

## **From mice to music: a historical critique of optimal arousal in music performance**

Katrina M. Rivera<sup>a</sup>, Lillian Smyth<sup>a</sup>, Susan West<sup>b</sup>, and Georgia Pike-Rowney<sup>c</sup>

<sup>a</sup> School of Medicine and Psychology, The Australian National University, Canberra, Australia; <sup>b</sup> Faculty of Health, University of Canberra, Canberra, Australia; <sup>c</sup> School of Literature, Languages and Linguistics, College of Arts and Social Sciences, The Australian National University

**ABSTRACT:** The theory of “optimal arousal” maintains that an increase in arousal improves performance quality up to a certain point, beyond which any increase in arousal decreases the quality of performance. Within music performance anxiety (MPA) literature, optimal arousal is conceptualized as “anxiety” and is currently an assumed concept, embedded within research study design, treatment, and practice in MPA. However, despite the concept’s assumed nature, its presentation throughout the literature is inconsistent with limited empirical evidence. This narrative review aims to address this gap in the literature via a historical critique of the Yerkes-Dodson law, the major support for optimal arousal in MPA literature. A transdisciplinary approach to synthesizing relevant literature is taken, drawing together literature from various disciplines in order to examine the problematic application of optimal arousal, conceptualized as “anxiety”, to MPA. The presentation of the concept within MPA literature is first examined, noting the inconsistencies and lack of substantial empirical evidence. This is followed by a historical review of the supporting concept, the Yerkes-Dodson law, including an overview of the original study, the concept’s transformation throughout the 20th century, and the concept’s current standing. Synthesising literature from various disciplines, the application of optimal arousal to MPA is then discussed within the context of this historical review. Findings reveal a lack of empirical support and controversial transformation leaving us unsure of the validity of the Yerkes-Dodson law. As a result of this discussion and examination of the Yerkes-Dodson law as

applied to music performance, it is proposed that the optimal arousal concept should be used with caution within the field of music psychology unless more comprehensive evidence becomes available. Implications for practice and future research are outlined.

**KEYWORDS:** Music performance anxiety, optimal arousal, Yerkes-Dodson law, sport psychology, conceptual substitution

### INTRODUCTION

Music Performance Anxiety (MPA) is a significant problem for professional and student musicians (Fernholz et al., 2019; Fishbein et al., 1988; Kenny & Ackermann, 2015; Osborne & McPherson, 2019; Paliuikiene et al., 2018), hampering professional careers and contributing to student attrition (Nagel, 2010; Orejudo Hernández et al., 2018; Wesner et al., 1990). MPA literature agrees on three key principles: 1) there is no guaranteed strategy or trait for avoiding MPA (Brugués, 2011a; Farnbach & Farnbach, 2001; Kenny, 2011; Salmon & Meyer, 1992); 2) some level of anxiety is necessary for peak performance (Biasutti & Concina, 2014; Salmon & Meyer, 1992; Wilson & Roland, 2002); and 3) various cognitive and behavioral strategies can help control the symptoms of MPA (for example, Braden et al., 2015; Juncos & Markman, 2016; Kenny & Halls, 2018; Khalsa et al., 2013). Recent MPA research does not focus on questioning or studying these disciplinary assumptions and includes: determining MPA incidence and experience of MPA (Barros et al., 2022; Sokoli et al., 2022; Spahn et al., 2021); the relation of MPA to other conditions or concepts (Bersh, 2021; Butkovic et al., 2022; González et al., 2017; Spahn et al., 2021); and the evaluation of the effectiveness of treatment options to reduce symptoms (Brooker, 2018; Kenny & Halls, 2018; Mahony et al., 2022; Tang & Ryan, 2020).

