172  Summaries

A stress marker in speech

E. L. van den Broek

This study examines the variability of the fundamental frequency of the voice (SD F0), as an indirect measure of physiological arousal, reflecting the intensity of emotions. The Subjective Unit of Distress (SUD) was applied to assess (a) the success of the experimental manipulation of stress, and (b) the validity of SD F0 as a stress measure. Twenty-five female participants suffering from a Panic Disorder with Agoraphobia participated. They relived an experience from the past and read a story aloud in both a stress triggering and a neutral condition. The increases in SUD, accompanied by decreases in SD F0, indicated that the experimental manipulation of stress was effective and validated the SD F0 as a stress marker. Hence, a new indirect physiological measure for the determination of stress was developed.

An analysis of chat conversations between elementary school pupils and their tutors

Mariken Bindels

This study focuses on the analyses of chat logs from chat conversations in which elementary school pupils ask help from their tutors. Starting from the initial observation that chat room communication and telephone conversation have certain obvious similarities I use results of conversation analysis studies into telephone conversations (Schegloff, Hopper, Houtkoop-Steenstra) to research the patterns of chat interaction. This provides me with the opportunity to have a detailed look into the sequence of chat conversations.

As regards the theoretical framework of the interaction analyses, it is an interesting finding that technical possibilities of the medium have an influence on the way in which the interaction by participants is structured. For instance, there is less need to go through an identification-frequency in chat communication than there is in telephone conversation. At the same time, the nature of the medium seems to influence the conversation subjects and the way in which the conversation participants interpret an interaction contribution. A pupil who is familiar with commercially available chat software, for instance Microsoft Messenger, has a tendency to bring up informal conversation instead of asking for help.
STRESS MARKER IN SPEECH

E.L. van den Broek, Nijmegen Institute for Cognition and Information (NICI), Catholic University of Nijmegen

1 Introduction

Already a century ago Helmholtz (1896) pointed out that one’s state of mind is mirrored by characteristics of one’s voice. However, a scientific method that reveals such a correlation still needs to be developed. The importance of such a method, relating behavioural measures, such as characteristics of the voice, to internal emotions or moods, is evident in a wide range of settings.

To assess personality or mood, psychologists use mood evaluation scales and psychiatric diagnoses (Knapp & VandeCreek, 1994). There are, however, multiple sources of potential error associated with these techniques, particularly in relation to the ability and willingness of persons to communicate about their actual state of mind (Sackheim & Gur, 1978).

This study, therefore, evaluates the potential of a more recent and different approach, namely that of using intonation patterns to assess the state of people’s minds or, more specifically, their experienced level of stress.

1.1 Stress defined

In order to develop an indirect physiological measure for stress, this term must be clearly defined. The wide use of the term stress has, however, resulted in a multitude of different definitions as well as diverse theoretical notions concerning the underlying processes (Scherer, 1981). In this study we define stress as an emotion episode that begins with the onset of the synchronization of various biological systems, following a particular stimulus evaluation pattern, resulting in an elevated muscle tone, and ends with an independent functioning of the biological systems. Consequently, we operationalize stress as an unusual environmental condition that causes physiological, emotional, behavioural, or cognitive changes in an individual or as the changes or...

1.2 Stress and fundamental frequency (F0)

According to several theories (e.g., Murray & Arnott, 1993), increased stress should result in an increase in F0, and in a decrease of F0 range and variability of F0 (see also Figure 1) due to a larger rigidity of the phonation mechanism under high muscular tension. This is illustrated in ‘fight or flight’ situation in which muscle tension is more constant. During recovery from stress, F0 should decrease again and F0’s range and variability should increase (e.g., Scherer, 1979). Most available evidence in literature supports F0 variation as a major carrier of prosodic information and as the main factor responsible for the expressiveness of speech (Scherer et al, 1991; see also Figure 1).

Figure 1: On the left the fundamental frequency of the voice (F0) of a person when being happy and on the right the F0 of the same person when being sad is plotted. Note the difference in variability of both F0s.

The variability of the F0 signal can be computed using the standard deviation (SD) of F0. The degree of subjective arousal experienced by a client can be measured by means of a clinical self-evaluation test, the Subjective Unit of Distress or SUD (Wolpe, 1958). This measure correlates highly with the experienced amount of anxiety and stress. It consists of a score form on which the participant can mark his or her level of experienced tension, on a scale of 1 to 10.

