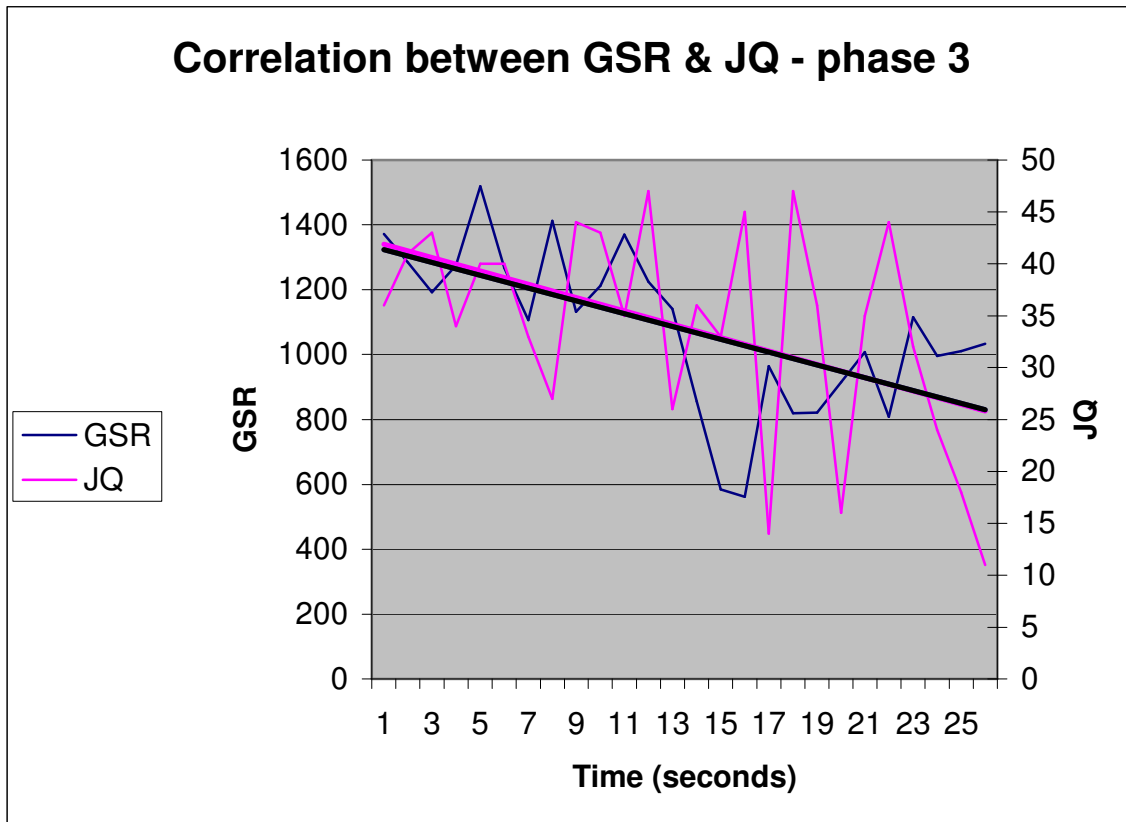


Figure 7: Phase 3



4. *Discussion and conclusions*

The analysis of the JQ parameter imbedded in the LVA voice analysis technology was hypothesized to measure Global Stress Level in voice samples. As the findings indicate, there is a significant (97%, α 0.03) correlation between the JQ parameter and the expected level of induced stress over time. The subjects were motivated by financial reward resulting in an increased level and in fact behaved as predicted. Other influencing factors for the increased stress level were being connected to a GSR monitor, two lapel microphones and the test environment of having to solve arithmetic problems “out loud” without the aid of paper and pencil.

The JQ level during the computation stage was significantly constant during all three test phases. This might be explained by an overriding of cognitive processes involved in the problem solving activity. This included concentration and the exerted mental effort invested in the task at hand. Once the solution had been verbalized, the subject was aware of the time restrictions which did not allow for corrections. Simple solutions showed JQ drop as opposed to more complex solutions which showed an increase in the JQ level.