One assumption underlying current research, thought, and practice around MPA is the concept of “optimal arousal”. Despite the conceptual name containing the word “arousal”, when applied or discussed in MPA literature, this concept most often refers to arousal conceptualized as “anxiety”. These two concepts are not analogous, arousal referring to a general state of “physical activation or cortical responsiveness” (American Psychological Association, 2018a) and anxiety a negatively valenced emotion, in response to “impending danger, catastrophe, or misfortune” (American Psychological Association, 2018b). In the context of MPA literature, “optimal arousal” maintains that an increase in anxiety improves the quality of music performance up to a certain point, beyond which any increase in anxiety decreases the quality of performance (for example of such a definition, see Rae & McCambridge, 2004). This concept is often represented graphically as an inverted-U curve, with “anxiety” on the x-axis and “performance” on the y-axis (e.g., Nagel, 2017). Optimal arousal as a concept is present in the majority of MPA literature, both explicitly and implicitly (reviewed below). Despite widespread reference to optimal arousal throughout MPA literature, only a few studies can provide conditional empirical evidence for the concept (Craske & Craig, 1984; Hamann, 1982; Hamann & Sobaje, 1983; Kokotsaki & Davidson, 2003). Few studies explicitly acknowledge or engage with the data from which this concept originated: a study examining the relationship between physical punishment, via electric shock, and habit-formation in mice (Yerkes & Dodson, 1908). Similarly, the historical transformation of the concept is rarely discussed in MPA literature, with little mention of the

extensive criticisms or controversy around optimal arousal in other academic disciplines.

Despite its assumed nature, the lack of evidence and inconsistent understanding of “optimal arousal” in MPA literature warrants a detailed examination of the concept’s validity and underlying supporting principles. This narrative review aims to address this gap in the literature via a historical critique of the Yerkes-Dodson law, the major support for optimal arousal in MPA literature, highlighting the shortcomings in the concept’s application to music performance. A transdisciplinary approach to synthesizing literature from various disciplines is used (Leavy, 2011), drawing together literature from music psychology, cognitive psychology, comparative psychology, and sports psychology to examine the application of optimal arousal to music performance. After sourcing the original study by Yerkes and Dodson, studies on the historical transformation were sourced via searching various databases, including Taylor and Francis Online, Sage Journals, and ProQuest, using search terms such as “history Yerkes Dodson law”. Reference lists of identified papers were then hand searched for further relevant studies.

This paper argues that “optimal arousal” is misapplied as “anxiety” in MPA literature, as the concept of anxiety does not have potential to improve the execution of musical performance. Throughout this paper we will use the terminology commonly found in MPA literature: the term “optimal arousal” will refer to arousal conceptualized as anxiety. This paper examines (1) the presentation of optimal arousal within MPA literature, (2) the study from which the Yerkes-Dodson law originates, (3) key events in the historical transformation from the concept’s origin to today’s presentation, and (4) the current standing of the concept. This historical context then informs a discussion on the impact of this knowledge on the concept’s application to MPA. Study limitations and implications for future research and practice are then outlined.

### **OPTIMAL AROUSAL AND MUSIC PERFORMANCE**

Optimal arousal, as applied to music performance, maintains that an increase in anxiety improves the quality of performance up to a certain point, beyond which an increase in anxiety decreases the quality of performance. This concept is often represented by an inverted-U shaped graph, supported theoretically by the Yerkes-Dodson law. This section will summarize the presentation of optimal arousal within MPA literature, including as an assumed tenet of MPA literature, its inconsistent presentation, and the limited supporting empirical evidence.

#### **An assumed tenet of MPA literature**

Optimal arousal is not only present in MPA literature, but also embedded in the methodological design and discussion around treatment strategies. Some authors within MPA literature explicitly refer to optimal arousal by name (for example, Kenny, 2011; Kokotsaki & Davidson, 2003; Papageorgi, 2007; Salmon, 1990), sometimes with an exemplar graph attached (Kenny, 2011; Roland, 1997; Spahn et al., 2010). Others refer to the concept via general statements without any accompanying citation or evidence for support (for example, James & Savage, 1984; Mitchell, 2011; Nagel, 2010; Salmon, 1990), indicating an underlying acceptance of its application to music performance. For example, “performance anxiety ... can provide a positive source of excitement to improve performing” (Nagel, 2010). Further evidence for this underlying belief in optimal arousal can be found in experimental

