Physiological evidence of stress during woodwind sight-reading

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Abstract
Music performance anxiety (MPA) research has investigated solo performance, using self-reports and questionnaires to measure the efficacy of interventions to reduce MPA. Studies examining physical symptoms of MPA have measured heart rate and muscle tension of players. This pilot study examined MPA’s effects during music sight-reading (SR) by measuring physiological responses and SR accuracy amongst undergraduate woodwind students. The results demonstrate increased arousal as testing materials became more challenging and SR accuracy decreased. Implications for future research and practice include the need to incorporate MPA interventions into SR training and gather physiological evidence to demonstrate the efficacy of therapeutic programmes for management of MPA.

Keywords
Electrodermal activity, heart rate, music performance anxiety, music sight-reading, physiological evidence

Introduction
Performance anxiety affects many musicians, resulting in less than optimal performance in stressful situations such as recitals, examinations, and competitions (Wilson, 1997; Wilson & Rolland, 2002).

The term “music performance anxiety” has been defined by Kenny (2010) as nervousness associated with musical performance that has accumulated over many years of negative experiences into disruptive symptoms that tend to flare up more acutely when the performance is perceived as important.

Music performance anxiety (MPA) has been documented in musicians of all ages and skill levels. Research has reported MPA symptoms amongst young children learning music (Britsch, 2005), teenage musicians (Fehm & Schmidt, 2006; Osborne, Kenny, & Holsomback, 2005), higher education music students (Biasutti & Concina, 2014; Kokotsaki & Davidson, 2003) and professional musicians (Biasutti & Concina, 2014). While professionals have more experience in managing MPA, nonetheless they may still experience anxiety before playing. This suggests that debilitating MPA symptoms can persist throughout the musician’s life.

MPA’s impact on musicians has a pronounced sex bias, with females reporting being affected more frequently by MPA symptoms than males at various stages of their careers. Research has now shown that young girls learning music (Ryan, 2004), teenage girls (Patson, 2014), higher education female students (Guven, 2017; Struder et al., 2011) and even professional female players (Kenny, Driscoll, & Ackermann, 2014) are reporting a higher incidence of MPA symptoms than their male peers. Music educators need to be aware of the higher incidence of MPA in females when helping their students to manage its affects.

Several studies have focused on measuring MPA symptoms using medical grade equipment to provide strong evidence of their existence and demonstrate adverse impact on music performance. In particular, research into physical symptoms of MPA has reported increased heart rate in musicians. For example, Abel and Larkin (1990) measured the heart rate and blood pressure of higher education students, using a photoplethysmography sensor attached to a finger. Researchers took a baseline measurement when students were relaxed and another just before a practical.
examination. Results showed that all students exhibited a higher heart rate preperformance but the females reported feeling higher anxiety. In another study LeBlanc, Jin, Obert, and Siivola (1997) used a Heart Rate Polar Vantage XL monitor (similar to today’s smart watch) to measure the heart rate of wind and brass high school instrumentalists playing in three conditions: an empty room; with one person listening; in front of audience and judges. A higher heart rate was detected when students played for audience and judges, with the female students playing better than the males but reporting higher anxiety. In a more recent study, Yoshiie, Kudo, Murakoshi, and Ohitsuki (2009) used a medical wristband to measure the heart rate of higher education and post-higher education pianists. In order not to disturb the natural hand movements of pianists, the wristband was worn on a belt around the waist. The results showed considerable increase in heart rate from a nonstressful rehearsal to a real-life competition performance in front of audience and judges; however, the data were not analyzed with regard to sex. While earlier research did not demonstrate sex differences in the heart rate of musicians, a recent study by Chanwimalueang et al. (2017) did report higher cardiovascular reactivity in female participants. This study compared advanced violin and flute students from United Kingdom and Switzerland conservatoriums in a sex-balanced sample, measuring their heart rate in low stress (no audience) and high stress (in front of an audition panel) performance using an electrocardiogram (ECG). This study provides physical evidence to support previous research that has reported higher self-perception of MPA symptoms by female musicians.

Researchers have also measured muscle tension and muscle fatigue in musicians experiencing MPA. For example, Rumsey, Aggarwal, Hobson, Park, and Pidcocke (2015) employed surface electromyography on the shoulder muscles of 27 undergraduate trumpet players, comparing results of an anxiety-induced group versus control. A warning that all errors were being counted resulted in greater muscle tension and muscle fatigue in the stressful condition group than in the control. Similarly, using surface electromyography, Yoshiie, et al. (2009) demonstrated higher levels of co-contraction of antagonistic muscles in pianists’ forearms and in proximal muscles of biceps and trapezium under stressful competition performance versus the relaxed rehearsal.

