The use of Galvanic Skin Response (GSR) and Peripheral Temperature (PT) to Monitor Relaxation during Mindfulness Imagery with Relaxing Music

Garry Kuan 1✉, Tony Morris 2 & Peter Terry 3

1 Exercise and Sports Science, School of Health Sciences, Universiti Sains Malaysia, Kelantan, Malaysia.
2 Institute of Sport, Exercise, and Active Living, College of Sport and Exercise Science, Victoria University, Melbourne, Australia
3 Department of Psychology, University of Southern Queensland, Toowoomba, Australia

Abstract
Anxiety is often a challenge for athletes making it difficult for them to perform at their optimum. Many successful athletes have acknowledged that imagery, deep breathing exercises, and relaxation techniques are important in anxiety management (Curtin, Munroe-Chandler, & Loughhead, 2015; Pineschi & DiPietro, 2013). Relaxation is important for low arousal sports, such as archery, shooting, and dart-throwing (Zhang, Si, Duan, Lyu, Keatley, & Chan, 2016). The Mindfulness-Acceptance-Commitment (MAC) approach has recently been introduced into the applied sport psychology field and is gaining interest (Gardner & Moore, 2007, 2012). Gardner and Moore claimed that MAC will result in improved quality of practice or training and competitive performance, as well as increased enjoyment of the athletic experience. Mindfulness imagery with music involves putting oneself in a relaxing state of mind that also relaxes the physical body. The combination of imagery and music can create experiences, such as enjoyment, positive thoughts, confidence, and “being in the zone”. GSR is a device to detect and monitor levels of relaxation, however, the use of peripheral temperature (PT) in relation to relaxation has not been studied. Samples of GSR and PT were collected from music and imagery of five elite shooters. Results showed that lower GSR and higher PT were detected when the shooters were performing mindfulness imagery. Further, in-depth interview with the participants provided insight that participants perceived that mindfulness imagery was important to maintain a high state of positive thoughts for performance enhancement and being in the optimal zone. Results of the study throw light on the role of mindfulness in the MAC approach to relaxation in sport imagery, as well as the value of music as an adjunct to imagery to elicit mindful experiences.

Keywords: Galvanic skin response, peripheral temperature, mindfulness imagery, music

Introduction
Anxiety is often a challenge for athletes making it difficult for them to perform at their optimum. Athletes often face being too “pumped up” or over excited (over-aroused); or being not excited enough, not pumped up (under-aroused) for an important competition. They can also be influenced by many external factors, such as different levels of competitive sports, the type of sport, such as high arousal or precision sports, physical fitness, duration of the competition, or experiences in a competition (Lee, Sakaki, Cheng, Velasco, & Mather, 2014). In fact, anxiety has been the most heavily researched area and most widely discussed theme among the sport psychology community (see Pineschi & DiPietro, 2013). There are many coping strategies suggested by sport psychology researchers (see Smith & Smoll, 2004). Many athletes have acknowledged that imagery, deep breathing exercises, autogenic training, biofeedback training, and progressive relaxation training are important strategies in anxiety management (Curtin et al., 2015; Pineschi & DiPietro, 2013; Zhang et al., 2016). Guided imagery is a psychological skill that is commonly used by athletes to enhance their sporting performance (Taylor & Shaw, 2002). Researchers have concluded that imagery is an effective sport performance enhancement technique (e.g., Gregg & Hall, 2006; Morris, Spittle, & Watt, 2005; Shearer et al., 2007), and it can also be used to manipulate psychological variables, such as anxiety, confidence, and motivation (Morris, Spittle, & Perry, 2004). Music has been used in combination with imagery. Studies have revealed that listening to music can facilitate imagery (Osborne, 1981; Quittner & Glueckauf, 1983). Music has been shown to have psychophysical effects that include lowered perceived effort, arousal control, improved affective states, and synchronization effects (Boutcher & Trenske, 1990; Copeland & Franks, 1991; Karageorghis & Terry, 1997). Music has been widely used as a therapy for relaxation promotion and in sport rehabilitation. Suinn (1976) proposed visuomotor behaviour rehearsal (VMBR), which combines the use of imagery and relaxation, as a way to reduce anxiety and enhance performance and these effects have been demonstrated in studies of VMBR (Gray, 1990; Onestak, 1997). Thus, music that reduces arousal level should facilitate imagery use in sport.