There was perfect compatibility regarding the JQ analysis between the two audio formats used. When measuring stress levels using the 11,025 Hz. and the 8,000 Hz., no differences were found.

GSR findings in this test demonstrated some tendency for correlation with JQ levels though not reaching statistical significance. This positive correlation was seen in figures 5-7. It should be noted that there is a latency period of a second or two in the GSR readings as

opposed to the JQ levels. The lack of significance may be explained through a vast number of artifacts in GSR recording due to technical imperfections of the GSR device itself.

This study hints that the propriety voice generated JQ parameter might serve as an indicator of a stress level in a setting with controlled background noise. Identification of stress through analysis of human voice is a noninvasive and non-obtrusive method that can be easily applied in real world environments. Its additional benefit is that the analysis can be performed both on-line and off-line. Good identification of JQ component in a narrow-path 8,000 Hz signal indicates that relatively simple recording equipment may be used for off-line analysis. Further research investigating the correlation between JQ and well established biological stress hormones such as cortisol²¹, dehydroepiandrosterone (DHEA)²², prolactin as well as physical measures - heart rate, blood pressure, respiration rate, vital lung capacity, and forced vital capacity²³ – may be indicated.

²¹ Rosmond R, Dallman MF. 1998. Stress-related cortisol secretion in men: Relationships with abdominal obesity and endocrine, metabolic and hemodynamic abnormalities. *J Clin. Endo & Metabolism*, 83(6):1853-1859

²² Goodyer IM, Herbert J, Tamplin A., Altham PME. 2000. Recent life events, cortisol, dehydroepiandrosterone and the onset of major depression in high-risk adolescents. *Br. J. Psychiatry*, 177: 499-504

²³ Sudakov KV, Glazachev OS. 2001. Multiple physiological assessments of long term stress at work and in daily life: a system approach. In Theorell T (ed.): *Everyday Biological Stress Mechanisms*. Adv Psychosom Med. Basel, Karger, 22:61-79

5. Bibliography

B. Womack, J.H.L. Hansen, (1994) "Speech Stress Classification and Feature Analysis using a Neural Network Classifier," *Journal of the Acoustical Society of America*, **96** (5) Pt. 2: 3351.

D. A. Cairns, J. H. L. Hansen, (1994) "Nonlinear Analysis and Detection of Speech Under Stressed Conditions", *J. Acoust. Soc. Am.*, **96**(6):3392-3400.

G.Zhou, J.H.L. Hansen, and J.F. Kaiser, (2001), "Nonlinear Feature Based Classification of Speech under Stress", *IEEE Trans. Speech & Audio Process.*, 9 (3):201-216.

Goodyer IM, Herbert J, Tamplin A., Altham PME. 2000. Recent live events, cortisol, dehydroepiandrosterone and the onset of major depression in high-risk adolescents. *Br. J. Psychiatry*, 177: 499-504.

Hecker, M. H. L., Stevens, K. N., von Bismark, G., and Williams, C. E.(1968). "Manifestations of task-induced stress in the acoustic speech signal," *J. Acoust. Soc. Am.* **44**, 993–1001.

J. H. L. Hansen, B. D. Womack, (1996) "Feature Analysis and Neural Network Based Classification of Speech Under Stress" *IEEE Trans. Speech Audio Process.*, **4**(4):307-313.

Kuroda, I., Fujiwara, O., Okamura, N., and Utsuki, N. (1976). "Method for determining pilot stress through analysis of voice communication," *Aviat. Space Environ. Med.* **47**, 528–533.

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Ruiz, R., Legros, C., and Guell, A. (1990). "Voice analysis to predict the psychological or physical state of a speaker," *Aviat. Space Environ. Med.* **61**, 266–271.

Scherer, K. R., Ladd, D. R., and Silverman, K. A. (1984). "Vocal cues to speaker affect: testing two models," *J. Acoust. Soc. Am.* **76**, 1346–1356.

Scherer, K. R. (1986) "Vocal affect expression: a review and a model for future research," *Psychol. Bull.* **99**, 143–165.

Streeter, L. A., Macdonald, N. H., Apple, W., Krauss, R. M., and Galotti, K. M. (1983). "Acoustic and perceptual indicators of emotional stress," *J. Acoust. Soc. Am.* **73**, 1354–1360.

