Transdisciplinary integration for applied linguistics: the case of electrophysiology

Saudi Journal of Language Studies

97

Received 7 June 2024
Revised 6 July 2024
Accepted 6 July 2024

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Abstract

Purpose – This study aims to promote transdisciplinary integration in applied linguistics research by exploring the potential contribution of electrophysiology to enhancing listening comprehension skills. Specifically, it examines the effectiveness of dynamic auto-adjustment of speech rate based on heart rate in mitigating listening stress. The study also discusses the implications and future directions of interdisciplinary efforts in applied linguistics.

Design/methodology/approach – This study combines literature review, theoretical analysis, and practical application. It begins with a review of existing literature on transdisciplinary integration in applied linguistics and electrophysiology research. Theoretical frameworks are then synthesized to inform the development of an innovative approach to mitigate listening stress through dynamic auto-adjustment of speech rate based on heart rate.

Findings – The analysis suggests that transdisciplinary integration in applied linguistics research, particularly through the incorporation of electrophysiology, holds significant promise for enhancing listening comprehension skills. The dynamic auto-adjustment of speech rate based on heart rate emerges as a promising strategy for mitigating listening stress, calling for empirical research into this topic.

Originality/value – This study contributes to the field of applied linguistics by advocating for transdisciplinary integration and exploring innovative approaches to address challenges in language learning. Incorporating electrophysiology and dynamic auto-adjustment of speech rate based on heart rate offers novel research directions for practical strategies for enhancing listening comprehension skills. This research has the potential to advance theoretical understanding as well as offering practical implications for educators and policymakers seeking to improve language learning outcomes in diverse educational settings.

Keywords Listening speed, Stress, Anxiety, Heart rate, Soft sciences

Paper type Research paper

Introduction

In 1959, Charles Percy Snow gave an influential lecture highlighting the divide between the sciences and the humanities. He pointed out that there was a profound gap between these two circles in knowledge and in communication, describing them as "two cultures." He argued that scientists lacked appreciation for the arts and humanities, making them basically culturally illiterate in terms of literature, history, philosophy, and other humanistic disciplines. Those specializing in the humanities, similarly, lacked basic knowledge about the scientific method, scientific principles, scientific discoveries, and viewed science as cold, mechanistic, and devoid of human values. According to Snow,

> A good many times I have been present at gatherings of people who, by the standards of the traditional culture, are thought highly educated and who have with considerable gusto been expressing their incredulity at the illiteracy of scientists. Once or twice I have been provoked and

Saudi Journal of Language Studies
Vol. 4 No. 2, 2024
pp. 97-105
Emerald Publishing Limited
e-ISSN: 2634-2448
p-ISSN: 2634-243X
DOI 10.1108/SJLS-06-2024-0028

> have asked the company how many of them could describe the Second Law of Thermodynamics. The response was cold: it was also negative. Yet I was asking something which is the scientific equivalent of: *Have you read a work of Shakespeare's?*
>
> I now believe that if I had asked an even simpler question – such as, What do you mean by mass, or acceleration, which is the scientific equivalent of saying, *Can you read?* – not more than one in ten of the highly educated would have felt that I was speaking the same language. So the great edifice of modern physics goes up, and the majority of the cleverest people in the western world have about as much insight into it as their neolithic ancestors would have had. (Snow, 1959, pp. 15–16)

About 2 decades later, Meehl (1978) made a parallel argument comparing the "hard" and "soft" sciences. The hard sciences (e.g. physics, chemistry, genetics and molecular biology) are interested in phenomena that are relatively easy to measure and manipulate under controlled laboratory settings. As a result, these disciplines are able to obtain precise models leading to replicable findings and well-established theories. In contrast, the soft sciences (e.g. psychology, sociology, education) have to grapple with more complex phenomena that are more difficult to measure, qualify, and predict. This situation, according to Meehl, has made most theories in the soft science "scientifically unimpressive and technologically worthless" (Meehl, 1978, p. 806). Researchers in these soft domains start with enthusiasm about their theories, but as they gather data, they realize just how complex the topics they are studying really are (Al-Hoorie *et al.*, 2023). Replication difficulties arise, various ad hoc excuses are given, and finally researchers simply lose interest and move on "as a function of baffled boredom" (Meehl, 1978, p. 807).