research design and the language used to describe treatment options for MPA. For example, interventions are designed to “control” (Brantigan et al., 1982; Kendrick et al., 1982; Morasky et al., 1983; Nagel et al., 1989; Nideffer & Hessler, 1978; Zhukov, 2019), “manage” (Hoffman & Hanrahan, 2012; McGrath, 2012; Osborne et al., 2014; Roland, 1994; Zhukov, 2019), “lower” (Nagel et al., 1989), “alleviate” (Brugués, 2011b; Kim, 2005), or “reduce” anxiety (Braden et al., 2015; Cohen & Bodner, 2019; Hingley, 1985; Kenny, 2005), not to entirely prevent anxiety. That is, there is an underlying assumption that some amount of anxiety is expected, or even desirable, in music performance.

It is rare to find studies that engage with the concept in any substance (for example, Frost, 1997; Kenny, 2011; Ruggiero, 2012). Authors that acknowledge the limitations and criticisms of the inverted-U hypothesis do not appear to change their assumption of the concept’s application to MPA (Frost, 1997; Kenny, 2011; Rae & McCambridge, 2004; Rosset i Llobet & Odam, 2007; Wilson, 1997). Recent literature does not question the concept, nor seek to test the concept empirically. For example, Herman and Clark’s (2023) recent review and critique of MPA literature advocates for a reconceptualization of MPA, from an illness that needs to be managed to its acceptance as a normal part of a “functioning autonomic nervous system” (p. 22). This collective assumption that optimal arousal applies to music performance has limited research to only evaluating interventions for decreasing symptoms of anxiety rather than pursuing research on the potential causes of this widespread anxiety or questioning its necessity.

### **Inconsistent presentation**

Despite the evidence for optimal arousal as an assumed tenet in MPA literature, examination of the concept’s presentation reveals disciplinary uncertainty around the concept. Throughout the literature there are inconsistencies in the textual and graphical presentations of the concept. Optimal arousal has been referred to by name as “optimum anxiety” (Roland, 1997), “optimal performance” (Brugués, 2009; Conklin, 2011; Kokotsaki & Davidson, 2003; Zarza Alzugaray et al., 2016), or “peak performance” (Armbrecht, 2012; Wilson & Roland, 2002). Some authors refer to the underlying psychological theories such as the Yerkes-Dodson law (for example, Biasutti & Concina, 2014; Guven, 2017; Papageorgi et al., 2007; Simoens et al., 2015; Zarza Alzugaray et al., 2016), or Drive theory (Hamann, 1982; Hamann & Sobaje, 1983).

The terms used to describe the conceptual relationship also vary greatly in the literature. The independent variable has been labelled as “arousal” (Barbeau, 2011; Farnbach & Farnbach, 2001; Spahn et al., 2010), “anxiety” (Kokotsaki & Davidson, 2003; Rae & McCambridge, 2004; Reubart, 1985; Roland, 1997), “activation” (Salmon & Meyer, 1992), “tension” (Steptoe, 2001), “apprehension” (James et al., 1978), or “stress” (Rosset i Llobet & Odam, 2007; Wolfe, 1989), with the dependent variable labelled “performance” (for example, Barbeau, 2011; Kenny, 2011; Kokotsaki & Davidson, 2003; Rae & McCambridge, 2004; Roland, 1997; Spahn et al., 2010; Steptoe, 2001), “effectiveness” (Reubart, 1985), or “task efficiency” (Farnbach & Farnbach, 2001; Salmon & Meyer, 1992). Despite the similarities between these terms, they are not analogous (see Discussion for further explanation for why these concepts are not all synonyms of each other).

The shapes of the graphs also vary widely, with variations of starting point (Kenny, 2011; Reubart, 1985; Roland, 1997), rate of incline and decline (Barbeau, 2011; Roland, 1997), and

whether other concepts are to be considered (Rosset i Llobet & Odam, 2007; Wilson & Roland, 2002). While MPA discourse assumes that optimal arousal applies to music performance, the varying terminology and graphical presentations found in the literature imply a lack of collective understanding of the concept and its application to MPA.