Given the results of previous research (e.g., Murray & Arnott, 1993) it is expected that the SD F0 will increase when the SUD decreases and vice versa. The extent to which this is true determines the validity of the SD F0 measure. Until now, no (automatic) method was developed for measuring a person’s arousal by voice. The results of previous research did not reveal solid unambiguous results nor did it provide well defined methods. In our attempt to setup a research providing a well...

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2 Method

2.1 Participants

Twenty-five Dutch clients who were in treatment at the Angstpoliklinik GGZN or waiting to be treated, participated in the experiment. All participants were adult females, younger than 65. Their average age was 38 (sd: 11.32) years.

The clients who participated in our study were all diagnosed as having a Panic Disorder with Agoraphobia (American Psychiatric Association, 1996). They suffer of recurrent and unexpected Panic Attacks. These are discrete periods of time in which there is the sudden onset of intense apprehension, fearfulness, or terror, often associated with feelings of impending doom. They suffered of Agoraphobia: anxiety about, or avoidance of, places or situations from which escape might be difficult (or embarrassing) or in which help may not be available in the event of having a Panic Attack or panic-like symptoms (American Psychiatric Association, 1996). This group of clients is, therefore, relatively sensitive to stress inducing factors and has a low threshold for becoming stressed.

All clients took part in the experiment on a voluntary basis, with consent for the audio-recording of the experimental session and the use of these recordings for scientific research. The specific goal of the experiments was revealed neither before nor after sessions. However, a more general aim of the study, i.e. the improvement of therapy evaluation techniques, was indicated in advance.

2.2 Apparatus

The recording equipment consisted of a personal computer, a microphone pre-amplifier, and a microphone. The recordings were saved on the hard-disk of the personal computer. The recording was done with a sample rate of 44.1 kHz, mono-channel, with a resolution of 16-bit. We have chosen this sample rate because it is a multiple of the sample rate necessary for analysis and because this provided the possibility to backup the data on cd, without a sample rate conversion.

Noise and pauses were removed from the recordings, that were divided in files of approximately one minute of speech. Next, the extraction of fundamental frequency (F0 or pitch) was done by way of a Fast Fourier Transform, followed by the gathering of statistical data (mean, median, quantiles of 10% and 90%). A detailed description of the Fast Fourier Transform, applied filters and specifications of the recordings as well as their analysis can be found in Van den Broek (2001).
2.3 Design

The experiment started with a practice session in continuous speaking for three minutes. During and after this session the participants received continuous feedback to speak more fluently. This feedback also allowed the participants to become more comfortable with the experimental setting.

The design of the experiment as a whole comprised seven conditions, including the practice session. The main part of the experiment consisted of two blocks, of two conditions each, preceded and followed by a baseline condition. The baselines, a pre-test and a post-test condition, were used to measure changes in participants' behaviour during the intervening time of the main experiment.

In the two blocks of the experiment, we manipulated the degree of anxiety, and with that stress, experienced by the participants by means of a more ecologically valid and a more experimentally controlled method. In one block participants spoke about recent experiences, in the other they read printed stories. The recent experience described in one condition concerned their last Panic Attack; in the other condition it concerned a pleasant experience. One of the printed stories to be read aloud, was a scary one, while the other was neutral.

<table>
<thead>
<tr>
<th>Practice condition</th>
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<th>Main experiment</th>
<th>Baseline condition (post-test)</th>
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<td></td>
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<td>Condition Block 1 (conditions c1_1 ... c2_3)</td>
<td>Condition Block 2 (conditions c3_1 ... c4_3)</td>
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Experienced stress was measured by the Subjective Unit of Distress (SUD) and by the F0. For each minute clients were asked to grade the degree of experienced distress on a scale from 1 to 10 (the SUD). For this purpose, the clients received a new score-form before the start of every condition. The recordings of the utterances were segmented afterward in periods of one minute each, so that the SD F0 of the utterances could be determined and compared with the SUD graded for the same periods of time.

To control for effects due to the order of the conditions, the two condition blocks, as well as the two conditions within them, were counterbalanced across clients.

2.4 Procedure

Before the start of the experiment, the therapist orally gave the clients the necessary general instructions followed later on by more specific ones. Next, the plan of the experiment was described. The experiment started with some questions, concerning the physical well-being of the participant, followed by the practice session. Based on a quick evaluation of this practice session, a few suggestions to facilitate continuous speaking were provided. After this, the start of the main experiment was announced and...
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Experienced stress was measured by the Subjective Unit of Distress (SUD) and by the FO. For each minute clients were asked to grade the degree of experienced distress on a scale from 1 to 10 (the SUD). For this purpose, the clients received a new score-form before the start of every condition. The recordings of the utterances were segmented afterward in periods of one minute each, so that the SD FO of the utterances could be determined and compared with the SUD graded for the same periods of time.

