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BIOENERGETICS OF SPEECH TIMBRE IN PECEPTION OF DIDACTIC INFORMATION

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The article deals with the role of speech timbre in perception of didactic information in English lecture discourse. It is an attempt to aproach the mechanisms of percetion through human voice timbre from a bioenergetic perspective which is a rather novel and interdisciplinary theme. The energetic perspective in language studies becomes particularly relevant and even urgent in the digital age, when technologies of synthesized speech reproduce the structural and acoustic parameters of communication but lack the authentic bioenergetic quality of the natural human voice.

The study explores the correlation between emotions and speech perception through the timbral characteristics of the lecturer's voice, viewing speech timbre not merely as an acoustic attribute but as a complex bioenergetic and perceptual category. The paper introduces the term "bioenergetics of speech timbre" which is not a standard fixed term in linguistics or phonetics. Thus, the bioenergetics of speech timbre is defined as the study of how the human body mobilizes, transforms, and distributes physiological energy to produce the perceptual quality of voice. It bridges acoustics, physiology, psychology, and communication. The proposed comparative overview, structured as a summary table integrating the main dimensions and parameters of speech timbre classification identified in phonetic and linguistic research, enhances the theoretical relevance of this study.

The assessment of timbral perception in the context of didactic communication was based on the major-minor mode dichotomy. During the course of a complex perceptual experiment with elements of psycholinguistic analysis the emotional dychotomy was subjectively rated using the scale major/positive timbre and minor/negative timbre. The outcomes of the auditors' evaluations within the framework of the emotional dichotomy confirmed the initial hypothesis that a positive, major timbre plays a significant role in the perception of oral didactic information. Thus, this experimental study confirmed the strong correlation between positive (major) emotions and the quality of perception of didactic information.

Key words: *prosodic organization, lecture discourse, voice quality, energetic approach to language, didactic interaction, positive/negative emotions, hedonysm, major-minor dychotomy.*

БІОЕНЕРГЕТИКА ТЕМБРУ МОВЛЕННЯ У СПРИЙНЯТТІ ДИДАКТИЧНОЇ ІНФОРМАЦІЇ

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У статті розглядається роль тембру мовлення у сприйнятті дидактичної інформації в англійському лекційному дискурсі. Це спроба підійти до механізмів сприйняття через тембр людського голосу з біоенергетичної точки зору, що є досить новою та міждисциплінарною темою. Енергетична перспектива в мовних дослідженнях стає особливо актуальною та навіть невідкладною в цифрову епоху, коли технології синтезованого мовлення відтворюють структурні та акустичні параметри комунікації, але не мають автентичної біоенергетичної якості природного людського голосу.

Дослідження досліджує кореляцію між емоціями та сприйняттям мовлення через тембральні характеристики голосу лектора, розглядаючи тембр мовлення не лише як акустичну властивість, а й як складну біоенергетичну та перцептивну категорію. У статті вводиться термін «біоенергетика тембру мовлення», який не є стандартним фіксованим терміном у лінгвістиці чи фонетиці. Таким чином, біоенергетика тембру мовлення визначається як вивчення того, як людський організм мобілізує, трансформує та розподіляє фізіологічну енергію для створення перцептивної якості голосу. Вона поєднує акустику, фізіологію, психологію та комунікацію. Запропонований порівняльний огляд подано у вигляді зведеної таблиці, яка систематизує основні виміри та параметри класифікації тембру мовлення, описані у фонетичних і лінгвістичних працях. Така структурна подача забезпечує теоретичну вагомість дослідження.

Оцінка сприйняття тембру в контексті дидактичної комунікації базувалася на дихотомії мажор-мінорний лад. Під час складного перцептивного експерименту з елементами психолінгвістичного аналізу емоційна дихотомія суб'єктивно оцінювалася за шкалою мажорний/позитивний тембр та мінорний/негативний тембр. Результати оцінювання аудиторами в рамках емоційної дихотомії підтвердили початкову гіпотезу про те, що позитивний, мажорний тембр відіграє значну роль у сприйнятті усної дидактичної інформації. Таким чином, це експериментальне дослідження підтвердило сильну кореляцію між позитивними (мажорними) емоціями та якістю сприйняття дидактичної інформації.