### **Empirical evidence**

Despite the assumption that some amount of anxiety is helpful for music performance quality, empirical evidence suggests that optimal arousal may only apply to players of a certain skill level. Others have found a negative, or no, relationship between anxiety and performance.

Very few studies over the approximately 50-year history of MPA research claim empirical support for the concept. Two studies often cited as evidence for optimal arousal in MPA literature, Hamann (1982) and Hamann and Sobaje (1983), used self-report measures State-Trait Anxiety Inventory (STAI) (Spielberger et al., 1970, as cited in Hamann & Sobaje, 1983) and State-Trait Personality Inventory (STPI) (Spielberger et al., 1979, as cited in Hamann & Sobaje, 1983) on 90 and 60 music students, respectively, to measure MPA in jury and non-jury performances. Both studies concluded that performance quality of subjects with higher task mastery (operationalized as years of formal training) was rated superior in the increased anxiety condition (performance class with audience). Another study compared anxiety levels (measured via self-report on the STAI) and performance marks for 43 second- and third-year tertiary music students. Third year students were generally more anxious when performing, yet were more likely to score more highly in their assessments (Kokotsaki & Davidson, 2003). The authors similarly concluded that those with higher years of formal training (i.e. third year students compared to second year students) perform superiorly under increased anxiety levels. Endo et al. (2014) investigated the effect of MPA on the movements and posture of 24 cellists, concluding that anxiety can benefit performance, but only when physiological arousal is at low levels, provided the resulting more open left elbow moment is required for their performance. Endo et al. (2014) advocate for a distinction between performance arousal and performance anxiety as physiological arousal may not always be associated with the negative effects of anxiety.

Despite understanding that “results indicate that some arousal during skilled performance in skilled performers is necessary to achieve a standard of performance that receives a high rating from an expert listener” (p. 487) for 20 tertiary flute players, Kenny et al. (2009, 2011) found no significant effect for MPA (measured via self-report on the K-MPAI (Kenny et al., 2004)) as a predictor for expert rating of performance. Guven (2017) found no significant relationship between piano course results and test anxiety or MPA in 129 music teaching students. Yoshie et al. (2008) also found no significant differences in performance quality in 12 pianists on an arpeggio accuracy task between evaluation and non-evaluation performing conditions. Other authors have found a negative linear relationship between anxiety and performance quality (Bissonnette et al., 2016; Craske & Craig, 1984; Hoffman & Hanrahan, 2012; Yoshie, Kudo, et al., 2009; Yoshie, Shigemasa, et al., 2009).

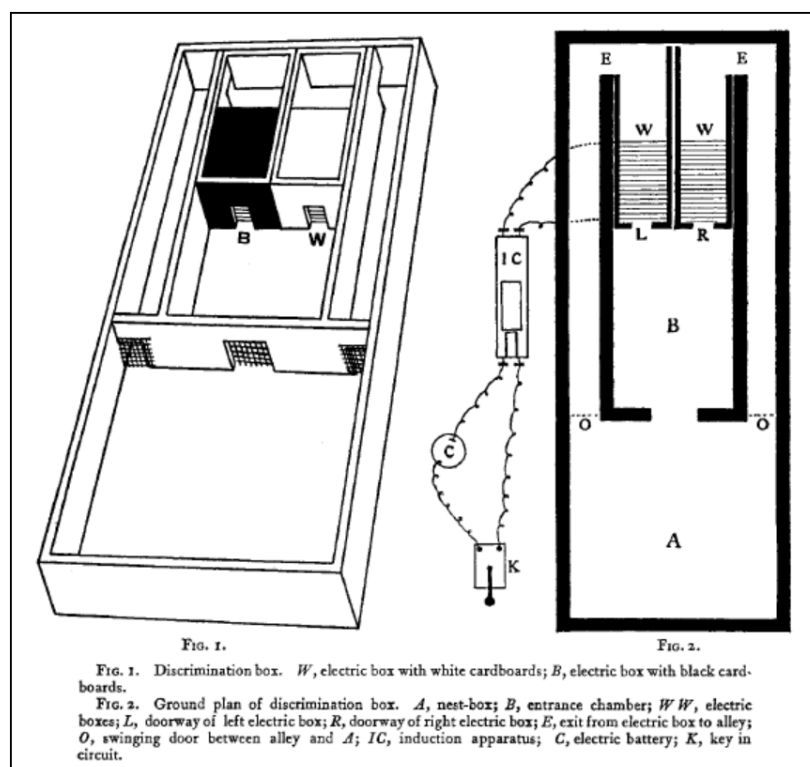
Despite the limited conditional empirical evidence, optimal arousal permeates understanding, research design, and practice around MPA. The concept is currently assumed to apply to music performance with the concept no longer questioned and rarely studied. Given the inconsistencies in its presentation and little evidence for the concept within MPA literature, a more detailed examination of optimal arousal and the underlying theoretical