In contrast to limited investigations measuring the physical symptoms of MPA, a large body of research into the psychological impact of MPA has relied heavily on self-reports, using surveys, inventories, and questionnaires to measure preexisting levels of anxiety in musicians and any improvements after therapeutic interventions aimed at reducing anxiety. There are many commonly used evaluation instruments, including Appraisal of Music Performance Stress (AMPS), General Health Questionnaire (GHQ-28), Kenny Music Performance Anxiety Inventory (K–MPAI), Music Performance Anxiety Questionnaire (MPAQ), Music Performance Stress Survey (MPSS), Performance Anxiety Inventory (PAI), Performance Anxiety Questionnaire (PAQ), Performance Anxiety Self-Statement Scale (PASSSS), State-Trait Anxiety Inventory (STAI) and Self-Assessed State Anxiety Scale (SASAS) (Kenny, 2011).

Few studies trialing MPA interventions have measured physiological changes in MPA symptoms in addition to administering standard survey instruments, as mentioned above. In one example, Kim (2008) used a finger thermometer available from a standard biofeedback supply store to record changes in finger temperature of university pianists to demonstrate the effectiveness of progressive muscle relation intervention that was accompanied by soothing music. The physical evidence gathered in this study was supported by the findings from the STAI and MPAQ administered to the participants. Lilley, Oberle, and Thompson (2014) conducted an interesting intervention to reduce test anxiety (though not in a music performance setting). They played either “calm or obnoxious” music to undergraduates before a mathematics test and measured their blood pressure and heart rate using a standard blood pressure cuff. Listening to calm music resulted in lower blood pressure, lower heart rate, and higher test scores from participants (p. 184). While this study suggests that listening to relaxing music may be beneficial prior to a stressful event, this idea is yet to be trialed on musicians as an MPA-mitigating strategy.

MPA research has focused largely on solo performance and little is known regarding MPA’s impact on the wide range of musical skills expected from today’s graduate; for example, improvising and sight-reading (SR). There is anecdotal evidence that some music students find SR stressful, with undergraduates reporting underdeveloped skills in this area. For example, Zhukov (2014) and Michalski (2008) have documented that SR expertise among Australian undergraduate pianists is low. The question of how to improve SR skills and prepare music students for portfolio careers is still being debated. For example, typical approaches to improving SR by practicing have been debunked (Zhukov, 2017), while research-based SR pedagogy that includes rhythm training, experience of different styles, and ensemble playing is showing promising results (Zhukov, Viney, Riddle, Teniswood-Harvey, & Fujimura, 2016).

This article asks the question: does the difficulty of a SR task bring about MPA symptoms? This pilot study investigates the physical symptoms exhibited during SR by measuring the physiological responses of undergraduate woodwind players elicited during sight-reading testing.

Method

Participants

After obtaining ethical clearance for the study, we recruited six volunteer undergraduate students (three flautists and
three clarinettists) at an Australian university. The students ranged from the first to the fourth year of their Bachelor of Music degree and 18–22 years of age ($M = 19.67$). Their expertise level varied from intermediate (grade 6, AMEB) to advanced (diploma level, AMEB). See Table 1 for sample demographics.

### Procedure

The experiments took place in a laboratory on campus. Music examples were displayed on computer screen and the student playing was recorded using a Polycom Speakerphone. Physiological data was collected using an Empatica E4 wristband (https://www.empatica.com; Empatica Inc., Cambridge, MA), which has the appearance of a sports watch with a single large button. The protocol included orientation around the laboratory, signing of consent forms, getting comfortable in a chair in front of the computer, playing a few passages on the instrument to warm up, sight-reading 11 musical examples and completing a short exit survey. Participants identified each of the three pre-testing events and 11 music SR events by pressing the marker button on the Empatica wristband.