While the nuances of these views did not go entirely unchallenged (e.g. Gould, 2003; Hedges, 1987), there is a general agreement in the academic discourse about the overarching concepts. Applied linguistics may be considered one of these soft sciences, to which the issues described above apply. Most applied linguists graduate from linguistics, English, and literature departments (Al-Hoorie *et al.*, 2021), with many lacking adequate training even in statistics methodology. However, language learning is not merely a psychological or social act. A complete understanding of language learning requires taking account of the role of the brain and neuroscience, hormones and biology, genetics, and computational science. Different disciplines might study the same phenomena from different perspectives, making their results complementary and informative to researchers in neighboring fields.

Admittedly, it is not humanly possible for one individual to specialize in all these disciplines, as there is always a trade-off between breadth and depth. As Dörnyei (2009) put it,

> disciplinary boundaries have become increasingly blurred and permeable, and scholars would have traditionally identified themselves as being aligned to applied linguistics . . . started to adopt multiple academic identities . . . we are in the middle of a major academic restructuring process in which different research directions cross-fertilize each other in an unprecedented manner. (p. 25)

At the same time, this sort of disciplinary crossing involves challenges, as "researchers and practitioners have often found themselves awash in a sea of conflicting claims and recommendations from these various theoretical sources" (MacWhinney, 2006, p. 729). Different disciplines become "academic tribes" each with its own territory (Becher and Trowler, 2001), thus impeding communication. This territoriality can foster insularity, making it difficult for ideas to cross boundaries and for scholars to engage in fruitful dialogue across disciplines.

One solution is engaging in transdisciplinary research (Hiver and Al-Hoorie, 2022; Hiver *et al.*, 2022; MacIntyre and Gregersen, 2022). Transdisciplinary research transcends disciplinary norms and adopts a problem-centered approach (Leavy, 2011). Experts from different disciplines sit together to address a problem of common interest, as addressing complex problems effectively requires drawing and exchanging knowledge from diverse academic disciplines (Fam *et al.*, 2018). Neuroscientists may, for example, provide insights into the brain's role in language processing, while biologists shed light on the hormonal influences on learning and memory. Geneticists contribute by exploring how genetic predispositions affect language acquisition, and computational scientists can develop models to simulate and predict language learning patterns. Research findings stemming from these diverse fields can create a more comprehensive picture of the dynamics of learning and teaching (Daneshpour and Kwegyir-Afful, 2022).

A transdisciplinary approach may additionally benefit applied linguistics by moving beyond its traditional boundaries and incorporating a richer, more nuanced understanding of language learning. This holistic view not only benefits academic research but also has practical implications for classroom instruction as well as educational policies, ultimately assisting learners to overcome challenges and achieve greater proficiency. This integrated approach can influence educational policies by providing evidence-based recommendations for language education. Policymakers may use these recommendations to allocate resources more effectively, support teacher training programs, and implement best practices to enhance language learning outcomes.

This approach enriches applied linguistics by combining the strengths of various fields, leading to a deeper and more effective understanding of language learning. This, in turn, empowers teachers to create more engaging and effective learning environments, helping learners to achieve higher levels of language proficiency and better preparing them for the demands of a globalized world. In this brief article, we introduce electrophysiology and reflect on how language learning research may benefit from it.

Electrophysiology

Electrophysiology is a branch of physiology that is concerned with the electrical properties of tissues and cells (Dörnyei, 2009). It involves the measurement of electrical activity, voltage changes, and electric currents. It may target the electrical activity of neurons (i.e. in neuroscience), larger-scale signals from the nervus system, or whole organs like the heart. In neuroscience, electrophysiology is used to study how neurons communicate and process information. Electrical signals that neurons produce provide insights into how the brain functions, how memories are formed, and how sensory information is processed, which in turn helps in understanding neurological disorders and developing new treatments. Electrophysiology also plays a role in cardiology. Examination of the heart's electrical activity can lead to the diagnosis and treatment of arrhythmias (irregular heartbeat) and other heart conditions. Techniques like electrocardiograms and intracardiac electrophysiological studies provide information about the heart's electrical pathways, helping to guide interventions such as pacemaker placement or catheter ablation. Electrophysiology can also be applied to study the electrical properties of muscles, contributing to understanding muscular disorders and conditions like myopathies (muscle disease). It also has applications in examining the electrical signals in the gastrointestinal tract, which can be useful for diagnosing and treating digestive disorders. Therefore, electrophysiology is an essential field within physiology that provides insights into the electrical mechanisms underlying various physiological processes. These mechanisms help researchers develop better diagnostic tools, treatments, and interventions for a wide range of medical conditions.

