The Situation Specific Arousal Analyzer: Innovation in the Physiological Assessment of Foreign Language Education Anxiety

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As the most studied affective variable within foreign language education, the emotion of anxiety continues to generate significant research interest. Owing to technological developments in wearable research devices, new opportunities have arisen to expand the research methodologies used in the recording and assessment of foreign language education anxiety. This article contends that foreign language education research has over-emphasized the experiential component of emotion while neglecting the behavioural and physiological components. Attention is first given to the emergence of emotion as a significant focal point in foreign language education. The position of anxiety as an affective variable in foreign language education is then documented along with the methodological limitations of experiential measures. The article then highlights technological innovations in physiological data measurement and analysis in the form of the Empatica E4 wristband and the recent development of the Situation Specific Arousal Analyzer (SSAA) application. The article demonstrates how foreign language education anxiety researchers can use the Empatica E4 and SSAA to document autonomic nervous system arousal in real-time communication situations using high-integrity metrics such as Heart Rate Variability (HRV) and Electrodermal Activity (EDA) under a range of tailored conditions. The article ends with a call to foreign language education anxiety researchers to extend their methodological repertoire beyond experiential self-report measures and to consider the opportunities afforded by physiological data capture and analysis technologies.

Keywords: anxiety, arousal, foreign language education, methodologies, physiological assessment

INTRODUCTION

Almost two decades prior an article was published entitled "predicting autonomic reactivity to public speaking: don't get fixed on self-report data!" (Schwerdtfeger, 2004) in which the author cautioned that self-report measures of emotionality often fail to align with autonomic reactivity assessments. More recently, prominent researchers have championed the "lift-off of emotion research in applied linguistics" (Dewaele, 2019) and shifts toward the greater inclusion of educational psychology within the remit of foreign language education have produced several studies examining the affective role of emotions (Zheng and Cheng, 2018; Dewaele et al., 2019; Li, 2019; Li et al., 2019; Botes et al., 2020; Dewaele and Li, 2020; Chen et al., 2021; Dewaele and Pavelescu, 2021; Li et al., 2021; Pan and Zhang, 2021). It has long been known that emotions are "influenced by internal physiological processes" (MacIntyre, 2017, p. 28) and "call forth a coordinated set of behavioral, experiential, and

physiological response tendencies that together influence how we respond to perceived challenges and opportunities" (Gross, 2002, p. 281). However, rather than taking flight, the research methodologies used to isolate, capture, define and analyze emotions have remained grounded and based upon the recalled documentation of personal experience.

This reflects a constructivist belief that emotions can sufficiently be understood on a social level of analysis. This trend is evident in foreign language education research wherein the experiential components of emotion (self-reports, interviews, narratives) have been emphasized while the behavioural (speech characteristics, facial expressions, gestures, movements) and, to a much greater extent, the physiological components (autonomic nervous system arousal) have been marginalized. Such limitations have reinforced the perception that emotions continue to be "poorly studied and poorly understood" (Swain, 2013, p. 195).

As research into emotion is now an interdisciplinary undertaking supported by technological innovation, a recalibration of research methodology is required for the benefit of students, teachers, and the integrity of future research output. This article therefore draws attention to the research methodologies used to isolate, capture, define and analyze anxiety within foreign language education. Attention is directed toward technological innovations in physiological data measurement and analysis informed by the premise that "conscious emotional experience is closely bound to changes in bodily sensations. Indeed, if one accepts the notion that consciousness is grounded in biological processes … emotional experience must, by its nature, be physiological" (Pace-Schott et al., 2019, p. 267). To this end, the article highlights advancements made in the health tracking provisions of wearable wristbands with a focus on the Empatica E4, a "medical-grade wearable device that offers real-time physiological data acquisition, enabling researchers to conduct in-depth analysis and visualization" (Empatica Inc., 2021). This article showcases how foreign language education researchers can use the device to document autonomic nervous system arousal in real-time communication situations using high-integrity metrics such as Heart Rate Variability (HRV) and Electrodermal Activity (EDA). To facilitate the uptake of such technological innovations among non-clinical practitioners, this article further introduces the Situation Specific Arousal Analyzer (SSAA) application. The SSAA allows practitioners to analyze physiological arousal under a range of tailored conditions focused on either the micro analysis of arousal in time specific segments (e.g., assessed every few seconds across the duration of an L2 spoken presentation) or relative to longer macro periods of analysis (e.g., assessed across an entire classroom period). The article ends with a call to foreign language education anxiety researchers to extend their methodological repertoire beyond experiential self-report measures and to consider the opportunities afforded by physiological data capture and analysis technologies.