support is necessary to examine the extent of the concept's application to MPA literature.

### ORIGIN: MICE AND ELECTRIC SHOCK

The major theoretical support for optimal arousal in MPA literature is the Yerkes-Dodson law, a psychological concept that can be traced to a study published in 1908 by R. Yerkes and J. Dodson titled: The relation of strength of stimulus to rapidity of habit-formation. This study is also the origin of the U-shaped graph that was later inverted and now found in a number of academic disciplines, including MPA. Despite some authors citing Yerkes and Dodson (1908) as support for optimal arousal in MPA literature (e.g., Biasutti & Concina, 2014; Guven, 2017; Patston & Osborne, 2015; Reubar, 1985; Salmon & Meyer, 1992; Simoens et al., 2015; Zarza Alzugaray et al., 2016), there is little evidence of their engagement with this original study. This section will outline the method and results of the original study, including its methodological problems.

Comparative psychologists, Yerkes and Dodson, sought to add to the knowledge of the Japanese Dancing mouse, specifically behavior modification, without any intention to relate it to the behavior of other animals or humans. The experiment was a punishment-based conditioning task, whereby rapidity of habit formation, operationalized as a white/black visual discrimination exit task (see Figure 1), was measured at varying strengths of electric shock punishment. Two pairs of male/female mice were tested ten times a day on consecutive mornings for each strength of electric shock. Results were recorded in terms of the number of errors, in line with other habit-formation studies at the time.



**Figure 1.** Yerkes and Dodson's (1908) depiction of the apparatus used in their study. Mice were moved into the entrance chamber (B) to make their choice between the left or right exits. Mice were able to pass freely if they exited via the white exit, or given an electric

shock by the experimenter if they exited via the black exit. Note. Figures 1 and 2 from "Relation of strength of stimulus to rapidity of habit-formation," by R. M. Yerkes and J. Dodson, 1908, *Journal of Comparative Neurology and Psychology*, 18(5), p. 479. Copyright © 1908 The Wister Institute of Anatomy and Biology. Reprinted with permission.

Only one experiment was planned, with two more experiments arising in response to the surprising results of the first: "Contrary to our expectations, this set of experiments did not prove that the rate of habit formation increases with increase in the strength of electric stimulus up to the point at which the shock becomes positively injurious" (Yerkes & Dodson, 1908, p. 471). Time for habit-formation was longer than expected (up to 23 days for the strong electrical shock) and the relationship between shock strength and speed of habit-formation was U-shaped, suggesting that the medium strength of electrical shock was most favorable of the three for habit formation.