One application of such physiological methods is the assessment of stress and anxiety (Rojo López *et al.*, 2021). Traditionally, stress is assessed using conventional questionnaire-type instruments, which rely on participants' self-reported perceptions of their states. However, these tools have limitations, as they are intrusive and require interrupting the activity, making them less suitable for frequent measurement. In contrast to these psychological measures, physiological biomarkers offer a more objective and less obtrusive way to assess stress. These biomarkers include heart rate elevation and cortisol secretion (Arza *et al.*, 2019; Schneiderman *et al.*, 2005). Heart rate measurement helps detect immediate physiological responses to stress, providing real-time data on how individuals react to different stressors. Similarly, cortisol levels, measured through saliva, blood, or urine samples, offer insights into the body's hormonal response to stress over time. Using these physiological methods allows for continuous and accurate monitoring of stress levels without interfering with the participants' activities. This approach is particularly useful in high-stress environments, such as workplaces or academic settings, where frequent assessment is necessary to understand stress dynamics and implement timely interventions. Furthermore, the integration of physiological measures with traditional self-reported tools can provide a more comprehensive understanding of stress and anxiety. Combining subjective perceptions with objective data can help identify discrepancies between how individuals feel and how their bodies respond, leading to more personalized and effective stress management strategies.

Language learning is a stress-prone activity. Learners may experience stress when they perceive their proficiency to be inadequate to the task at hand, when they are unfamiliar with the task demands, and when they are tasked with giving a public speech. High levels of stress can in turn negatively affect learning and performance in relation to different areas including content, grammatical accuracy, speech rate, intonation, pitch, and voice quality (Korpal, 2016). Research may, for instance, aim to identify biomarker correlates of language tasks, in order to help learners cope with stress sources or intervene to lower the impact of these stressors. Physiological responses associated with different language learning activities, such as increased heart rate or cortisol levels, can suggest strategies to mitigate stress. This might include designing more supportive learning environments in these instances, offering personalized feedback, or incorporating relaxation techniques into language instruction. Identifying these biomarkers allows for real-time monitoring of stress levels, providing immediate feedback on how learners are responding to various tasks. This information can be used to adjust teaching methods and materials to better suit individual needs. For example, if a learner shows signs of stress during a particular task, teachers can modify the difficulty of the task or provide additional support to help the learner manage their stress and continue learning.

As mentioned above, integrating biomarker data with traditional assessment methods can give a more comprehensive picture of a learner's experience. This integrative approach can help identify patterns of stress across different activities and times, enabling more targeted interventions. Recognizing these physiological aspects of stress in language learning helps teachers improve their instructional strategies while fostering a more positive and effective learning environment. Understanding and managing stress in language learning is crucial for effective language learning and teaching. Physiological insights have the potential to help researchers and teachers create more adaptive, responsive, and supportive learning environments that enhance both the well-being and proficiency of language learners. Additionally, the use of physiological data can guide the development of personalized learning plans that cater to the specific needs of each student. Identifying individual stress responses can help teachers adjust their teaching methods and materials to better support each learner. This personalized approach ensures that students receive a suitable level of challenge and support, maximizing their potential for success. For instance, if biomarker data reveals that students experience high stress levels during oral presentations, teachers can implement strategies such as gradual exposure to public speaking with positive feedback and support at each step before the presentation. Such targeted interventions can help learners build confidence and reduce anxiety, leading to better performance and a more enjoyable learning experience.

As an illustration, Gregersen *et al.* (2014) compared heart rate, idiodynamic ratings, and self-reported anxiety in an interview. In idiodynamic ratings, participants watch a recording of their language activity (e.g. giving a speech) and then rate their stress moment-by-moment (or at longer intervals) on specialized software (see MacIntyre and Ducker, 2022). In the study by Gregersen *et al.* (2014), the participants were English speakers learning Spanish as a second language and were scheduled to give class presentations. They wore wristwatch heart monitors with chest straps to collect heart rate data while they were giving their presentations. The results showed a degree of convergence between heart rate measurements and idiodynamic ratings with correlations ranging between 0.59–0.79, suggesting heart rate data can complement idiodynamic measurements by providing a physiological index of ongoing changes in arousal. In another study, Rojo López *et al.* (2021) examined the association between heart rate, self-reported anxiety, and performance in a telephone interpreting task where learners translated oral communication from English to Spanish. Heart rate data were collected via a wrist-based heart rate monitor. The results showed that heart rate was a sensitive marker detecting students' stress response during the task, though it was not a significant predictor of exam performance, explaining only 30% of its variance. In another study, Shachter *et al.* (2022) examined the relationship between heart rate response and affective states in language learning. The participants, who were Japanese university learners of English, engaged in dialog in pairs for about two minutes while they were seated, and their heart rate was monitored using a Fitbit device. Heart rate was correlated with self-reported feelings at three stages: class-start, pre-performance, and post-performance. The researchers found a significant relationship between heart rate response and self-reported feelings of distress and embarrassment.

