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Cognitive Effect of Acoustic Variations on the Perception of English Words

Najah Jameel Salman
Republic of Iraq Ministry Of Education General Directorate of Education in Wasit
Al-Mawadda Preparatory School for Girls
E-mail: najah99j@gmail.com

الأثر المعرفي للمتغيرات الصوتية على إدراك الكلمات الإنكليزية

نجاح جميل سلمان
جمهورية العراق وزارة التربية المديرية العامة لتربية واسط اعدادية المودة للبنات

ABSTACT
The purpose of this study is to investigate the influence of acoustic variation in spoken English (pitch, intensity, speech rate, rhythm and place of pauses) on cognitive processing in word perception and word comprehension. The research done in phonetics, psycholinguistics and cognitive science shows that there is a better understanding of speech when hearing slight and expected sound changes which make the sounds stand out from the rest and facilitate the listener's focus and language understanding. The listener will be required to exert greater mental effort as the extreme sound changes occur intermittently and disrupt comprehension of speech. Cognitive load is the highest for listeners when speech language changes are made from year to year, as this interferes with listeners' expected rhythm movements. Changes in pitch and intensity involve medium level processing, but intensity changes cause less processing unless they get very intense. These phenomena have significant cognitive effects on non-native listeners who are already cognitively challenged because of their struggles to understand speech in noisy conditions. The article presented a theoretical framework to describe the relationship between acoustic changes and cognitive processes in the perception of speech, and showed the importance of balancing acoustic changes with listeners' expectations. The study offers practical applications to promote language learning, improve speech technology and to create more effective communication strategies.
Keywords: Acoustic variation, Speech perception, Temporal variation.

المستخلص
يتناول هذا البحث تأثير التنوعات الصوتية في اللغة الإنجليزية المنطوقة، ولا سيما التغيرات في درجة الصوت، والشدة، والجوانب الزمنية مثل سرعة الكلام، والإيقاع، ومواضع الوقفات، على المعالجة المعرفية أثناء إدراك الكلمات وفهمها. واستنادًا إلى دراسات في علم الأصوات، وعلم اللغة النفسي، والعلوم المعرفية، يوضح البحث أن التعديلات الصوتية المعتدلة والمتوقعة تسهم في تحسين الفهم من خلال زيادة الوضوح الإدراكي، وتوجيه انتباه المستمع، وتعزيز كفاءة معالجة اللغة، في حين تؤدي التغيرات المفرطة أو غير المنتظمة أو غير المتوقعة إلى زيادة العبء المعرفي وصعوبة الفهم. وتشير النتائج إلى أن التعديلات الزمنية تفرض أعلى مستوى من الجهد المعرفي، خاصة عندما تنحرف سرعة الكلام أو إيقاعه بشكل كبير عن توقعات المستمع، بينما تمثل تغيرات درجة الصوت عبئًا متوسطًا، وتظل تغيرات الشدة الأقل تأثيرًا ما لم تكن مبالغًا فيها. وتزداد هذه التأثيرات لدى المستمعين غير الناطقين الأصليين وفي البيئات الصاخبة، حيث تكون الموارد المعرفية أكثر استنزافًا. ويقترح البحث إطارًا نظريًا يربط بين التنوع الصوتي والآليات المعرفية المسؤولة عن إدراك الكلام، مؤكدًا أهمية تحقيق التوازن بين المرونة الصوتية وتوقعات المستمع،مع

إبراز تطبيقات عملية في تعليم اللغة، وتقنيات الكلام، واستراتيجيات التواصل الفعّال.**الكلمات المفتاحية: التغيرات الصوتية، إدراك الكلام، التغيرات الزمنية.**

1. Introduction

The acoustic variations that include pitch changes and volume shifts and timing alterations function as essential components of speech production and perception because they enable speakers to show emphasis and emotional expressions and their communicative intent while using the same words (Cutler, 2012; Johnson, 2015). Speech perception represents an active cognitive process, which requires people to decode sound waves through decoding while they combine sounds with their linguistic and contextual knowledge. The variations in speech directly affect how well people understand speech because their understanding abilities increase when they hear moderate and predictable speech patterns but their understanding abilities decrease when they encounter unexpected speech patterns, which lead to cognitive load, and processing challenges.The temporal features of speech, which include speech rate, syllable timing, and pause placement hold particular importance because they determine how people deliver linguistic information but they can either help or hinder understanding through their effect on rhythm and predictability (Goldman-Eisler, 1968; Miller, 1981; Sweller, 2011). Researchers have analyzed how people use categorical perception to recognize speech sounds yet researchers have not studied how tiny acoustic changes will affect word recognition processes. This research examines how these variations affect comprehension and processing efficiency and mental effort together with their respective reasons.