The Mindfulness-Acceptance-Commitment (MAC) approach has been integrated into the sport psychology context, with the aim of improving athletes’ performance (Gardner & Moore, 2007; 2012). The MAC uses two widely recognised mindfulness-based training programs, namely mindfulness-based cognitive therapy (Huijbers et al., 2015; Segal, Williams, & Taedale, 2002), and ac-
ceptance and commitment therapy (Hayes, Strosahl, & Wilson, 1999). In the MAC approach, mindfulness is a key step in the management of thoughts and feelings. It promotes awareness, acceptance of internal experiences, and avoiding ineffective or counterproductive psychological states (Gardner & Moore, 2012). Thus, athletes receiving the MAC intervention will demonstrate enhanced attention control, emotion regulation, and self-awareness (Gardner & Moore, 2007, 2012). Wright et al. (2009) concluded that mindfulness-based interventions have the potential to elicit cognitive, affective, and behavioural manifestations, which will lead to reduction of stress, anxiety, depressive relapse, and psychosis. Mindfulness imagery with music involves putting oneself in a relaxing state of mind that also relaxes the physical body. It can create experiences, such as enjoyment, focus and re-focus, and can promote positive body energy, positive thoughts, positive emotions, self-confidence and “being in the zone” (Gardner & Moore, 2012).

Despite these relationships between music and relaxation during imagery, study of the effect of music on physiological and psychological indicators during mindfulness imagery is limited. Monitoring physiological indicators of level of arousal during imagery with music has potential to illuminate the relaxing effects of music that facilitate imagery. Galvanic skin response (GSR) is a widely-used measure of conductivity of the skin. There are specific sweat glands (eccrine glands) that cause skin conductivity to change and result in the GSR. Located in the palms of the hands and soles of the feet, these sweat glands respond to psychological stimulation, rather than simply to temperature changes in the body (Stern, Ray, & Quiley, 2001). GSR is a linear correlate to relaxation and reflects emotional responses as well as cognitive activity (Lang, 1995). Thus, changes in skin conductance co-vary with changes in arousal level. A decrease in autonomic arousal (relaxation) usually results in a decrease in skin conductivity. Peripheral Temperature (PT) is a measure of the temperature in the extremities of the skin, which varies according to the amount of blood perfusing to the skin (Charkoudian, 2003). PT is dependent on the state of sympathetic arousal. When people become stressed, their fingers tend to get colder. It is hypothesized that relaxation training involves learning to voluntarily increase finger temperature (Tahmoush, Malley, & Jennings, 1983). Temperature changes as a function of the amount of blood perfusing to the tissue. The arterioles, which supply blood to the tissues, are surrounded by smooth muscle fibres that are innervated by the sympathetic nervous system (SNS). When sympathetically aroused, the muscles contract causing vasoconstriction, reducing blood flow to the skin and producing a decrease in tissue temperature (Charkoudian, 2003).

Although mindfulness imagery is a crucial area to be researched in the context of sport, because of the claim that mindfulness enhances performance and satisfaction, we have not found research on mindfulness imagery in the sport context. In addition, there are no published studies addressing the effect of relaxing music during mindfulness imagery on GSR and PT. Thus, the purpose of this study was to investigate the use of GSR and PT as indicators of relaxation during mindfulness imagery. This should throw light on the role of mindfulness in the MAC approach to relaxation during sport imagery, stimulating more applied work in sport psychology.

Methods

Participants

Participants were five elite national shooters (3 males, 2 females), aged from 29 to 34 years old. All participants had at least 2 years of competitive experience in the sport of shooting at national level. We selected the sport of shooting to avoid power, strength, and speed tasks, where increases in arousal triggered by imagining the task could confound the effect of relaxing music on arousal level. All participants had normal hearing.

Measures

In this study, participants’ stress was measured using two physiological indicators, GSR and PT. Both sets of physiological data were collected with the ProComp+ system and BioGraph Software version 5.0 from Thought Technologies™. The GSR and PT data were collected at the rate of 32 data/second. Then, data was converted to 1 data/second using Matlab software.

Galvanic skin response (GSR). The GSR was measured with two Ag/AgCl electrodes with two hook and loop fastener style finger sensors snapped into the cable. The sensor was embedded into the hook and loop fastener band and was secured around the finger by connecting the hook and loop fastener. The sensors were worn on the fingers of the non-dominant hand. This skin conduction sensor can measure at the range of 0 to 30i Siemens (0.5 – 50 micromohs).