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The fictive stories used in the main experiment, that had to be read aloud by the participants, were controlled both on both syntactic structure and on the complexity of the line of story. The words used were also controlled on the frequency of appearance in everyday use and on complexity of pronunciation. The stories were furthermore judged by therapists and psychologists on respectively their characteristics as anxiety triggering (by use of anxiety triggering words) and their characteristic as neutral. The two example sentences presented below are taken from the fictive stories used in this research. For the full stories we refer to Van den Broek (2001).

Example 1: An anxiety triggering sentence.
"Aan hoeveel oorlog en geweld er is."
Example 2: A neutral sentence.
"Aan hoeveel dingen ik ermee kan doen."
In Example 1 the words 'oorlog' and 'geweld' were used to trigger anxiety.

3 Results

We have applied two series of analysis. In the first analysis, SUD and SD FO were analysed separately for each of the conditions and compared afterwards. In the second, the behaviour of both measures was analysed across time, followed by a comparison of both measures.

3.1 First series of analysis: the conditions

First, we analysed the SUD data by means of five Repeated Measures Multivariate ANOVAs. As within participant factors we included: Block, the core experiment consisted of a reliving and of a story-telling block; Condition, each block consisted of two conditions, one in which stress was triggered and one neutral condition; and Time, of each core condition the first, the second, and the third minute were analysed separately.

A strong difference in SUD was found between the two blocks (F(1,23)=8.176, p<.01). A main effect of Condition in the same analysis indicated that our experimental manipulation of stress in the experiment was effective (F(3,21)=14.908, p<.001). On average, the SUD in the stress triggering conditions (3.76) was higher than in the neutral conditions (2.83). The factor Time also showed a significant main effect (F(2,22)=6.735, p<.005). The SUD generally increased over time in the stress triggering conditions, while it decreased in the neutral conditions.

Second, the SD FO data was analysed by means of a Repeated Measures Multivariate ANOVA, including Block, Condition, and Time as within participant factors. The SD FO was determined for the first, second, and third minute of each condition. The Block*Condition interaction (F(1,23)=13.085, p<.005), the Block*Time interaction (F(2,46)=4.744, p<.05) and the Condition*Time interaction (F(2,46)=3.597, p<.05) were all significant.
interaction ($F(2,22)=6.337$, $p<.005$), and the Condition*Time interaction SD F0 ($F(2,22)=2.886$, $p<.05$) indicated the opposite behaviour in both blocks for each of the conditions. The average SD F0 of the reliving conditions was higher than that of the story-telling conditions. Next to this, the SD F0 decreased sharply in the reliving conditions and increased in both the story-telling conditions.

Third, for each of the blocks separately, a Repeated Measures Multivariate ANOVA was conducted on the SUD and SD F0 data, using Condition and Time as within-participant factors. In the story-telling block, the average SD F0 of the stress triggering condition (36.93) was lower than that of the neutral condition (39.78) ($F(1,20)=13.229$, $p<.005$), while no difference was found between the two conditions in the reliving block.

Fourth, in the first series of analyses, we furthermore compared the analyses of both measures to determine their relation. We found that the interaction of the factors Block and Condition both affected the SUD ($F(1,23)=5.850$, $p<.05$) and the SD F0 ($F(1,23)=13.085$, $p<.005$). The same held for the interaction of Condition and Time (SUD: $F(2,22)=13.130$, $p<.001$; SD F0: $F(2,22)=2.886$, $p<.05$).

Last, an additional Repeated Measures Multivariate ANOVA, both including Condition and Time as within-participant factors, was performed for both blocks. The average values of both measures in the story-telling block showed an opposite relation between both conditions ($r=-0.82$, $p<.05$, $n=6$). The SUD was lower in the neutral condition (2.70) than in the stress triggering condition (3.52) ($F(1,23)=4.417$, $p<.05$), whereas the SD F0 was higher in the neutral condition (39.78) than in the stress triggering condition (36.93) ($F(1,23)=13.229$, $p<.005$). These findings were, however, not clearly present in the reliving block.