Anxiety in Foreign Language Education

Since the mid 1980s research attention within foreign language education has fixated on the emotion of anxiety and its negative impact upon the language learner (Aida, 1994; MacIntyre and Gardner, 1994; Onwuegbuzie et al., 1999; Gregersen and Horwitz, 2002; Dewaele et al., 2008). Drawing attention to the experiential and physiological components of anxiety, the American Psychological Association (2021) defines the emotion as being "characterized by feelings of tension, worried thoughts and physical changes like increased blood pressure". While the physiological properties of anxiety may be universal, the situational onset of anxiety lends itself to a basic distinction between trait anxiety and state anxiety. This distinction is significant in that "many investigations use the word 'anxiety' without being specific about what they are talking about" (Robinson et al., 2013, p. 14). Trait anxiety denotes a relatively stable feature of an individual's personality profile and reflects a predisposition to psychopathological conditions and heightened states of arousal such as panic attacks, whereas state anxiety or experimentally-induced anxiety is a more temporal situation-specific experience (Spielberger et al., 1983) often occurring in the absence of underlying psychopathological conditions. As a response to environmental stimuli, anxiety is a particularly important emotion due to its evolutionary function in survival and the avoidance of threat. The underlying mechanisms concerning the processing of environmental stimuli as threatening also informs conditions such as social anxiety disorder, agoraphobia, and a range of panic disorders which now constitute a considerable worldwide burden having social and economic consequence. Emotions which relate to evolutionary survival are more likely to be inclusive of physiological activity as the body prepares to defend itself or flea the perceived threat. Researchers have used this to explain why certain emotions such as happiness and joy often have no accompanying physiological profile (Levenson, 2003).

Prompted by the seminal work of Horwitz et al. (1986) and the Foreign Language Classroom Anxiety Scale (FLCAS), state anxiety has developed into the most studied affective variable in foreign language education research. Horwitz et al. (1986) detail how anxiety within the context of foreign language education can be distinguished from trait anxiety and conceptualized as a "specific anxiety reaction" which presents "a major obstacle to be overcome in learning to speak another language" (p. 125). As rationale in the development of the contentious, but still widely used, Foreign Language Classroom Anxiety Scale (FLCAS), the authors assert that "the symptoms and consequences of foreign language anxiety" should "become readily identifiable to those concerned with language learning and teaching" (p. 125). Over three decades since this research was published, the domain of foreign language education has not conclusively identified the symptoms or consequences of the specific anxiety reaction, made distinctions between adaptive and maladaptive experiences of anxiety, nor clarified important differences between temporal mood states, worry, stress, intolerance of uncertainty and specific anxiety reactions. This lack of development is in part due to the methodologies used to confirm the presence of the concept and the challenge of attributing cause-effect relations.

Experiential Data

Psychological problems such as anxiety concern emotion regulation or "the processes by which we influence which emotions we have, when we have them, and how we experience and express them" (Gross, 2002, p. 282). With a similar focus, Horwitz et al. (1986) contend that Foreign Language Classroom Anxiety (FLCA) is "a distinct complex of self-perceptions, beliefs, feelings and behaviours related to classroom learning arising from the uniqueness of the language learning process" (p. 128). This definition essentially concerns cognition in the form of self-perceptions, beliefs and feelings within a generalized environment, albeit one dramatically different from the new realities of language education being created through learning online. State anxiety can therefore be linked, as both cause and effect, to faulty perceptions of interpersonal threat and poor emotion regulation. The irrational beliefs and feelings generated under perception of interpersonal threat are either reappraised or suppressed by the individual, with the latter option having been found to reduce emotional memory recall (Richards and Gross, 2000). It has further been shown that the suppression of state anxiety not only impinges upon accurate memory recall but also results in the production of a greater physiological response to stressful stimuli (Malouff et al., 1992; Egloff et al., 2006).