Ключові слова: *просодична організація, лекційний дискурс, якість голосу, енергетичний підхід до мови, дидактична взаємодія, позитивні/негативні емоції, гедонізм, дихотомія мажор-мінор.*

Introduction. Didactic information conveyed in a lecture is predominantly perceived through the auditory channel (Rose 1998: 5), therefore, studies of the prosodic organization of lecture discourse from a cognitive standpoint are central to the processes of describing the cognitive mechanism of perception. Perception is one of the fundamental concepts of psychology in general and cognitive psychology and cognitive science in particular (Goldstein, 2019; Thagard, 2005). Representatives of the perceptually oriented branch of cognitive linguistics reveal the relationship between the organization of language and perception, consider them as completely or partially identical phenomena. "Perception of speech is the process of isolating the content that lies behind the external form of speech acts" (Pisoni & Remez, 2005). It is obvious that when relying on auditory perception of didactic information, the first stage will be the perception of the acoustic signal, which serves as the basis for further decoding and cognitive processing of other linguistic levels.

From a bioenergetic perspective, the acoustic parameters embody the dynamic energy of speech, which mediates the emotional and cognitive impact on the transmittion of oral information. Speech rhythm, prosody, intensity and timbre may be interpreted as surface realizations of underlying energetic processes. The transformation of affective energy into acoustic form by means of rhythm, tempo, and timbre represents a key concern of contemporary phonetic studies in this field.

Based on the textbook statement of W. von Humboldt that "language is not a product of activity *(ergon)*, but activity *(energia)*", researchers are increasingly considering language as an energy system (Мініч, 2012; Бацевич, 2008; Smith, 2016; Kalyta, 2016), interpreting the energy phenomenon of language as a material object that only copies the energy structures that form it. Phoneticians (Taranenko & Schaefer, 2018) emphasize on the study of the prosodic features influenced by structural, emotional and pragmatic factors, which are defined within the framework of a new energetic approach to the research of phonetic phenomena, by introducing energy-grams in the description. Certain scholars have advanced non-traditional interdisciplinary approaches to lingual-and-energetic research. In their work, the authors propose an analytical method grounded in the concept of a psycho-energygram, which models the self-development of cognitive processes underlying speech and thought within the individual's spiritual sphere (Kalyta & Klymenyuk, 2021: 51).

Soter & Connors (2017) underscore the relevance of such studies in pedagogacal communication in the educational process. The researchers maintain that "language as a field of energy matters in language pedagogy, in classrooms at all levels, as well as within teacher education and teacher professional development" (Soter & Connors, 2017: 27). The researchers define language as a field of energy in the following way: "as language operating as a "region" in which a force operates to bring about some influence resulting in an effect or having an impact on one's own behaviors, on the behaviors of others, as well as having the capacity to influence emotions, and/or the course of events" (Soter & Connors, 2017: 27).

The present study examines the correlation of bioenergetics of speech timbre, emotions and the perception of didactic informanion in lecture discourse. We believe that an energetic perspective on language has become particularly significant and even imperative in the digital age. Contemporary communication technologies, including artificial intelligence and synthesized speech systems, are capable of reproducing linguistic form and informational content with remarkable precision, however, they inherently lack the *bioenergetic dimension* that characterizes the living human voice. This dimension encompasses the subtle vibrational and emotional energy transmitted through natural speech timbre, prosody, and rhythm.

In the context of education, where AI-driven tools are increasingly integrated into the learning process, this issue acquires special relevance. The substitution of human speech with synthesized

voices risks diminishing the emotional resonance and motivational impact of didactic interaction. Hence, exploring language as an energy system allows for a deeper understanding of the human factor in communication, its affective, physiological, and bioenergetic foundations which remain essential for maintaining empathy, engagement, and the authenticity of pedagogical discourse.