3.2 The second series of analysis: the experiment over time

A second series of analyses was conducted to detect effects caused by the different orders of conditions that were not visible in the previous analyses. For both condition blocks, an additional Repeated Measures Multivariate ANOVA was conducted on both SUD and SD F0 data, including Condition and Time as within-participant factors and as covariate the factor Order of Conditions. Order was no factor of influence for the SUD. For the SD F0, however, a very strong interaction effect between Condition and Order of conditions was detected ($F(21,32)=4.021$, $p<.001$). The decreasing trend of SD F0 during the conditions became less clear while the experiment progressed. In a subsequent analysis we therefore analysed the four conditions using their order of appearance for each participant as a criterion. With this the difference in experimental manipulation between both the blocks and the conditions within them was more or less ignored. So, the focus of interest lies solely on the comparison of both measures during and between the conditions over time.

We will first discuss the pattern of behaviour of the SUD and SD F0 over time separately for each measure and then compare them. Let us start with the SUD. As can be seen in Figure 2, a sharp increase in SUD was present during all four core conditions ($F(1,23)=9.953$, $p<.001$). In three of the four core conditions, the SD F0 showed a sharp and almost linear decrease ($F(1,23)=5.618$, $p<.01$). In addition, a clear and stable
interaction (F(2,22)=6.337, p<.005), and the Condition*Time interaction SD F0 (F(2,22)=2.886, p<.05) indicated the opposite behaviour in both blocks for each of the conditions. The average SD F0 of the reliving conditions was higher than that of the story-telling conditions. Next to this, the SD F0 decreased sharply in the reliving conditions and increased in both the story-telling conditions.

Third, for each of the blocks separately, a Repeated Measures Multivariate ANOVA was conducted on the SUD and SD F0 data, using Condition and Time as within participant factors. In the story-telling block, the average SD F0 of the stress triggering condition (36.93) was lower than that of the neutral condition (39.78) (F(1,120)=13.229, p<.005), while no difference was found between the two conditions in the reliving block.

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**Figure 2:** Average SUD and SD F0 over time for each minute, in the core conditions of the experiment

A significant correlation of -0.59 (p<.05, n=12) was found between SD F0 and SUD over all four conditions. An even stronger correlation arose between SUD and SD F0 of -0.88 (p<.05, n=6) for the first block, while a correlation of -0.69 (p<.07, n=6) was found for the second block (Figure 2).

4 Discussion

After this introduction we will discuss the results of the story-telling condition-block, the results of the reliving condition-block, and their relation. Within each of these sections SUD, SD F0 as well as their relation are discussed, ending with final conclusions and some remarks. In a final section, the general conclusions and some remarks are made.

4.1 The manipulation of stress

We conclude that manipulation of stress in the story-telling experiment was effective: The SUD became larger with an increase of stress and smaller with a decrease of the experimentally induced stress. The degree of experienced stress (SUD) increased in the
stress provoking condition, whereas it decreased in the neutral condition (see also Figure 2). Stronger induced effects on the SUD were present in the reliving block than in the story-telling block. This latter finding is in accordance with previous findings (e.g., Scherer, 1979; 1981; Streeter et al, 1983) that emotions experienced in more realistic conditions are much stronger than those in experimental conditions.

4.2 The relation between SUD and SD F0

The comparison of both SUD and SD F0 revealed the expected behaviour in the story-telling block. In the reliving block, however, no difference was found in the SD F0 between the stress triggering condition and the neutral condition, which contradicted the data of the SUD. The sharp decline of SD F0 in both conditions of the reliving block did not seem to confirm our expectations. However, the difference in measured tension by the SD F0 and the SUD in the reliving block can be explained by referring to the intensity of the emotions triggered during the two conditions. In both stress triggering conditions of both blocks the increasing degree of tension can be ascribed to the stress triggered by anxiety; in the neutral reliving condition, on the other hand, an intense reliving of positive emotions was present that also resulted in a high degree of (positive) tension. According to the SD F0, only in the neutral story-telling condition a relief in tension was present. So, we may conclude that the SD F0 did measure the amount of tension, but does not discriminate tension as a consequence of pleasant or non-pleasant emotions. The SUD on the other hand, does react on differences in the source of tension.