This is problematic in that the experiential self-reports used to capture the cognitive aspects of the individual demand participants to recall information based on experience under the assumption that all individuals are equipped to perform this task to a high degree of accuracy. The reliability and validity of the data gathered are therefore beyond the immediate control of the researcher and dependent upon the subjectivities of the individual. Moreover, it is known that physiological processes can "influence emotion below the level of conscious awareness" which further "raises the question of whether emotion can be experienced or expressed with absent or attenuated consciousness" (Pace-Schott et al., 2019, p. 270). The information recalled in relation to generalized environmental stimuli necessitates that even when reliable cognitive recall is possible, the intensity, duration and momentary fluctuations within the experience are beyond the conscious awareness of most individuals (Schwerdtfeger, 2004). Harmon-Jones et al. (2016) assert that it is therefore inappropriate "to assume that a null effect on a self-report measure means that emotional processes were not involved in the psychological phenomena of interest. That is, the (often poor) measurement of emotion should not be conflated with emotion itself" (p. 2). Experiential self-report methods of data collection are are often thus negligent to the conceptual distinction between actual lived sensory experience and post-activity semantic recall (Robinson and Clore, 2002).

Physiological Data

Due to its evolutionary function in protecting individuals from situations perceived as threatening, anxiety is an ideal emotion for the incorporation of physiological measurement, especially as state anxiety can be experimentally induced. Physiological data provides a more reliable foundation for the attribution of cause-effect relations as it is "difficult for individuals to mask or control, which creates the possibility of more objectively gauging individuals' arousal" (Roos et al., 2021, p. 583). As one of a select few integrated assessments of state anxiety within foreign language education, Gregersen et al. (2014) triangulated physiological, idiodynamic, interview, and self-report data. However, the somewhat invasive procedure was technologically limited and promoted the misattribution of experimental stimuli. The process included recording a presentation (behavioural) and having participants self-rate their moment-by-moment anxiety 42 times over three-and-a-half-minutes (experiential). Moreover, while the study made use of wearable technology to measure physiological responses, this was limited to heart rate. The use of heart rate monitors to assess state anxiety dates to the 1960s where studies used pulse-monitored heart rate as an indicator of test-anxiety (Harleston et al., 1965). It is now known that the use of heart rate as an indicator of autonomic nervous system arousal is problematic due to the combined role of the sympathetic and parasympathetic nervous systems (Cohen et al., 2000). For instance, an individual's heart rate is impacted by factors such as food consumption, caffeine intake, lack of sleep and general fatigue.

Further problems with the use of heart rate concern the fact that it cannot be fixed as a reliable indicator of emotional state or cognitive perception. Within the Gregersen et al. (2014) study inconsistencies were found between high heart rate readings and individual perceptions of anxiety. The authors explain how one participant "could have construed her racing heart as a debilitating sign of anxiety, thus initiating a downward spiral or negative-narrowing emotion; instead, she interpreted the accelerated heart rate as positive-broadening energy, which resulted in her channeling it into enthusiasm" (p. 586). Physiological arousal processed as indicative of anxiety may be reflective of excitement under the same experimental conditions dependent on the cognitive processing and emotion regulation of the individual. Brooks (2014) confirms that "anxiety and excitement have divergent effects on performance, but the experience of these two emotions is quite similar" (p. 1144). Roos et al. (2021) also caution that "different emotions (e.g., anxiety and excitement) can have the same physiological signatures". From this psycho-physiological insight further questions can be asked as to why the research literature on foreign language education has conclusively framed anxiety as a negative emotion (Rossi and Pourtois, 2012).