1.1. The Problem

The majority of research on speech perception investigates phonemic contrast and categorical boundary identification (Liberman et al., 1957). Real-world listening situations present listeners with continuous acoustic changes, which affect their recognition speed and comprehension accuracy and meaning interpretation. Research studies, which examine small acoustic effects, present a major research gap in phonetics and psycholinguistics and cognitive science research. Most studies of speech perception have focused on the phonemic opposition and categorical distinction (Liberman et al., 1957)People communicate through real life situations, which provide listeners with various acoustic changes that determine their recognition speed and comprehension accuracy and meaning interpretation capacity. This study aims to solve the research problem because scientists need to understand how people perceive auditory details, which phonetics, psycholinguistics, and cognitive science have not yet studied.

1.2. Purpose of Study

The study investigates which sound patterns from spoken English produce cognitive effects. The research examines how identification accuracy and processing speed are affected by these particular sound variations. The study aims to enhance existing theoretical frameworks, which describe how acoustic variations affect speech perception cognitive processing.

1.3. The Questions of Study

The emphasis of the given study is the following questions:

1- What is the effect of pitch and intensity differences on cognitive processing in the perception of English words?

2- What is the change in temporal speech and understanding performance connected with it?

3- Are certain kinds of acoustic variation more of a cognitive load to participants than others?

1.4. Significance of the Study

A better understanding of the effect of acoustic variation on cognitive processing holds much importance in many fields. It may be applied in language teaching to help improve the design of pronunciation lessons and listening comprehension tasks by making them more like how they actually work in actual speakers (Cutler and Clifton, 1999). The insights can be applied in speech technology to create a more natural-sounding and easily understandable synthetic speech system (Johnson, 2015). Furthermore, knowledge may be applied in the context of clinical practice to advance the diagnostic methods and interventions strategies towards individuals with the problem of auditory processing.

1.5. Literature Review

Studies on prosody and intonation show that suprasegmental features are important in determining the comprehension and interpretation of emotional meaning (Cutler and Clifton, 1999). Johnson (2015) also adds that even the slightest acoustic alterations can affect the perception of vowels and consonants of listeners. Cognitively, Sweller (2011) cognitive load theory describes that the decreased clarity in auditory signals can cause an increase in the mental effort needed to process them, which can adversely affect the speed and accuracy of recognition. However, even with these insights, a complete incorporation of acoustic phonetics with cognitive processing in one explanatory framework, in particular with respect to the perception of English words, remains wanting.

2. Speech Rate and Processing Load

One of the most studied temporal factors of spoken language comprehension is speech rate. A speedy speech causes a decrease in the time that can be devoted to lexical processing that can demand more cognitive resources (Dupoux and Green, 1997; Tauroza and Allison, 1990). Conversely, a slowed rate of speech usually allows listeners more processing time which can often be particularly helpful when complex or unfamiliar material is involved (Foulke and Sticht, 1969). However, in those situations when the speech is too slow, it might negatively affect the natural prosodic flow and consequently the process of engagement with the listeners will become less fluent.

3. Cognitive Load and Acoustic Variation

Cognitive load theory describes that mental load is increased when there is lack of clarity, prediction, and complexity in auditory information (Sweller, 2011). In speech perception, acoustic differences can assist in understanding when they attract attention to important information and enhance clarity. Nevertheless, they may also complicate the understanding process by making signals less predictable or compelling the audience to reinterpret the signal repeatedly (Bradlow & Bent, 2002).