Peripheral temperature (PT). Peripheral temperature (PT) was measured using a temperature sensor called a thermistor. The sensor was placed on the pad of the last finger of the non-dominant hand and was held by 3M micropore tape. The sensor can measure across the range of 10 to 45 degrees Celsius.

Music Selection

We selected pieces of relaxing music, which were chosen from unfamiliar relaxing classical music. Relaxing classical music is regarded as music that creates physical and mental calmness in listeners. It usually is based on slower beat, and tends to have smooth and longer melodic patterns. This music can decrease the arousing emotions of listeners, thus, creating a less tense, less formal, less restrained, and more relaxing environment for listeners (Nercessian, 2007). All music was pre-selected by music therapists and professional musicians from a selection of 80 classical albums from music therapy lists. Then, it was pre-screened, and the selected pieces were finalised by two registered sport psychologists, who reduced the
selections to three pieces of music they considered most relaxing.

A preliminary study was conducted before the main study began. In this study, we chose unfamiliar classical music to minimise associations, which tend to be individual and which can affect arousal level in unpredictable ways. Thus, the pre-selected music was obscure and not likely to be known by participants. This minimised confounding effects of familiarity and past associations. All the excerpts of music were pre-tested with five undergraduate sport science students. We monitored their physiological reactions, to explore which music influenced relaxation level most clearly and consistently. We also asked the participants in this preliminary study whether they had heard the music before and what was their subjective reaction to it.

Procedures

Necessary permissions and consent were obtained prior to the study. We told participants that all results would be confidential and they could withdraw from the study at any time. All participants listened to three relaxing, unfamiliar pieces of classical music on three occasions before their normal training schedule. We advised participants not to do any arousing activities for two hours prior to coming for testing, e.g., running, cycling, or swimming. This was to avoid high arousal before the data collection. The study was conducted inside a quiet meeting room in the shooting centre, with no pistol shooting sound or interruption from the surrounding environment. The participants sat in a comfortable chair, and the GSR and PT were fixed on their non-dominant hand. We took baseline readings of GSR and PT before starting the imagery and relaxing music session. We asked participants to imagine their normal training routine, including successful completion of the skill being practised, and to imagine this routine vividly and clearly. We played the relaxing music at 50 to 80 decibels, which is the pleasant hearing range for individuals with normal hearing (Job, Cian, Esquivie, Leifflen, et al., 2004) without changing the volume of the music. We then monitored the level of relaxation during the imagery with each piece of relaxing music using the GSR and PT. When participants had completed the music and imagery conditions, we conducted a short interview to further explore participants’ subjective experience of the relaxing music. The total duration of each session was approximately 10 to 20 minutes (depending on the measured baseline). Finally, we debriefed participants and thanked them for their participation.

Statistical Analysis

We conducted statistical analysis using SPSS 20.0. We examined descriptive statistics to identify trends of arousal while participants listened to three selected excerpts of classical music played while they performed imagery. During the session, we monitored GSR and PT before the task ($t_0$) and at each 10-second point for 180 seconds. The measurements at each time point were averaged among the participants. Then, we plotted graphs to observe and compare the physiological changes that occurred during listening to each piece of music. Analysis of Variance (ANOVA) was used to assess between-group comparisons at baseline. Time, group, and finally, interaction effects at pre-test ($t_0$), 90 seconds ($t_{90}$), and 180 seconds ($t_{180}$) were examined using repeated measures ANOVA.

Results

The results for GSR and PT are presented separately. The results were presented from time $t_0$ to $t_{180}$ (180 seconds) during imagery with music.

![Figure 1. Galvanic skin response (kΩ) of relaxing music 1, relaxing music 2, and relaxing music 3 on time $t_0$ to $t_{180}$ seconds during imagery and music](image1)

![Figure 2. Peripheral Temperature (°C) of relaxing music 1, relaxing music 2, and relaxing music 3 on time $t_0$ to $t_{180}$ seconds of imagery and music](image2)
Galvanic skin response
Figure 1 shows that mean GSR (in kΩ) decreased from $t_0$ to $t_{180}$ (seconds) for all three pieces of relaxing music during imagery. Music 2 showed a monotonic decrease from $t_0$ to $t_{180}$ (seconds), whereas Music 3 showed a steady decrease from $t_0$ to $t_{70}$, with a plateau between $t_{70}$ and $t_{130}$ (seconds). For Music 1, a slower decrease was evident throughout the imagery, but visually GSR started at a notably lower level than for Music 2 or Music 3 and remained clearly lower throughout the 180-second measurement period. There was no significant difference in GSR at $t_0$ between the three pieces of music ($F_{2,14} = 0.20$, $p > 0.05$). Significant changes were observed over time, for the three pieces of music, $F_{2,24} = 12.31$, $p < 0.05$, $\eta^2 = 0.51$. However, the assumption of the test was not met as Mauchly’s Test of Sphericity showed a significant $p$-value ($p < 0.05$). This might be due to the small sample size.