Two of the most prominent metrics used in the physiological assessment of anxiety are Heart Rate Variability (HRV) and Electrodermal Activity (EDA) (Croft et al., 2004; Blom et al., 2010; Nikolic et al., 2018; Sebastiao, 2021). As a reliable psychophysiological marker of health and well-being, HRV reflects an unobtrusive measure relating to the modulation of heart rate under instruction of the autonomic nervous system. HRV represents the variance in duration between heart beats or fluctuations in heart beat over a period of time measured in milliseconds. It is believed that low variation in duration between heart beats is indicative of the priming of the fight-or-flight response and is thus linked to greater levels of anxious arousal whereas a more relaxed individual might demonstrate a higher
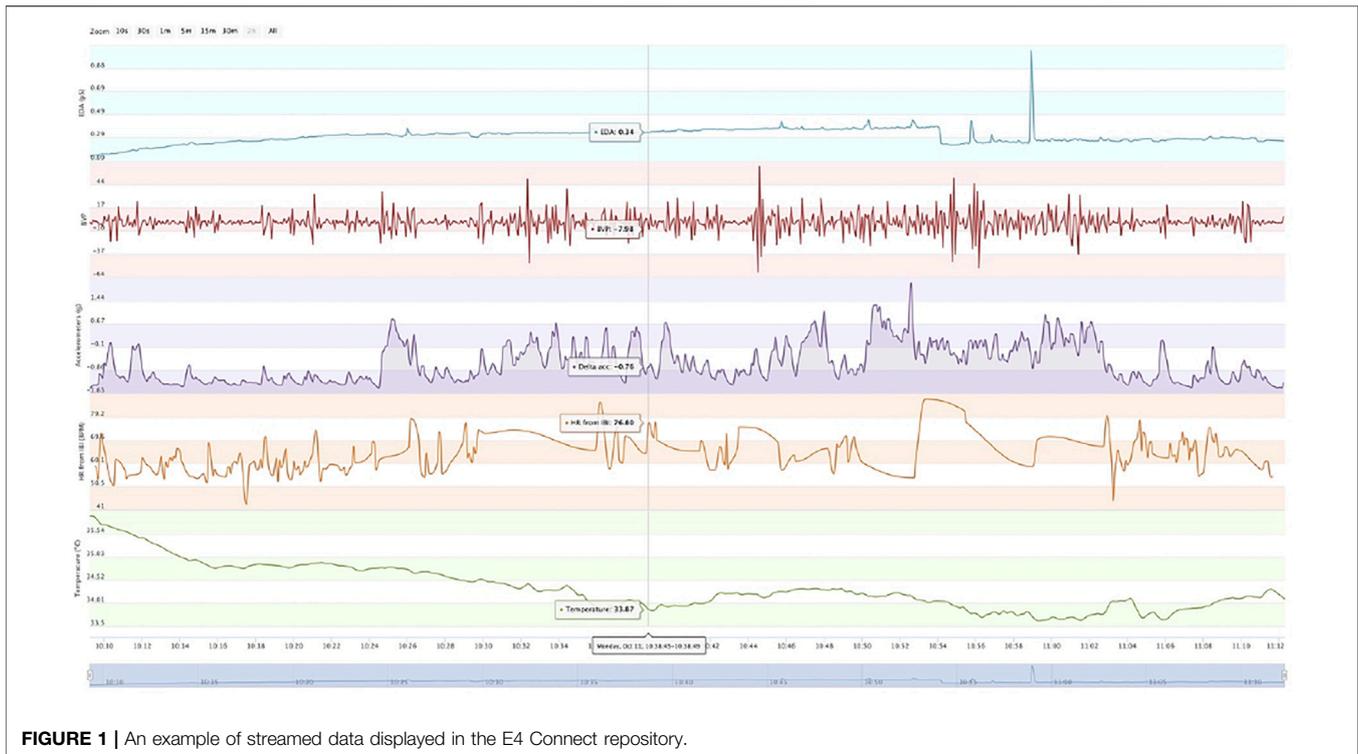
FIGURE 1 | An example of streamed data displayed in the E4 Connect repository.

variation in the duration between heart beats (Buccelletti et al., 2009). Reduced resting-state HRV has been linked to depression, alcoholism and pathological worry (Kemp et al., 2010; Quintana et al., 2013; Tully et al., 2013) while it has been reported that sufferers of anxiety are often characterized by a reduced HRV in comparison to non-anxiety sufferers. Held et al. (2021) report that "individuals suffering from an anxiety disorder are characterized by chronically low heart rate variability compared to healthy individuals during resting state conditions" (p. 1). HRV has further been linked to psychological well-being, cardiovascular health and mortality (Chalmers et al., 2014). In contrast to HRV, EDA detects autonomic changes in the electrical properties of skin which allows researchers to remove the parasympathetic contamination found within the use of heart rate monitors (Braithwaite et al., 2013). EDA has been described as providing an objective indication of arousal (Posada-Quintero and Chon, 2020). As a correlate of sympathetic nervous system activity, EDA concerns the volume of sweat produced by eccrine sweat glands. It is believed that the greater the volume of sweat present, the more electrical conductivity can be measured (Figner and Murphy, 2011). EDA has been used as a metric within studies of mathematics anxiety (Pizzie and Kraemer, 2021) and as a predictor of public speaking anxiety (Egloff et al., 2006; Sevinc, 2018; Lee et al., 2020).