4. Types of Acoustic Variation

4. 1. Pitch Variation

One of the most significant elements of speech that helps convey prosody, stress, and the intention of the speaker is pitch or fundamental frequency (Johnson, 2015). Pitch shifts that are moderate in nature and which follow anticipated patterns have the potential to render speech more intelligible and comprehensible. Conversely, the abnormal or exaggerated movements of the pitch may slow the recognition of a signal, as listeners must change their expectations to interpret the signal (Patel, 2008). However, listeners typically can adapt to these changes with the use of contextual information that allows them to reduce the overall effect they have on comprehension. The moderate pitch and loudness shifts may assist in guiding the listeners' attention and help to better segment speech (Kjelgaard and Speer, 1999). However, when these changes are extreme or unpredictable, they can disrupt the normal prosodic expectations and slow down processing (Breen et al., 2010). To give an example, a sudden shift in the pitch might give the listeners a sense that the speakers intend to convey something different, whereas a sudden change in the volume can make the listeners concentrate on the volume instead of the meaning that the speakers are conveying

4.2. Intensity Variation

The variation of loudness is a common tool in speech that is used to stress the important information in speech and to transmit some emotional power. It enhances clarity and makes key words more detectable and more so in noisy environments when used in a natural and proper way (Bradlow and Alexander, 2007; Cooke, 2006). Cognitively, the way that well-structured changes in intensity are implemented can help reduce processing effort by assisting the listeners' structure and interpret speech more efficiently (Mattys et al., 2012). But when these changes are sudden, inconsistent, or unpredictable, these changes may interfere with the understanding by disrupting the process of processing and making it more difficult to distinguish meaningful emphasis and irrelevant variation.Variations in loudness are usually employed to provide emphasis and promote important facts in speech. A correct degree of intensity modulation can improve word recognition especially in noisy environments (Bradlow and Alexander, 2007). Cognitively, intensity cues that are placed appropriately help to reduce effort since speech structure becomes more clear (Mattys et al., 2012). On the other hand, if the volume changes in any unnatural way or an unexpected volume change occurs, processing flow will be interrupted and the process of understanding will be delayed.

4. 3. Temporal Variation

The timing, pauses, and rate of speech are important aspects of the temporal characteristics of spoken language communication and understanding (Goldman-Eisler, 1968). Predictability and natural rhythm in speech in turn come back to favour the smooth processing. But sometimes it can be unpredictable or unnatural and interfere with the flow and place a heavier load on cognition, particularly on working memory. Due to the direct effect of timing on how linguistic information can be organized and processed, temporal variation can often have more significant effect on comprehension compared to other acoustic features (Janse, 2004)Timing of speech, rate of speech and pause placement are key elements in how listeners divide and comprehend language. Slightly reduced speech rate can facilitate understanding since it provides more processing time especially in case of second language listeners (Munro and Derwing, 2001). Nevertheless, excessively slow speech can impose additional memory loads since the information has to be stored longer before they are integrated. On the other hand, fast speech can overwhelm processing capacity and lead to missed information (Wingfield et al., 1999).

4. 4. Comparative Cognitive Demand

Studies show that temporal variation tends to place the highest cognitive load, particularly when it decreases the predictability of speech timing. In some cases, the pitch variation can also make processing more difficult, although the listeners are normally able to adapt to it based on the surrounding. Comparatively, the change of intensity is likely to have the least impact on understanding, unless it interferes with clarity or is accompanied by other acoustic disturbances (Mattys et al., 2012).

4. 5. Implications

The knowledge of the impact of acoustic variation on cognition has a variety of applications. It may be applied in speech technology to enhance the naturalness and intelligibility of synthesized speech. In teaching language, it may serve the purpose of enabling the students to adjust to the differences in spoken English in the real world. In audiology, it can inform the design of hearing aids that would be more able to preserve significant temporal cues in speech.Achieving the knowledge of what kind of acoustic variations produce the greatest cognitive load may find some practical application in the following areas:Operations: Speech technology: Refining text-to-speech systems by ensuring natural timing, and preventing too much time variation in synthetic speech. (Wingfield et al., 1999).Language teaching: The creation of training methods to assist the learners to adapt to the natural variations in the pitch, speech rate, and rhythm of the real communication.

Audiology: Improving the design of hearing aids to retain significant temporal information that enhances clarity and speech comprehension in hearing aid users.

5. Cognitive Load in Speech Perception

The cognitive load theory posits that understanding is more challenging when hearing involves too much thinking (Sweller, 2011). This is usually observed in the speech perception when the acoustic patterns are either unexpected or unclear, and the listeners must depend on the resources of attention and working memory (Pichora-Fuller et al., 2016).