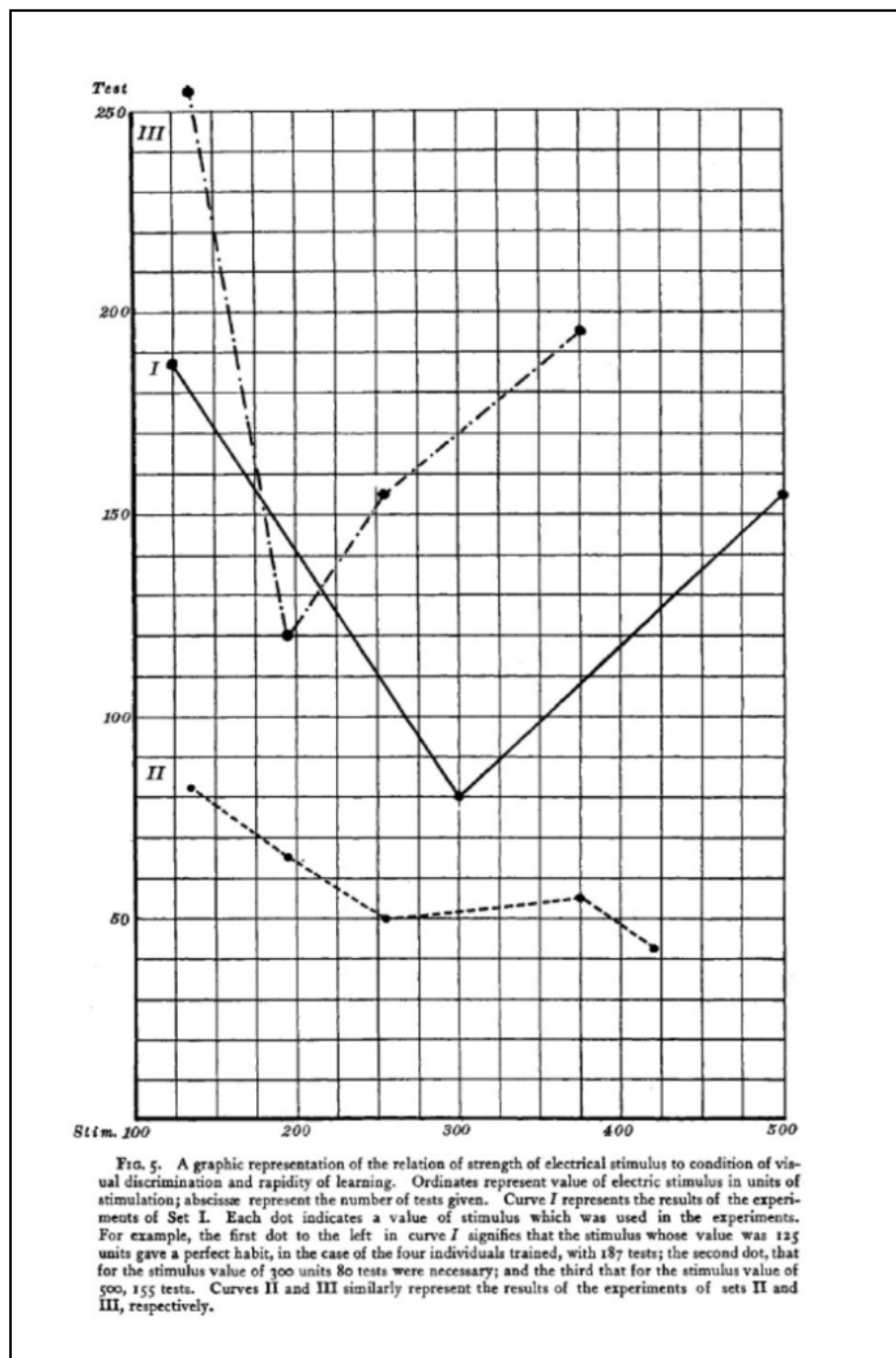
To decrease the number of days until habit formation, the visual contrast between the two exit boxes were increased; that is, visual discrimination made "easier" and the experiment repeated. This second experiment resulted in a negative linear graph, where the rate of habit formation increased (i.e. number of errors decreased) as strength of electric increased, yielding results that were more in line with the authors' original hypothesis. The authors hypothesized that the different results were due to the different levels of visual discrimination between the two experiments and carried out a third experiment where the black and white exits contrasted less than the first set, making visual discrimination more "difficult". The resulting graph of all three sets of data can be found in Figure 2.