The Situation Specific Arousal Analyzer

State specific anxiety is dynamic rather than static and momentary fluctuations in arousal can be expected even within the context of exposure to specific stimuli. Given that state anxiety corresponds to a specific stimulus, it is incumbent upon researchers to establish a clear start and end to accurately connect the stimulus to the response and avoid the misattribution of emotions to uncontrolled factors. However, within foreign language education research fixed durations including fluctuations across the timespan have not been documented due to methodological limitations and challenges in data processing. Recent advances in wearable health tracking devices have now created new opportunities for improvements to be made in terms of methodology and assessment. As one such device, the Empatica E4 wristband uses four censors which allow data to be "unobtrusively and continuously acquired while participants are performing the cognitive task" (Shackman et al., 2006, p. 42). Within the Empatica eco-system data from the E4 wristband can be captured in real-time and uploaded to the E4 Connect repository where the data files can then be downloaded into specialized software for further analysis. **Figure 1** shows the streamed data displayed in the E4 Connect repository. For non-clinical researchers knowing how to process this data and how such data can then support the study of emotions in the classroom is challenging. The data uses a range of complex metrics and formulae which demand specialized reading often beyond the domain of foreign language education. From a technical perspective, it is therefore understandable as to why complex physiological data has not found its way into the methodological repertoire of studies into foreign language education anxiety until now.

Informed by the challenges outlined, the Situation Specific Arousal Analyzer (SSAA) application has been devised for use within the context of foreign language education to for the on-off

TABLE 1 | An example of the tabulated data generated by the SSAA.

Metric	Baseline	Five minute L2 spoken presentation				
		0–60 s	60–120 s	120–180 s	180–240 s	240–300 s
HR Mean (bpm)	69.989	61.139	61.736	67.277	67.252	65.425
HR SD (bpm)	5.21	5.322	5.979	9.522	3.027	1.696
NN Mean (ms)	1,007.5	1,050	997.396	1,011.837	1,011.068	995.924
NN SD (ms)	78.502	45.793	61.588	72.242	79.603	69.274
VLF (ms2/Hz)	991.945	73.596	669.639	353.985	849.354	749.903
LF (ms2/Hz)	1,083.81	524.313	665.508	1,183.549	1,122.134	1,636.343
HF (ms2/Hz)	834.375	355.717	790.207	1,015.255	744.214	219.904
LF/HF	1.299	1.474	0.842	1.166	1.508	7.441
PP SD1 (ms)	49.973	26.865	44.672	44.115	62.704	30.205
PP SD2 (ms)	99.685	57.905	70.824	92.491	95.01	95.51
EDA Mean (uS)	0.183	0.253	0.263	0.276	0.302	0.312
EDA SD (uS)	0.03	0.006	0.004	0.004	0.004	0.004
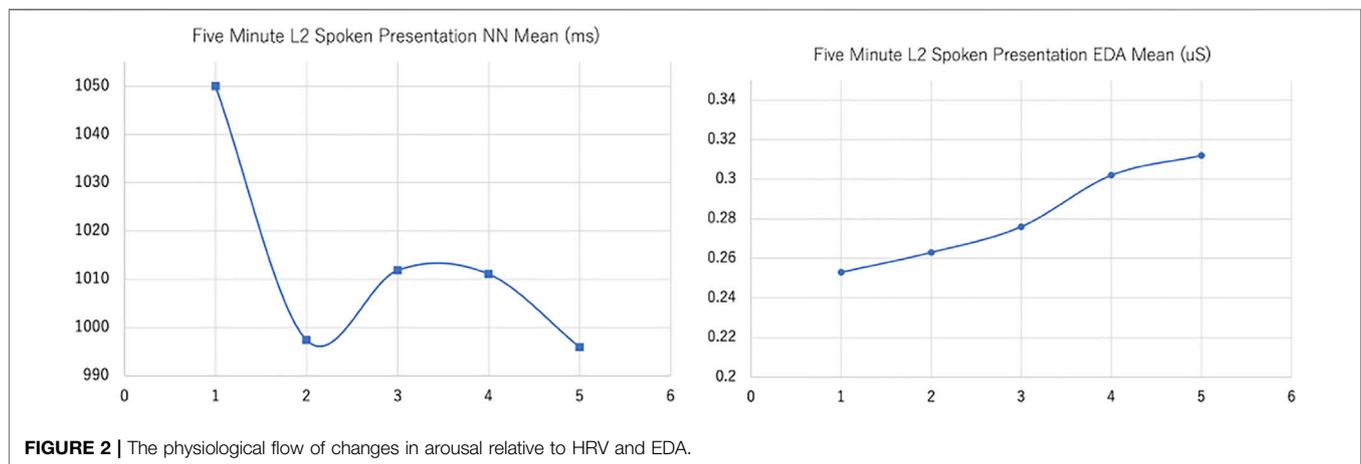
FIGURE 2 | The physiological flow of changes in arousal relative to HRV and EDA.