4.3 Emotional versus emotive communication

These findings are in line with the existing theoretical distinction of emotional and emotive communication (Marty, 1908). Emotional communication is a type of spontaneous, unintentional leakage or bursting out of emotion in speech, while emotive communication has no automatic or necessary relation to ‘real’ inner affective states, but is a strategic signalling of affective information in speaking. (see also Caffi & Janney, 1994). It is plausible that in the reliving conditions relatively more emotional communication took place, than in the story-telling conditions that were based more on features of emotive communication. It may be the difference between emotional and emotive expressions that is reflected in the difference in variability of the F0.

4.4 SD F0 as indicator for stress

An additional post-hoc test showed that the order of presentation of the conditions had an effect on the SD F0. We, therefore, checked how the degree of tension experienced by the participants varied across the session not just across blocks but from minute to minute, using both the SUD and SD F0. A strong effect of time on the observed degree of stress, as indicated by both measures, was found. Whereas the degree of stress measured by SUD and SD F0 slowly declined across the experiment as a whole, the stress experienced by the participants, according to both measures, increased time and again during the stress triggering condition. SUD and SD F0 both changed in the reliving block, and in the neutral condition in the reliving block (indirect emotion).

4.5 SD F0 as indicator for stress

Despite experiential and emotive communication, emotion is placed on the spectrum of SD F0 in which emotions triggered the degree of tension.

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5 Conclusions

The incongruent findings might be explained by the use of the two measures in the study, which were less powerful in determining...
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The comparison of both SUD and SD FO revealed the expected behaviour in the story-telling block. In the reliving block, however, no difference was found in the SD FO between the stress triggering condition and the neutral condition, which contradicted the data of the SUD. The sharp decline of SD FO in both conditions of the reliving block did not seem to confirm our expectations. However, the difference in measured tension by the SD FO and the SUD in the reliving block can be explained by referring to the intensity of the emotions triggered during the two conditions. In both stress triggering conditions of both blocks the increasing degree of tension can be ascribed to the stress triggered by anxiety; in the neutral reliving condition, on the other hand, an intense reliving of positive emotions was present that also resulted in a high degree of (positive) tension. According to the SD FO, only in the neutral story-telling condition a relief in tension was present. So, we may conclude that the SD FO did measure the amount of tension, but does not discriminate tension as a consequence of pleasant or non-pleasant emotions. The SUD on the other hand, does react on differences in the source of tension.

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4.5 Cognitive versus emotional stress

Despite the successful exploitation of the SD FO as an objective measure of experienced distress, the current study is limited because it cannot distinguish cognitive and emotional stress. This problem is also known as the problem of emotion specificity. Emotion specificity distinguishes cognitive stress, the information processing load placed on the human operator while performing a particular task (Lively et al., 1993), and emotional stress, the psychological and physiological tension due to emotions triggered before or during the task. We aimed to trigger stress by manipulating the degree of stress experienced by the participants.

4.6 The strength of SUD and SD FO combined

Given the problem of emotion specificity, it is hard to make a distinction between cognitive and emotional stress, solely on the basis of SD FO. The main strength of the SD FO lies not in making the distinction between emotional states, but in measuring the intensity of emotions. This confirmed previous findings that the variability of FO mirrors the amount of stress present (Banse & Scherer, 1996; Murray & Arnott, 1993). The main strength of the SUD (Subjective Unit of Distress), on the other hand, was that it makes the distinction between levels of experienced (dis)comfort with the emotions. In combination, the two measures can, therefore, make a complete and reliable diagnosis of both the coping style and the emotional well-being of persons.

5 Conclusions

The incorporation of direct physiological measures (EMG, EEG, etc.) is not easy from practical, technical, and financial points of view and clients feel uncomfortable when they are connected to all kinds of machinery. Audio-recordings and their automated analysis, on the other hand, do not lead to discomfort and are suitable in a wide range of settings. They require only a small endeavour of the analyst and provide her a powerful additional diagnostic tool. Other potential benefits of FO analyses, lie in the determination of the coping style of clients and in the determination of the severity of
clinical disorders. Probably the SD F0 can make a differentiation between emotive and emotional communication.

Promising fields of application for a stress marker such as this, are the enhancement of speech recognition and the facilitation of better human-computer interaction, by way of voice. Human communication abilities take into account the emotional state of the partner in conversation. Humans are able to automatically adapt their communication style, which can be useful in speech recognition.

So, the stress marker presented in this study is objective, easily usable, and enormously powerful in determining the emotional state of a person and can be used in a wide range of settings: therapy evaluation, speech recognition, and human-computer interaction.

Bibliography


A stress marker in speech