Immediately, there are some obvious differences between this graph and the usual graph describing optimal arousal in MPA literature. Firstly, the original study has three differently shaped graphs, one for each level of discrimination difficulty, whereas in MPA literature a single, even, inverted-U curve is found (note that these original graphs are actually more V-shaped than "U-shaped"). The single curve found in MPA literature does not indicate any change in effect as task difficulty varies in music performance. Secondly, the original curved graphs are U-shaped, a common practice in habit-formation studies at the time measured by the number of errors, while the graphs found in MPA literature are inverted. This difference in shape could indicate that the two graphs represent different concepts. Thirdly, in the original study, points of data note specific values of errors and electric shock used, while the MPA graph is a continuous curve with no x- and y-axis values. This highlights the difference between the empirical and conceptual nature of the two types of relationships: exact amounts of anxiety cannot be measured and manipulated, but the strength of electric shock and the number of errors can.

Yerkes and Dodson presented five conclusions from their data, which are summarized as follows:

- Rate of learning the habit increases as the visual discrimination between exits contrasts greatly in brightness.
- The relationship between strength of electrical stimulus and habit-formation depends upon the difficulty of the conditions of discrimination.
- For easy discrimination tasks, habit-formation increases as the strength of electric shock increases, even to the point of near-harmful levels of stimulation (presented tentatively, subject to future research).

- When discrimination between exits is difficult, lower strengths of electric shock are more favorable for habit-formation.
- As visual discrimination increases in difficulty, the strength of electric shock most favorable for habit-formation decreases.



**Figure 2.** Graphical representation of the three experiments by Yerkes and Dodson (1908). Set I (medium difficulty task) is represented by the solid line, Set II (easy task) represented by the evenly dotted line, and Set III (difficult task) represented by the uneven dash/dot

line. Note: Figure 5 from "Relation of strength of stimulus to rapidity of habit-formation," by R. M. Yerkes and J. Dodson, 1908, *Journal of Comparative Neurology and Psychology*, 18(5), p. 479. Copyright © 1908 The Wistar Institute of Anatomy and Biology. Reprinted with permission.

It is important to note in terms of the shape of the graph used to describe the concept in MPA literature: none of the five conclusions explicitly relate to the results given for the medium difficulty discrimination task, the curve shape that most resembles the graph known today as the Yerkes-Dodson law. The importance of the overall relationship between strength of electric shock and task difficulty was emphasized, rather than the optimal amount of electrical stimulus required for each individual "curve".

The authors believed that their final and fifth conclusion to be obviously of "great importance to students of animal behavior and animal psychology" (Yerkes & Dodson, 1908, p. 482), with no intention to relate the results to human behavior at the time. As true comparative psychologists, Yerkes and Dodson (1908) concluded with their intentions to repeat the experiments in other animal species:

Naturally we do not propose to rest the conclusions which have just been formulated upon our study of the mouse alone. We shall now repeat our experiments, in the light of the experience which has been gained, with other animals. (p. 482)

Psychology as a research field was relatively new at the time of publication, with methods of measurement still developing. Yerkes and Dodson (1908) would require further data to confirm their results, as there were unsystematic variations in the number and strengths of electric shock and numbers of subjects per condition. Set I (medium difficulty task) had three strengths of shock approximated at  $125 \pm 10$ ,  $300 \pm 25$  and  $500 \pm 50$  units, Set II (easy task) had five strengths at 135, 195, 225, 375, and 420 units, and Set III (difficult task) had four strengths at 135, 195, 225, and 375 units. Sets I and II had two pairs of male/female mice per condition (i.e. four in total), and only one pair of male/female mice per condition for Set III (two in total). The inconsistencies in number of subjects per condition and the number and measurement of electric shock make comparison between the three sets of data difficult and limit the reproducibility of the experiment. This impacts on the reliability of the study and therefore on further application of the concept, questioning its place as support for the application of optimal arousal to music performance.

Yerkes and Dodson (1908) is the origin of the well-known Yerkes-Dodson law which provides the theoretical support for optimal arousal in MPA literature (as well as many other fields, e.g. sport). This single study was an exploratory study requiring further replication to confirm or deny the findings. Given how far removed the subject matter and study is from the concept's presentation of optimal arousal in MPA literature, further examination of the concept's transformation is warranted. How did a single, unreplicated, exploratory study end up as an assumed tenet of MPA understanding and treatment?