5.1. Pauses and Comprehension

Pauses are significant in the process of segmentation of the speech in the spoken language; they mark syntactic and semantic boundaries, which help to structure the incoming information (Goldman-Eisler, 1968; Grosjean and Deschamps, 1975). Properly placed pauses can facilitate understanding by decreasing processing load and creating time to syntactically analyze and activate meaning (Ferreira, 1991). Conversely, the discontinuation of the flow of attention, weakening the coherence, and disturbing the smooth incorporation of semantic information may occur because of irregular or excessively long pauses.

6. Temporal Rhythm and Predictability

The speech rhythm patterns assist the listeners in developing expectation about the linguistic information that follows, which aids in the smoother and more efficient comprehension (Cutler, 1994; Port, 2003). The distortions of these patterns can therefore either heighten attention or cause confusion according to the predictability of the distortion, as well as the context in which the distortion occurs. Consequently, a natural rhythm and manipulation of temporal aspects of speech is crucial to the preservation of the efficiency of comprehension.

7. Temporal Modifications

The variations in the rate of speech and the distribution of pauses have a great impact on the efficiency of the comprehension (Goldman-Eisler, 1968; Tauroza and Allison, 1990). Very fast speech leaves less time to recognize the word, and in both instances, excessively slow or irregular timing can cause disruption to the normal rhythm, resulting in increased effort in recognition in both cases. These time-varying effects are particularly challenging to second-language listeners, who tend to rely more on steady patterns in timing to help them understand (Dupoux and Green, 1997).

8. Spectral and Voice Quality Changes

Processing difficulty may also be increased by variations in spectral characteristics, such as the movement of formant frequencies or voice quality changes, including breathy, creaky or nasalized speech. These changes may make the listeners change their perception of phonemes, especially in challenging listening conditions (Pisoni and Luce, 1987; Johnson, 2015). In addition, it has been indicated that the overall cognitive demand is higher when several acoustic features are altered at once compared to when only one feature is altered at a time

(Mattys et al., 2012)Several factors interact to determine the cognitive load that comes with acoustic variation. Predictability is one of these factors; when the speech changes are accompanied by the expected prosodic patterns, the changes are generally easier to process and comprehend by the listeners, whereas deviations that are unexpected require more cognitive work. Another important factor to consider is magnitude, as finer differences have more of a chance of enabling processing, whereas large or sudden changes tend to increase processing demands. In addition to this, dimensional complexity also plays a role to play because simultaneous changes in all acoustic characteristics is more difficult to process than changes in a single acoustic feature. Factors related to the listener are also important contributors with non-native speakers and people with hearing difficulties often having increased difficulties in processing acoustic variabilityAppliedly, the lessons are applicable in a variety of fields. In speech technology, e.g., text-to-speech systems are not expected to be over-emphasized, unless some particular information is supposed to be emphasized. In language, teaching exposure to manipulated but realistic variation of the speech can benefit the learner in assisting him or her to adjust without straining his or her cognitive resources. Clinical applications can also be done using them to determine more effective methods of auditory training and rehabilitation.

9. Effects on Recognition Accuracy and Processing Efficiency

How far the recognition is correct is highly dependent on the predictability of the acoustic cues. In cases where the use of pitch and intensity is predictable, it can be perceived that the listeners can recall the words much quicker and with a greater degree of accuracy (Altmann and Kamide, 1999). A similar case is, natural speech timing that is consistent with cognitive processing will help in efficient understanding, whereas inconsistent timing will help in increase in errors and delays in understanding. These characteristics tend to interact such that moderate slowing of speech and emphasis on key words will help to improve comprehension and memory retention.