In this paper we introduce the term "bioenergetics of speech timbre" which is not a standard fixed term in linguistics or phonetics. In voice research, the term sometimes appears metaphorically to describe the energetic processes underlying voice production: how the body mobilizes muscular, respiratory, and neural resources to generate sound (see Gobl & Ní Chasaide, 2003; Kent & Read, 2015). In sum, the bioenergetics of speech timbre is the study of how the human body mobilizes, transforms, and distributes physiological energy to produce the perceptual quality of voice. As can be observed, this concept integrates perspectives from phonetics, acoustics, physiology, psychology, and communication.

Thus, the bioenergetics of speech timbre can be understood as the study of how physiological energy (respiratory airflow, phonatory activity, and articulatory modulation) is transformed into acoustic energy that determines vocal quality. In a broader sense, it links biological energy expenditure with perceptual qualities of voice i.e. how timbre signals emotion, identity etc.

Literature overwiew. Certain aspects of timbre were first examined in the late nineteenth century by Helmholtz (1885). However, comprehensive exploration of the complex nature of timbre became possible only with the advent of advanced methodological tools in the 1950s and 1960s, first systematically applied to timbre analysis by Plomp (1970). In the field of phonetics, speech timbre was investigated by several prominent scholars, including Abercrombie (1967), Laver (1980), Esling (2010), Gibbon (2010), and McAdams (2019). Ukrainian researchers have also made significant contributions to the study of speech timbre across various linguistic domains, notably Ieremenko (2004), Kalyta (2001), Chernyshuk (2019) and Olenets (2018). Despite the substantial body of research devoted to this topic, the observation made by the classic authority in phonetics D. Abercrombie (1967) that "voice quality in phonetics has been relatively neglected in comparison with other strands of speech description" remains relevant today.

Timbre is characterized by a certain ambiguity in its interpretation. The present study focuses on the timbral parameters of didactic communication from a **bioenergetic perspective**, a dimension that has not yet received sufficient attention in linguistic research. Thus, the *goal* of the research is to explore the bioenergetic parameters of speech timbre and their role in shaping the perceptual and cognitive processes involved in the perception of didactic information. The ***object* of the study** is speech timbre in the context of didactic communication. The *scientific relevance* of this research lies in its interdisciplinary approach that integrates phonetic, psychological, and pedagogical perspectives to explore the energetic and perceptual aspects of speech timbre. By examining the bioenergetic basis of vocal timbre, the study contributes to the understanding of how acoustic energy affects the transmission and perception of didactic information in lecture discourse.

Presentation of the main material of the research. In the field of speech timbre research, terminology is often inconsistent (e.g., vocal timbre, voice quality, tone colour, phonation type). We use the term ***speech timbre*** which is traditionally defined in phonetics as "the set of auditory characteristics of a voice that allow us to distinguish one voice from another, independent of pitch and loudness" (Laver, 1980). Each speech sound comprises a fundamental frequency ***(F_0),*** which is specific among speakers but relatively stable across different phonations of the same individual. Superimposed on it are overtones or harmonics (higher-order oscillations resulting from fractional vibrations of the vocal folds), whose amplitudes are lower than that of the fundamental frequency. The acoustic structure of the sound also includes several formants, i.e. bands of resonant frequencies shaped by the configuration of the supraglottal cavities. These resonances arise through the phenomenon of acoustic amplification within the vocal tract, where changes in the shape and volume of the resonators determine the spectral characteristics of each sound. Thus, voice timbre represents a composite acoustic parameter determined by the interaction of the fundamental frequency, its harmonics, and the system of formant resonances (Близнюк, 2019: 6).

McAdams (2019) in a recent overview of the perceptual representation of timbre emphasizes timbre's complexity and the fact that many aspects remain poorly understood, comparatively under-investigated despite its importance. Timbre remains one of the least investigated component of intonation from the physical and functional points of view (Town & Bizley, 2013; McAdams, 2019; Abercrombie, 1967). Olenets (Оленець,

2018: 140) also argues that timbre is an incredibly complex feature in the analysis of sound speech, requiring special study. There is still no satisfactory and reliable unit for describing timbre.