Sudakov KV, Glazachev OS. 2001. Multiple physiological assessments of long term stress at work and in daily life: a system approach. In Theorell T (ed.): *Everyday Biological Stress Mechanisms*. Adv Psychosom Med. Basel, Karger, 22:61-79.

Williams, C. E., and Stevens, K. N. (1969). "On determining the emotional state of pilots during flight: an exploratory study," *Aerospace Med.* **40**, 1369–1372.

Wilson G.M. and Sasse M.A. (2000) "Do users always know what's good for them? Utilising physiological responses to assess media quality". In *People and Computers XIV - Usability or Else! Proceedings of HCI2000*. Edited by McDonald S., Waern Y. and Cockton G. Springer-Verlag, London, UK. pp 327-341.

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3 Ongoing NSBRI-NASA research project. National Space Biomedical Research Institute. One Baylor Plaza, NA-425, Houston, TX 77030.

6. *Appendix*

7.1 *Consent Form*

7.2 *Arithmetic Problems* - Phase 1

7.3 *Arithmetic Problems* - Phase 2

7.4 *Arithmetic Problems* - Phase 3

Appendix 7.1

Experiment Participation consent Form

I, the undersigned, _____, hereby undertake towards Nemesysco Ltd. As follows:

1. On March 23rd, 2005, I will participate in an experiment.
2. The experiment is for the sole purpose of research and evaluation of the technology.
3. The experiment will take place on the company's premises, 8 Hamachshev st. Netanya, Israel.
4. I will be asked to solve a series of arithmetic problems. The series will have a time limitation.
5. I will be asked to verbalize my thoughts.
6. I will be recorded and Video taped.
7. I will be paid 30 NIS for my participation.
8. I will be paid an additional amount of money (Bonus) for a successful completion of the task.
9. I will not disclose any information regarding the experiment and will not share any additional information with others.

By: _____

Appendix 7.2

Arithmetic Worksheet – Format 1

1.	$\begin{array}{r} 224 \\ - 62 \\ \hline \end{array}$		11.	$\begin{array}{r} 866 \\ - 55 \\ \hline \end{array}$
2.	$\begin{array}{r} 630 \\ - 47 \\ \hline \end{array}$		12.	$\begin{array}{r} 182 \\ - 73 \\ \hline \end{array}$
3.	$\begin{array}{r} 507 \\ - 18 \\ \hline \end{array}$		13.	$\begin{array}{r} 956 \\ - 55 \\ \hline \end{array}$
4.	$\begin{array}{r} 324 \\ - 62 \\ \hline \end{array}$		14.	$\begin{array}{r} 702 \\ - 87 \\ \hline \end{array}$
5.	$\begin{array}{r} 183 \\ - 83 \\ \hline \end{array}$		15.	$\begin{array}{r} 755 \\ - 92 \\ \hline \end{array}$
6.	$\begin{array}{r} 573 \\ - 45 \\ \hline \end{array}$		16.	$\begin{array}{r} 500 \\ - 38 \\ \hline \end{array}$
7.	$\begin{array}{r} 856 \\ - 52 \\ \hline \end{array}$		17.	$\begin{array}{r} 397 \\ - 0 \\ \hline \end{array}$
8.	$\begin{array}{r} 410 \\ - 97 \\ \hline \end{array}$		18.	$\begin{array}{r} 573 \\ - 43 \\ \hline \end{array}$
9.	$\begin{array}{r} 993 \\ - 12 \\ \hline \end{array}$		19.	$\begin{array}{r} 905 \\ - 89 \\ \hline \end{array}$
10	$\begin{array}{r} 575 \\ - 88 \\ \hline \end{array}$		20.	$\begin{array}{r} 60 \\ - 8 \\ \hline \end{array}$

Subject ID: _____

Arithmetic Worksheet– Format 1- Answers (1 minute)