Peripheral temperature
Figure 2 shows changes in peripheral temperature (in °C) from $t_0$ to $t_{180}$ (0 – 180 seconds). Music 1 and Music 2 showed a consistent increase in peripheral temperature from baseline ($t_0$) through to $t_{120}$ (seconds), then a plateau from $t_{120}$ to the end of the music pieces. This is consistent with the results for GSR because increases in PT reflect reductions in level of arousal, that is, increases in relaxation. For Music 3, a slight decrease and plateau was shown throughout the 180 seconds of imagery and music. There was no significant difference of temperature at $t_0$ between the three pieces of music ($F_{2,14} = 0.06$, $p > 0.05$). There were no significant changes in temperature among the three different types of music over the 180-second trials ($F_{2,24} = 1.85$, $p > 0.05$, $\eta^2 = 0.13$).

Figures 3, 4, 5, and 6 below show some examples of the results from the GSR and PT for individuals, with short comments from different participants about their subjective experiences.

Figure 3. Participant ‘A’ mentioned: “I focused very well. I felt relax, I can feel what I am doing and I achieved it successfully. I was self-confidence and I am see myself imagine what I want to reach. I am very satisfied with it”.

Figure 4. Participant ‘B’ mentioned: “I believe this is the best music I heard, I am very clear on I am thinking. It synchronies with my imagery and slowly brought me up although I felt a bit off in the initial part. I am happy with my overall performance”.

Figure 5. Participant ‘C’ mentioned: “The music takes me up and down, sometimes I can concentrate, and sometimes not, it didn’t give me enough time to get in the imagery I want. The imagery image is fading away”.

Figure 6. Participant ‘D’ mentioned: “I like the music, but, I think it is just helping me to see myself doing better, I enjoyed it but not helping me in my imagery and not distracting”.
Discussion

The present study provides preliminary evidence on the effect of music during mindfulness imagery among elite level shooters. Overall, when the shooters undertook imagery with relaxing music, the GSR of the participants gradually decreased. Similarly, when the shooters undertook imagery with relaxing music, the PT of the participants increased, which was expected because relaxation is associated with warmth in the body. Thus, both physiological indicators (GSR and PT) confirmed the predictions that skilled shooters would perceive relaxing music to be physiologically relaxing. These findings are consistent with the study conducted by Burns et al. (2002), who used the classical music “Serenata Notturna”, KV239 by Wolfgang Amadeus Mozart, and found it to be more relaxing as evidenced by physiological responses of participants in skin temperature, muscle tension, and heart rate, compared to the arousing hard rock music of “So Close” by the rock band Alice in Chains. The results of the present study supported other research that has indicated that listening to relaxing music during a task, such as performing surgery (Allen & Blascovich, 1994), helps decrease individuals’ physiological arousal. However, we found no research in the literature comparing the physiological and psychological responses of relaxing music using solely classical music. We also found no research that has examined the physiological and psychological responses of sports performers to music played during imagery.

We could not identify any literature examining unfamiliar relaxing classical music used during imagery training. We chose relaxing classical music because it has been reported to create physical and mental calmness in listeners (Nercessian, 2007). In addition, we chose unfamiliar music, so that we could examine the properties of the music without confounding effects of familiarity and prior associations, or established preferences. Although this study supported the use of unfamiliar relaxing classical music to achieve the aims we stated, future research using this kind of systematic approach is encouraged to further clarify the effects of familiar and unfamiliar music on relaxation levels in general and specifically during imagery. Studies should carefully compare selected pieces of familiar relaxing music with unfamiliar relaxing music to give more insight into the effects of different kinds of music on relaxation level during imagery.