Traditionally phonetic studies of speech timbre describe it in terms of ***physiological settings*** (laryngeal and supralaryngeal), ***acoustic correlates*** (formant structure, spectral tilt, harmonic-to-noise ratio), and ***perceptual labels*** (breathy, creaky, harsh, nasal, etc.). Therefore, to systematize the existing approaches to the analysis of speech timbre, it is necessary to integrate articulatory, acoustic, and perceptual perspectives. For greater coceptual clarity, Table 1 presents a comparative overview that summarizes the main dimensions and parameters of speech timbre classification described in phonetic and linguistic studies.

In this paper speech timbre is approached through perceptual correlates. The complexity of speech timbre has led to the development of diverse frameworks for its perceptual identification and classification (Калита, 2001; Єременко, 2004; Солощук, 2006; Laver, 1980; McAdams et al., 2019; Kreiman & Gerratt 2010).

The selection of the classification scale that divides speech timbres into positive and negative categories was made intentionally, as it aligns most appropriately with the objectives of our study. Some studies of pedagogical speech state that speech timbre is one of the leading parameters that is evaluated by listeners during the initial perception of the flow of speech, it can increase or decrease the overall effect of speech perception: "It causes a certain reaction in listeners if the timbre reflects negative emotions, then, accordingly, a negative reaction" (Оленець, 2018: 139). Timbre is increasingly seen as an ***energetic-prosodic resource*** that encodes emotion, attitude, and speaker identity.

According to the *hypothesis* put forward, positive, major timbre plays an important role in the processes of perception of oral didactic information. Such assumptions were based on theoretical developments on issues of positive pedagogics, pedagogical rhetoric (Матвієнко & Саранюк, 2015: 36–38), in particular the theory of *hedonism* (from the Greek *hedone* – rejoice). Hedonistic discourse involves the creation of a general positive atmosphere of pedagogical communication, the psychological result of which is joy. Speech in such discourse acts as one of the main means of indirect information of the addressee (or audience) and contributes to the mechanisms of synchronization and harmonization between the participants in communication. Increasingly, in recent years, scientists have been discussing the problem of using the musical terms "majority" and "minority" in linguistics (Кушнерик, 2004: 325). Continuing this idea, Kushneryk (2004) states that the concepts of majority/minority have also taken a prominent place among phonetic explorations.

Methodology. In the framework of *a complex perceptual experiment* integrating psycholinguistic analysis, informants were presented with twelve acoustically contrasting lecture excerpts *(n = 12)* each read by a different announcer. The material included recordings produced by six female and six male voices. This gender balanced ratio was chosen to ensure the "purity" of the experiment and to minimize potential complications in data approximation. The perceptual analysis was conducted in two stages. In the first stage, the informants' task was to assess the cognitive perceptibility of didactic information of the announcers' speech and to categorize it using a suggested three-point interval scale ("good," "average," "bad") through a questionnaire. Both subjective and objective estimates were included.

The decision to select announcers for subsequent stages of the experimental analysis was made if the total coincidence rate of the assess-

Table 1

Comparative overview of multidimensional approaches to speech timbre classification

Dimension	Basis of Classification	Typical Categories / Descriptors	Representative Authors
Physiological / Phonatic	laryngeal and vocal tract settings	modal, breathy, creaky, harsh, tense, lax	Laver (1980), Catford (1964), Esling (2005)
Acoustic / Spectral	spectral shape, harmonicity, formant patterns	bright–dark, rough–smooth, resonant–flat	Sundberg (1995), Müller et al. (2022)
Perceptual / Cognitive	listener-based rating dimensions	breathy, warm, metallic, nasal, soft, sharp	McAdams et al. (2019), Kreiman & Gerratt (2010)
Functional / Communicative	discourse and emotional functions	expressive, didactic, persuasive, intimate	Gobl & Ní Chasaide (2003), Taranenko & Schaefer (2018)

ments reached at least 68.3% *(one-sigma rule)*. Applying this procedure to the protocol data obtained during the analysis, six announcers' speech samples were identified *(n = 6)*: female speaker (FS) 3, male speaker (MS) 2 and male speaker (MS) 3 were rated as "good", female speaker (FS) 5 as "average" and female speaker (FS) 2, female speaker (FS) 4 as "bad".