The few studies that have utilized heart rate measurements have been primarily descriptive. These studies aimed to determine whether there was an association between heart rate variability and both subjective measures (e.g. stress levels) and objective measures (e.g. performance accuracy). In contrast, there has been little research exploring whether interventions aimed at reducing stress and anxiety, as indicated by heart rate deceleration, would impact language learning engagement and performance (Kennedy and Parker, 2019). The scarcity of research in this area is understandable, as it involves devising effective methods to lower stress and slow heart rate. Developing and implementing such interventions can be complex, requiring a nuanced understanding of both physiological and psychological factors. Despite these challenges, exploring the impact of stress-reducing interventions on language learning could yield significant benefits. For instance, if it were found that reducing heart rate through certain relaxation techniques or mindfulness practices leads to improved language performance, teachers could incorporate these strategies into their teaching methods. This could help create a more supportive and effective learning environment. Additionally, understanding the link between physiological stress markers and language learning outcomes could inform the development of more personalized educational approaches. If they are able to monitor heart rate variability, teachers could identify students who are experiencing high levels of stress and provide targeted support to help them manage their anxiety.

In summary, while the current research on heart rate variability in language learning is limited and primarily descriptive, it highlights an important area for further investigation. Exploring the potential benefits of stress-reducing interventions can help in creating more effective and supportive learning environments that enhance both the well-being and performance of language learners. In the next section, we describe one electrophysiological approach to real-time measurement of stress levels.

Controlling speed rate

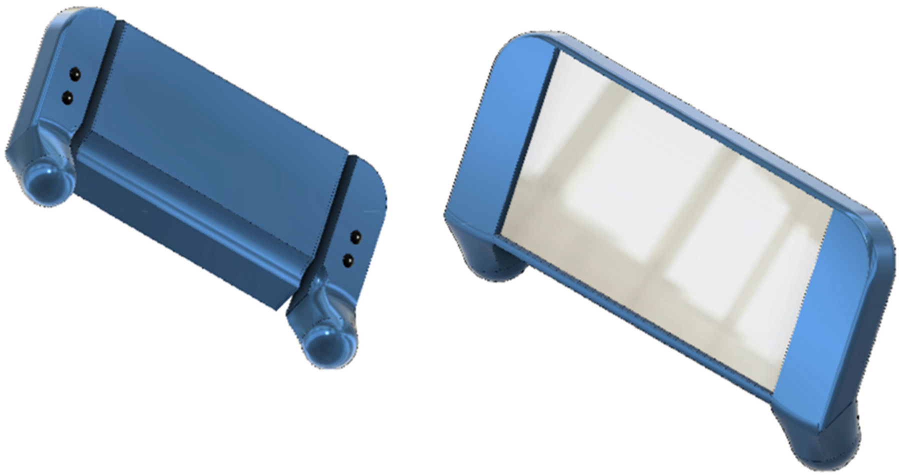
One approach to intervening and lowering listening stress is to control speech rate. One reason why language learners struggle with listening comprehension is fast speed rate

(Zhao, 1997). Language learners, especially at lower proficiency levels, tend to experience listening comprehension difficulties at higher speed rates because their processing skills, which have yet to become fully automatic (Révész and Brunfaut, 2013). Experimental research by Griffiths (1990, 1992) similarly showed that increasing speech rate negatively affects comprehension for low-intermediate Japanese learners of English. Giving learners control over speech rate so that it aligns with their comprehension ability helps them improve their listening comprehensions skills. Furthermore, when Zhao (1997) gave learners the opportunity to adjust speech rate, most of them preferred slower speeds, which in turn had a positive effect on their listening comprehension.

Against this backdrop, Al-Hoorie and AlAwdah (2023) proposed a methodology to reduce stress during listening activities. Instead of requiring learners to manually adjust the speed of the audio, this method automatically adjusts the speed based on the learner's heart rate. Specifically, an inverse relationship is established between the speed of the audio and the learner's heart rate, such that as the heart rate increases, the audio speed decreases. One significant advantage of this approach is its automation. By removing the need for learners to manually adjust the speed, they can maintain their focus on the learning material itself. This streamlines the learning process and reduces cognitive load, allowing learners to concentrate more fully on comprehension and retention. Furthermore, this automated adjustment provides reassurance to learners. Knowing that the speed will automatically slow down if they experience stress can help them relax and reduce anxiety. This, in turn, may create a more conducive learning environment where learners can engage with the material without the added pressure of managing their stress levels.