**Physiological Measurements.** The Empatica E4 wristband is a wireless device that collects real-time data using four sensors. The photoplethysmography sensor provides blood volume pulse, from which heart rate may be derived. The electrodermal activity sensor measures the arousal of the sympathetic nervous system by capturing variations in skin conductance. The wristband streams live data to the Empatica app, installed on a mobile phone. The app uploads the data to a secure platform (Empatica Connect) where it can be accessed at a later date. The software provides a variety of outputs including electrodermal activity (EDA) and heart rate (HR). The raw data is downloaded in comma-separated values (CSV) file format with time stamps indicating individual events within a single recording session.

### Stimuli Materials

Sight-reading materials were sourced from the Watkins-Farnum Performance Scale (1954), which has been used by researchers and music teachers as a standard SR test for band instruments for over 60 years. The musical examples are identical for each instrument but transposed into a suitable key and range. The first 11 out of 14 available examples were chosen in this study as appropriate to the expertise level of the participants and were presented in sequential order of increased difficulty.

### Analyses

**Scoring of SR Accuracy.** Two highly experienced researchers/music educators independently scored the recorded audio files for pitch and rhythm accuracy, as per instructions in the Watkins-Farnum Performance Scale (1954). Intercjudge correlation was carried out to confirm the veracity of scoring.

**Physiological Outputs Analyses.** EDA and HR outputs for each participant were downloaded from the Empatica Connect platform in CSV format. EDA was measured four times per second and HR once per second. Using time stamps, the continuous output was sliced into 14 events (three pretesting events and 11 SR testing events) and the mean for each event was calculated. Mean values were plotted on a graph to provide a visual representation of physiological changes across the experiment.

**Statistical Analyses.** To investigate any links between the SR performance accuracy and physiological data, nonparametric correlations (Spearman’s rho) were performed between SR, EDA, and HR means across the 11 music events, using SPSS 22.0 software.

### Results

**SR Accuracy Analyses**

The inter-judge correlation for scoring of overall SR accuracy was .948, $p < .05$, higher than predicted by the Watkins-Farnum Performance Scale (1954). Table 2 provides scores for overall SR accuracy.

To examine more closely how participants performed as testing materials became more difficult, SR means for each musical example were plotted on a graph (Figure 1).

The graph shows that few errors were made by participants in the first five examples; however, as materials became more difficult the number of errors increased dramatically, particularly for P05 and P03. The most consistent and accurate performance was by P01, with P02, P04, and P06 having varied levels of success with the more difficult musical examples.

### Table 1. Sample demographics.

| Participant ID | Age (years) | Sex | Years of learning the instrument | Exam level passed |
|----------------|-------------|-----|----------------------------------|------------------|
| P01            | 22          | F   | 11                               | Diploma Level 2  |
| P02            | 19          | M   | 15                               | Diploma Level 1  |
| P03            | 19          | F   | 13                               | Grade 8          |
| P04            | 19          | F   | 9                                | Grade 7          |
| P05            | 18          | F   | 6                                | Grade 6          |
| P06            | 21          | F   | 13                               | 6                |
| Mean           | 19.67       | 11.17| 7.67                            |                  |

Zhukov
EDA Analyses

EDA is a measurement of variations in skin conductance, reflecting the physiological or psychological arousal of a participant during the experiment. While each participant began with a different level of EDA (some higher and some lower), it is the EDA trajectory across the duration of the experiment that tells an interesting story about the individual participant’s arousal (Figure 2).

The analysis of physiological data suggests that EDA continued to increase as the music examples became more difficult for five out of the six participants, with only one participant (P01) remaining utterly calm and composed throughout the experiment, demonstrating a flat line EDA.

HR Analyses

HR results present a complex picture of coping with challenges of the experiment. The decreases in HR over the first three pretesting events illustrate how all participants settled during the lab-orientation procedures. Once SR testing began, students’ HR means varied a great deal between each participant. For example, the most accurate SR (P01) displayed the most stable HR over the experiment. The HRs of the two participants with lowest SR scoring were for the five final musical events the most elevated (Figure 3).

Statistical Analyses Across SR, EDA, and HR Categories

Nonparametric correlations (Spearman’s rho) between SR, EDA and HR means across the Event Trials revealed the following statistically significant correlations: a strong negative correlation between SR and Event Trial Number, a strong positive correlation between EDA Event Trial Number, a strong negative correlation between SR and EDA, and a moderately strong positive correlation between SR and HR (Table 3).