1.	$224 - 62 = \mathbf{162}$		11.	$866 - 55 = \mathbf{811}$
2.	$630 - 47 = \mathbf{583}$		12.	$182 - 73 = \mathbf{109}$
3.	$507 - 18 = \mathbf{489}$		13.	$956 - 55 = \mathbf{901}$
4.	$324 - 62 = \mathbf{262}$		14.	$702 - 87 = \mathbf{615}$
5.	$183 - 83 = \mathbf{100}$		15.	$755 - 92 = \mathbf{663}$
6.	$573 - 45 = \mathbf{528}$		16.	$500 - 38 = \mathbf{462}$
7.	$856 - 52 = \mathbf{804}$		17.	$397 - 0 = \mathbf{397}$
8.	$410 - 97 = \mathbf{313}$		18.	$573 - 43 = \mathbf{530}$
9.	$993 - 12 = \mathbf{981}$		19.	$905 - 89 = \mathbf{816}$
10.	$575 - 88 = \mathbf{487}$		20.	$60 - 8 = \mathbf{52}$

Appendix 7.3

Arithmetic Worksheet– Format 2

1.	$\begin{array}{r} 557 \\ + 998 \\ \hline \hline \end{array}$	6.	$\begin{array}{r} 843 \\ + 989 \\ \hline \hline \end{array}$
2.	$\begin{array}{r} 672 \\ + 717 \\ \hline \hline \end{array}$	7.	$\begin{array}{r} 337 \\ + 200 \\ \hline \hline \end{array}$
3.	$\begin{array}{r} 227 \\ + 855 \\ \hline \hline \end{array}$	8.	$\begin{array}{r} 901 \\ + 441 \\ \hline \hline \end{array}$
4.	$\begin{array}{r} 721 \\ + 812 \\ \hline \hline \end{array}$	9.	$\begin{array}{r} 714 \\ + 442 \\ \hline \hline \end{array}$
5.	$\begin{array}{r} 162 \\ + 283 \\ \hline \hline \end{array}$	10.	$\begin{array}{r} 929 \\ + 783 \\ \hline \hline \end{array}$

Subject ID: _____

Arithmetic Worksheet– Format 2 – Answers (45 seconds)

1.	$557 + 998 = \mathbf{1,555}$
2.	$672 + 717 = \mathbf{1,389}$
3.	$227 + 855 = \mathbf{1,082}$
4.	$721 + 812 = \mathbf{1,533}$
5.	$162 + 283 = \mathbf{445}$
6.	$843 + 989 = \mathbf{1,832}$
7.	$337 + 200 = \mathbf{537}$
8.	$901 + 441 = \mathbf{1,342}$
9.	$714 + 442 = \mathbf{1,156}$
10.	$929 + 783 = \mathbf{1,712}$

Appendix 7.4

Arithmetic Worksheet– Format 3

1). $4 \times 3 + 5 - 1$

2). $4 - 3 - 1 - 0 \times 7$

3). $4 + 5 + (6 + 2) + 3$

4). $(4 + 6) - 5 + 6$

5). $3 - (5 + 0) + 5 + 6$

6). $7 - 3 + (1 + 2) \times 6 + 0$

7). $(3 - 3) \times 4 + 0 + 3 \times 2$

8). $5 + 0 - (0 \times 7) + 3$

9). $7 \times 1 + (3 + 2)$

10). $(7 \times 0) + 3 \times 6$

Subject ID: _____

Arithmetic Worksheet– Format 3 - Answers (30 seconds)

$$4 \times 3 + 5 - 1 = \mathbf{16}$$

$$4 - 3 - 1 - 0 \times 7 = \mathbf{0}$$

$$4 + 5 + (6 + 2) + 3 = \mathbf{20}$$

$$(4 + 6) - 5 + 6 = \mathbf{11}$$

$$3 - (5 + 0) + 5 + 6 = \mathbf{9}$$

$$7 - 3 + (1 + 2) \times 6 + 0 = \mathbf{22}$$

$$(3 - 3) \times 4 + 0 + 3 \times 2 = \mathbf{6}$$

$$5 + 0 - (0 \times 7) + 3 = \mathbf{8}$$

$$7 \times 1 + (3 + 2) = \mathbf{12}$$

$$(7 \times 0) + 3 \times 6 = \mathbf{18}$$