The second stage of the study engaged trained phonetician-auditors to determine the perceptual features of the selected speech samples differing in cognitive perceptual quality. The bioenergetic parameters of speech timbre were examined and evaluated through subjective perception. The assessment of timbral perception in the context of didactic communication was based on the major-minor mode dichotomy. The emotional dychotomy was subjectively rated using the scale major/positive timbre and minor/negative timbre.

Results and discussion. The outcomes of the auditors' evaluations within the framework of the emotional dichotomy confirmed the initial hypothesis that a positive, major timbre plays a significant role in the perception of oral didactic information. The experimental speech samples were distributed as follows: for the "good" category – major 60%, major/light 33%, and minor 7%; for the "average" category – major 60% and major/light 40%; and for the "bad" category – major 10%, major/light 20%, and minor/soft 70%. For clarity and ease of interpretation, these results are presented in Figure 1.

The lecturer's speech samples that received "good" or "average" evaluations from informants were identified by expert auditors as demonstrating a **major/positive** timbre, as evidenced by the high percentage of agreement in assessments – 93% and 70% respectively. According to statistical analysis *(one-sigma rule)*, these results provide sufficient grounds to conclude that **major** timbres exert a significant positive influence on the cognitive perceptibility and overall cognitive quality of didactic speech. They contribute more effectively to information assimilation than **minor** timbres, which demonstrate a comparatively negative impact in this regard.

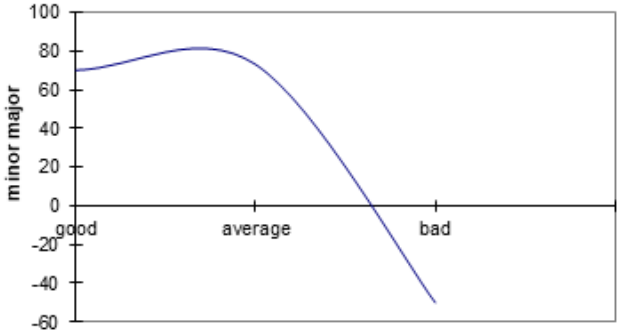

Fig. 1. Dependence of the perceptual effectiveness of didactic information on the timbral parameters of speech

As noted by Carraturo et al. (2024), the **major** mode is closely associated with the expression of active emotions, which appear to stimulate the recipient's mental activity and enhance cognitive engagement. In contrast, the **minor** mode correlates with passive emotional states and does not facilitate the cognitive quality of speech in an educational context. The experiment revealed that the perceptual experience of the **major** mode is linked to increased loudness, ascending melodic contours and nuclear tones, a higher pitch register, and specific tempo modifications. In contrast, the **minor** mode is characterized by reduced loudness, predominantly descending melodic patterns, and a moderately lower pitch level. The subsequent research aims to correlate the perceptual indicators of the **major** mode with instrumental data, particularly with respect to vowel formant frequency tracks.

Conclusions. Speech timbre not only distinguishes voices but also functions as a primary vehicle of emotional communication, shaping how speech is perceived, understood, and remembered. Thus, within the framework of the bioenergetics of speech timbre, the study has demonstrated that timbre functions as a significant prosodic parameter mediating the energetic and perceptual dynamics of didactic communication. It was found that a positive, major, bright timbre positively affects the degree of assimilation of oral information. Moreover, the experiment also makes it possible to empirically confirm some postulates of pedagogical rhetoric, hedonistic theory in particular. *Future research* on the bioenergetic parameters of speech timbre in didactic communication should aim to deepen the understanding of how vocal energy dynamics influence the cognitive and emotional engagement of learners. Expanding the methodological framework to include instrumental acoustic analysis would provide a more objective basis for assessing the interaction between speech energy, timbral colouration, and perceptual response. Comparative studies across languages and age groups can help identify universal and culturally specific patterns in the bioenergetics of pedagogical speech.

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