task physiological measurement and tracking of autonomic nervous system arousal. The SSAA application can be used through either the OS X or Windows platform and primarily focuses on the calculation of Heart Rate (HR), Heart Rate Variability (HRV) (time-domain methods, frequency-domain methods, non-linear domain methods) and Electrodermal Activity (EDA). The interface can be tailored to meet a range of experimental conditions focused on the micro analysis of arousal in time specific segments such as every few seconds during an L2 spoken presentation, or relative to longer macro periods of analysis such as across an entire classroom period. For the HRV time-domain, the beat-to-beat interval (NNMean) can be calculated up to once per 0.015625 (1/64) second while for the EDAMean it is possible to capture data once per 0.25 (1/4) second. The SSAA generates and exports these results as tabulated CSV files and visualizations. **Table 1** provides an example of the tabulated output from the SSAA application based on the assessment of a five-minute L2 spoken presentation with measurements at 60-s intervals.

The SSAA application also produces data outputs and visualizations for the HRV frequency-domain (low frequency (LF), high frequency (HF) and the ratio of LF and HF (LF/HF)) and for the HRV non-linear domain (SD1 and SD2 Poincaré Plots) although these outputs are not anticipated to be as useful within the context of foreign language education due to their complexity. The tabulated data for each student can be plotted into more accessible line charts for the basis of analyzing the physiological flow of changes in arousal relative to each metric within and between students. **Figure 2** shows the physiological flow for HRV mean and EDA mean for an individual L2 presentation across a five-minute duration.

While "there are some works in the literature regarding the physiological signals and their correlation with emotional experiences, the accuracy of the analysis seems to be dependent on the data set" (TaheriNejad and Pollreisz, 2017, p. 107) (see Blascovich and Tomaka, 1996; Huwe et al., 1998). The data quantification undertaken by the SSAA represents a significant innovation in accessible research methodology applicable to the study of foreign language education anxiety. The data generated through the SSAA permits correlations and affective relationships to be analyzed with other variables such as language acquisition and achievement (Dewaele and Li, 2020), emotional intelligence (Chen et al., 2021), intellectual humility (Moskowitz and Dewaele, 2020) and motivation and personality (Pan and Zhang, 2021). More importantly, the SSAA application supports the view of emotion as a multifaceted process inclusive

of "components such as appraisal of the situation, action preparation, physiological responses, expressive behavior, and subjective feelings" (Scherer and Moors, 2019, p. 721). It provides greater access to a much-needed physiological component in the study of state specific anxiety and an overdue partner to the experiential self-report measures currently used.

CONCLUSION

This article has directed attention toward the need for more innovative assessments of state anxiety within foreign language education. The current situation and methodological lag can be likened to police assessments of driving under the influence of alcohol which are no longer informed by the experiential self-reports of the driver, but through the technological affordances provided in the form of an easily administrable breathalyzer device. In the same way that the physiological assessment of anxiety infers the emotion through the presence of autonomic nervous system arousal, the breathalyzer does not directly assess blood alcohol content, but rather estimates it through the amount of alcohol in the breath of an individual. To most readers it perhaps seems unimaginable to think of a contemporary police service which would now be reliant upon the experiential self-reports of the driver rather than combining such narratives with the more robust physiological assessments provided by technological innovation. This article has outlined why physiological data must now become a more prominent feature of research output if situation specific anxiety is to remain the most studied affective variable within the domain of foreign language education. It is acknowledged that "there is no 'gold standard' measure of emotional responding" (Mauss and Robinson, 2009, p. 209) and the physiological data generated by the Empatica E4 and processed by the SSAA should ideally be used alongside experiential self-report measures and behavioural video recordings thus reflecting the tripartite profile of human emotion. The extent to which physiological data relates to experiential self-report measures or observed behavioural indications of arousal remains undocumented within the context of foreign language education and represents an exciting area of future research. It is hoped that innovations such as the SSAA encourage more non-clinical researchers to accommodate physiological data into their methodological repertoire to align the study of foreign language education anxiety with the technological opportunities now available.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and has approved it for publication.

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