Another benefit of this approach is that it encourages learners to listen at faster speeds over time. When given the option, some learners may opt to listen at slower speeds even after they have developed the capability to comprehend at faster rates. The auto-increasing speed feature gently pushes these learners to adapt to a higher pace of listening, ensuring that they become proficient in understanding auditory content at normal speeds. This gradual increase in speed may help learners build confidence and improve their overall listening comprehension skills. Additionally, this approach could be particularly beneficial in real-world applications where listening at a normal or faster pace is essential. For instance, in academic or professional settings, where information is often presented quickly, learners who have trained with this system may be better equipped to keep up with the pace and process information efficiently.

One practical implementation of this approach is through a specially designed tablet-like device (see Figure 1). The demonstration in Figure 1 shows a device with two detachable handles, each equipped with two sensors. These sensors first establish the baseline heart rate for the individual user, serving as a point of comparison for later measurements. The use of two sensors on each handle enhances the accuracy of heart rate monitoring. Alternatively, this technology could be implemented via a smartphone and an associated app, where heart rate is measured using a smartwatch. This setup offers flexibility and convenience, allowing users to integrate the stress-reducing methodology into their everyday devices. As the learner begins listening to or watching the target material, their heart rate is continuously monitored. This real-time data enables the automatic adjustment of the material's speed based on the learner's stress levels. The learner also has the option to customize their experience by adjusting preferences. For example, they can set how slowly the auditory material should progress (e.g. 0.75x, 0.50x) or choose to rewind to a specific number of seconds when the heart rate reaches a predetermined point. This personalized approach aims to ensure that learners remain comfortable and relaxed, reducing stress and enhancing their ability to engage with the material. The ability to adjust playback speed and rewind based on physiological feedback creates a more adaptive and supportive learning environment.



Source(s): Figure by authors

Figure 1.
A demonstration of a speed auto-adjusting device

The approach proposed here presents novel and interesting directions for future research. As an initial step, conducting qualitative research to explore learners' experiences and perceptions with speed auto-adjustment would be informative. This research could investigate how learners feel about the technology, how it impacts their learning process, and any challenges they encounter. Additionally, research could examine which preferences learners choose, such as playback speed, and evaluate the effectiveness of these choices. Understanding learners' preferences and their outcomes could help refine the technology and make it more effective and user-friendly. Another important area of research would be investigating the impact of this approach on learner motivation, engagement, and listening comprehension. It is crucial to determine whether the automatic adjustment of speed based on heart rate not only reduces stress but also enhances these critical aspects of language learning. Furthermore, this research should consider various learner factors, including proficiency levels, learning needs, and (special) learning differences. Different learners may respond differently to the technology, and understanding these differences can help tailor the approach to meet diverse needs effectively. Finally, researchers could explore the role of feedback in enhancing learners' awareness and self-regulation during speed-adjusted listening activities. Providing learners with insights into their stress levels and how the adjustments are helping them could boost their self-awareness and enable them to take more active control of their learning process.

Conclusion

In this article, we underscored the importance of engaging in transdisciplinary research, where scholars from various academic disciplines collaborate on studies that address real-world problems. Our focus was on the potential contribution of electrophysiology research, particularly the measurement of heart rate, to enhancing listening comprehension skills. Specifically, we explored one approach aimed at alleviating listening stress: auto-adjusting listening speed based on heart rate measurements.

Drawing on insights from researchers in this field, we emphasize the need for caution and advocate for multi-method research approaches (Rojo López *et al.*, 2021). While electrophysiological measures such as heart rate monitoring offer valuable insights into stress levels during language learning, it is nevertheless essential to supplement these with traditional psychological measures. Combining different methodologies may lead to a more comprehensive understanding of learners' experiences and responses to stress. Furthermore, we highlight the potential limitations of electrophysiological measurements, such as susceptibility to extraneous factors like body movement and changes in respiratory patterns (Gregersen *et al.*, 2014). Recognizing these limitations is critical for ensuring the validity and reliability of research findings in this area.

We hope that this article serves as a catalyst for further research into integrating psychological instruments with electrophysiological measures to alleviate stress and enhance language learning outcomes. Exploring innovative approaches that leverage the strengths of both fields can help researchers develop more effective interventions and instructional strategies that support learners in achieving their language learning goals.

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