Discussion

Research has demonstrated that higher education music students experience MPA symptoms in relation to solo
performance (Biasutti & Concina, 2014; Kokotsaki & Davidson, 2003). Little is known regarding of MPA’s impact on the broader range of music skills, such as SR. While lack of SR training and weaknesses in this skill have been reported in Australian higher education settings (Michalski, 2008; Zhukov, 2014), the link between MPA and SR performance has not been investigated as yet.

Previous research measuring physiological symptoms of MPA has focused on musicians’ heart rate (Abel & Larkin, 1990; Chanwimalueang et al., 2017; LeBlanc, Jin, Obert, & Siivola, 1997; Yoshie, Kudo, Murakoshi, & Ohtsuki, 2009) and muscle tension and fatigue (Rumsey, Aggarwal, Hobson, Park, & Pidcoe, 2015; Yoshie et al., 2009). New technological developments such as the Empatica E4 medical grade wristband and associated software are giving researchers new tools to gather physiological data such as heart rate and electrodermal activation during various musical activities.

This study gathered physiological data to provide new insights into MPA’s impact on music skills that are not typically investigated by MPA research. SR accuracy declined for most participants as the testing materials became more difficult. This is seen as a sharp decline in accuracy scores over the last three events in Figure 1. Only P01 remained fairly accurate throughout SR testing. This finding is confirmed by the correlation of \(-0.886 (p < .01)\) between SR and Event Trial Number.

EDA results appeared to be linked to SR accuracy results, with the best sight-reader (P01) displaying a steady, flat-lining EDA throughout the experiments and the other participants displaying increased EDA as test materials became more challenging. The EDA findings were supported by the statistical analyses that showed correlation of \(0.999 (p < .01)\) between EDA and Event Trial Number, demonstrating that increased difficulty of music examples was accompanied by increased arousal. The correlation of \(-0.886 (p < .01)\) between the EDA and SR confirmed that arousal increased at the same time as SR accuracy fell.

The EDA results present an interesting point for speculation, with three participants indicating no anxiety in their exit survey despite the physical evidence showing an increased arousal. This suggests that perhaps these participants managed to frame their increased arousal positively (for example, as excitement) and did not experience arousal as anxiety. Research has shown that reframing the stressor in positive ways is the most frequently used coping strategy among undergraduate music students (Araujo et al., 2017). This issue needs further investigation.

HR results were less clear, as seen in Figure 3. The participants acclimatizing to the lab environment could explain the initial drop in HR over the first three “nonmusic” events. As testing materials became more challenging, variations in HR were unique to each participant, though generally slightly higher towards the end of the experiment. This is borne out by the statistical analyses that showed a correlation of \(0.653 (p < .029)\) between HR and SR but no significant correlations between HR and EDA and HR and Event Trial Number. One participant described feeling the waves of “panic” throughout the experiment: being in control for one or two music examples, panicking during another example, feeling calmer again—all occurring several times over the duration of the experiment. This description illustrates the cyclical nature of MPA symptoms that may explain why HR results were not as clear-cut as EDA results.

The findings of this study provide physiological evidence that some music students experience stress during SR, with five out of six participants demonstrating increased EDA as test examples became more difficult. The HR results were more complex; however, the most accurate SR participant displayed the most stable HR throughout the experiment, while the two weakest SR participants showed the most elevated HR towards the end of the testing. These findings suggest that the difficulty of a SR task can impact MPA symptoms.

**Conclusions**

Due to a very small sample with only one male participant, it was not possible to analyze data by sex. Future research needs to be conducted with larger sex-balanced samples to gather physical evidence of differences in MPA symptoms between female and male musicians to verify self-perceptions reported by psychological research.
The findings of this pilot study highlight the need for large-scale MPA interventions to broaden their scope by investigating specific music skills important for classical music careers in the 21st century instead of focusing only on solo performance.

Similarly, SR research should consider including MPA assessment as part of experimental design. In particular, training of SR skills might need to include MPA interventions in order to be fully effective. Future research could also investigate if the use of effective SR strategies could mitigate the impact of anxiety on SR accuracy/performance. For example, we do not know whether a simple strategy of scanning the score prior to SR has any impact on perceived anxiety or physiological indicators such as EDA and HR. More research is urgently needed, with findings particularly beneficial to orchestral musicians who have to sight-read during orchestral auditions where SR and a solo performance overlap completely.

Other implications for future MPA research include the need to validate the effectiveness of interventions aimed at reducing MPA through the collection of pre and post physiological evidence in addition to the use of self-reports.

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