Further, results from the short interview, together with a discussion with the pistol shooters’ coaches, and the results from interviews, focusing on participants’ subjective experiences, showed that PT seemed to be related to the content of participants’ imagery during the imagery and music session. Higher PT was observed from participants, who gave positive comments, showing that they enjoyed the imagery session. In contrast, a gradual decrease in PT was observed from participants, who did not enjoy the imagery session. For example, participant “C” from Figure 5 mentioned: “The music takes me up and down, sometimes I can concentrate, and sometimes not, it didn’t give me enough time to get in the imagery I want. The image is fading away”. Thus, it is proposed that participants with positive increments in PT created more positive thoughts in their imagery processes, such as positive emotions, positive thoughts, and self-confidence. Similarly, Gardner and Moore (2012) also proposed that these kinds of positive cognitive and affective experiences occur during “Mindfulness Imagery”. We suggest that mindfulness imagery plays an important role in influencing the body’s physiological and psychological reactions, such as physiological and mental relaxation.

Results from this study showed that GSR and PT can be used to detect differences in relaxation. Figure 1 showed all three unfamiliar relaxing music excerpts were associated with decreases in GSR level. However, in terms of PT, only relaxing music 1 and 2 showed an increase in PT, which is associated with relaxation. For music 3, PT did not increase as much as relaxing music 1 and 2, this might be due to participants relaxing, but not performing mindfulness imagery while listening to relaxing music 3. Thus, PT remained at the same level or even slightly decreased, reflected as a plateau in Figure 2. Again, further discussion from the pistol shooters’ coaches and the interviews examining subjective experiences of the participants suggests that participants with lower GSR and higher PT were more likely to experience a ‘mindfulness’ state. Participants who displayed lower PT subjectively reported less concentration, unsynchronized imagery, feeling bored, not being motivated, and perceiving they had less capability to perform mindfulness imagery successfully.

Examples of the comments made by participants, which were shown in Figures 3, 4, 5, and 6, reflected participants’ subjective experience during the imagery with different pieces of relaxing music. The participant who is quoted in Figure 3 showed a substantial decrease in GSR and an increase in PT, both reflecting relaxation. In the subjective experiences interview, that participant also stated: “I focused very well. I felt relaxed, I could feel what I am doing and I achieved it successfully. I was self-confident and I saw myself imagine what I wanted to reach. I am very satisfied with it”. Similarly, another participant reported: “I believe this is the best music I heard, I was very clear on what I was thinking. It synchronized with my imagery and slowly brought me up, although I felt a bit off in the initial part. I am happy with my overall performance”. Both participants made comments that were consistent with their physiological data. Furthermore, similar comments and physiological data trends were also observed from others participants. Thus, participants’ subjective reports were positive when their physiological measures showed signs of relaxation. From these subjective experiences and the GSR and PT gathered from the participants, it seems that participants responded differently to the music excerpts, for which they stated greater preference compared to the other pieces of music. Although this was not the objective of this study, it suggests that, in future, researchers should consider working on the association between the musical preferences of athletes and their physiological response. According to Gardner and Moore (2012) MAC can enhance attention control,
emotion regulation, and self-awareness, leading to more focus and relaxation.

One of the limitations of this study was involvement of skilled performers from the sport of shooting in the measurement of levels of arousal. Shooters are typically located at the very low end of the arousal continuum during their performance, which could limit the generalizability of the findings. In this study, we selected shooters because they do very little physical movement during performance. Physical movement affects level of arousal, so it could confound measurement of the physiological level of arousal caused by music excerpts. Because shooting is a sport that requires level of arousal at the very low end of the arousal continuum, replication of this study in other fine motor skill sports and in strength and power tasks would be helpful to clarify the potential for generalization of these results. Further study can facilitate a clearer and comprehensible understanding of the importance of using mindfulness imagery as well as to monitor and encourage the learning of physiological control that is necessary for peak performance.

In conclusion, it seems that there is a relationship between unfamiliar, relaxing classical music and level of relaxation. Different pieces of music produce varying levels of relaxation. In addition, there seem to be differences between individuals, which might relate to personal preferences. We recommend further examination of the characteristics of music that influence its relaxing qualities, as well as study of the role of personal music preferences. This study indicated that relaxing, unfamiliar classical music did reduce level of arousal and participants reported that the resulting relaxation facilitated mindfulness imagery. This proposition should be explored further in research where the effects of imagery on performance are monitored.

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References
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© Garry Kuan
Exercise and Sports Science, School of Health Sciences, Universiti Sains Malaysia, Kelantan, Malaysia.
Email: garry@usm.my