10. Findings

The literature review has several key findings highlighting the effect of acoustic differences on the perception of English words. The variations in the fundamental frequency in pitch also act as important prosodic clues that draw attention and aid in lexical recognition (Cutler, 2012; Johnson, 2015). By making important information significant and explaining sentence structure, the moderate and predictable changes in the tone of the voice contribute to a better understanding of the message. Nonetheless, sudden or extreme changes in pitch are most likely to cause an increase in cognitive demands, as listeners would have to make their expectations to understand the meaning (Breen et al., 2010)The variations in intensity also result in a perceptual clarity as important words become more salient, especially in noisy listening scenarios, which enhances word detection and processing efficiency (Bradlow and Bent, 2002; Mattys et al., 2012). However, the processing fluency can be impaired when inconsistent or sudden changes in loudness occur with other acoustic disruptions. Temporal features, such as, rate of speech, distribution of pauses, and timing of syllables, cause the greatest effect on comprehension. A marginally slower speech rate may be helpful as it may provide more processing time, enhance accuracy and memory, particularly among non-native listeners (Munro and Derwing, 2001; Wingfield et al., 1999). Conversely, excessive speed or uneven timing may cause overload of the working memory and decrease in efficiency; hence, temporal variation is among the most challenging acoustic factors.Beyond individual features, interactions between acoustic dimensions also play a crucial role. When there is a combination of changes in pitch, intensity and timing, the cognitive load is more than when changes occur independently (Mattys et al., 2012; Sweller, 2011). Nevertheless, when these variations are predictable, consistent with natural speech patterns, they can be easier to process and decode by the listeners. Overall, the results indicate a two-step model of speech processing, where the acoustic signals are initially perceptually decoded, and then combined with the linguistic and contextual information. Processing is most effectively done when the acoustic variation is moderate, structured, and in line with what the listener expects, and when deviations of natural prosodic patterns are done, additional cognitive resources are required (Sweller, 2011).In practical terms, these hints are useful. In speech technology, it has been shown that to enhance intelligibility in synthetic speech systems it is important to maintain natural patterns of pitch, intensity, and timing. Training of learners in language education can serve to expose learners to realistic variation in spoken English. Clinically, this information may be used to inform interventions to support individuals with deficiencies in their auditory or cognitive processing.

11. Conclusion

Temporal variations in speech have a strong impact on the efficiency with which listeners comprehend spoken language since they affect processing speed, speech segmentation and overall cognitive load. The best way to comprehend is usually when timing patterns are natural and consistent with the anticipated rhythm of speech. Although a slower delivery and well-placed pauses can be helpful in the cognitive process, overly altered natural timing can disrupt fluency and decrease the interest of the listener. Not every acoustic change has the same impact on the listener. Unpredictable, excessive, and simultaneous changes in multiple acoustic features are more likely to impose significant demands on processing resources and memory. Quite to the contrary, moderate and anticipated changes that are detected to follow the patterns of normal speech, in fact, may serve to help people to understand, as they pay attention to the important information. This shows the necessity of further research on how listeners can adapt to various acoustic conditions with time elapsing, and how this may be used in the field of education and technology.In general, various acoustic characteristics vary in the extent of cognitive effort demanded. The overall effect of the temporal variation on processing complexity is as follows: the temporal variation in general has the strongest influence on processing complexity, followed by pitch-changes, and then intensity-changes, although the latter are less demanding in most cases unless this variation interferes with clarity or occurs in conjunction with other distortions. The significance of predictability in speech and capability of the listener to accommodate the variation are emphasized through this pattern.Intensity, pitch and timing are not peripheral features of speech but are central features of the processing of spoken language. They influence the level of word recognition accuracy, the information processing efficiency, and the meaning comprehension. With the integration of these acoustic properties in cognitive models, one single approach, which involves the combination of these properties in both theoretical and practical applications in speech technology, language teaching and clinical support can be used to improve theoretical knowledge and practical application of such a combination in both theoretical and practical applications.In general, the notion of the acoustic variation is a significant consideration in the attainment of spoken language understanding. Pitch helps to attract attention and sense when used in a natural manner but when it is overdoing it may result in more work. However, it can be difficult to listen when there is a lot of noise and the intensity can help but sudden shifts can disrupt fluent processing. The temporal features, however, have the most direct influence, as they directly affect the way the speech is organized, remembered and understood. The combination of these factors, their predictability, and their structure can either help or hinder comprehension based on their structure and predictability.It has always been clear that there is an unequivocal hierarchy of cognitive demand: the most demanding is the temporal variation, then the pitch, and the intensity. The importance of understanding this hierarchy is two-fold; to enhance models of speech perception as well as in practical use in teaching, designing technology and in auditory rehabilitation.A complex model of speech processing postulates that perception of acoustic information at a sensory level and following perception of the perceived acoustic information within linguistic and contextual frameworks are the first stage of speech processing. Communication requires being balanced in terms of clarity, natural flow, and variation that is regulated. At this point, the balance is obtained and the listening process becomes more straightforward and less demanding in terms of mental effort.Finally, acoustic variation illustrates the extent to which physical properties of speech are connected with the mental processes of human beings that enable human beings to comprehend and interpret language.

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