### **TRANSFORMATION: FROM MICE TO MUSIC**

The transformation of the Yerkes-Dodson law can be traced via a number of published research articles and books from Yerkes and Dodson (1908) to its current presentation today. To inform a discussion on the application of optimal arousal in a music performance context, this section will outline the transformation of the Yerkes-Dodson law in terms of the

experimental replications and a common practice of conceptual substitution. Further information on the transformation of the Yerkes-Dodson law can be found in Calabrese (2008), Hancock and Ganey (2003), Hanoach and Vitouch (2004), Staal (2004), and Teigen (1994).

### **Experimental replications**

Despite their understanding, early replications did not completely reproduce the findings of Yerkes and Dodson (1908). See Figure 3 for a comparison of the results of the early replications with the original Yerkes and Dodson (1908) data. A replication in young chickens (Cole, 1911) used more (six) subjects per condition and produced similar results to Yerkes and Dodson (1908) for the easy and medium level tasks. However, for the difficult task, a decrease in the number of trials for habit-formation was found as strength of electric shock increased, that is, habit-formation increased as strength of electric shock increased. A number of chicks failed to complete the habit for the difficult task at the medium and strong stimulus levels, the subjects eventually refusing to enter either exit.

A replication with kittens (Dodson, 1915) used only two to four kittens per condition, with similar findings to Yerkes and Dodson (1908) for the easy task only. For the medium and difficult tasks, only two points of data were collected, resulting in linear functions between the medium and strong electrical stimulus: the number of trials decreasing (faster habit formation) for the medium task, and the number of trials increasing (longer habit-formation) for the difficult task. Dodson's results of the difficult task are in direct contrast to those found by Cole (1911). Despite not gathering three points of data for two of three tasks and explicitly noting the limitations of such small numbers of subjects per condition, Dodson (1915) understood his results to support those found by Yerkes and Dodson in 1908: "if any conclusion may be drawn from the use of so few animals those conclusions are in accord with previous findings in the dancer"<sup>1</sup> (Dodson, 1915, p. 335). In the decades following these early replications of Yerkes and Dodson (1908), the idea seemed to lay dormant, with few references to the concept throughout the first half of the 20th century (Broadhurst, 1957; Calabrese, 2008; Corbett, 2015; Teigen, 1994).

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1 "dancer" referring to the Japanese dancing mouse, the breed of mouse used in Yerkes and Dodson (1908).



**Figure 3.** Graphical comparison of the results obtained by Yerkes and Dodson (1908) and the replication studies of Cole (1911), Dodson (1915), and Broadhurst (1957).

Some 50 years later, animal psychologist P. L. Broadhurst attempted to revive the concept with his own replication of the study on the white rat with some variations in the experimental set-up (Broadhurst, 1957). A Y-shaped apparatus submerged underwater was used, with the source of “motivation” four intensities of air deprivation: subjects were held underwater for different lengths of time before being released to swim to the exits at the junction of the “Y” and make their exit decision. Each arm of the “Y” apparatus was blocked by a doorway, on one side the exit was fixed in place, and the other able to be opened by the rats. Three levels of difficulty (different levels of contrast between the amount of light behind the two exit passageways), two levels of emotionality (indicated by the number of fecal

deposits per day), and four intensities of air deprivation, created a 3 X 2 X 4 factorial design. Along with increased numbers of subjects per condition (ten) and analysis via statistical tests of variance, this factorial design addressed some of the crucial criticisms of the early experiments.

Broadhurst maintained that his study reproduced the results of Yerkes and Dodson (1908): "Analysis of variance of the results shows that the Yerkes-Dodson Law, as demonstrated by an appropriate interaction between difficulty and motivation, is confirmed at an acceptable level of significance" (Broadhurst, 1957, p. 351). However, despite Broadhurst's methodological improvements, a comparison of experimental procedures suggests that the procedure is not comparable with Yerkes and Dodson (1908). Firstly, the types of "motivation" in each experiment may not be comparable. Both types of motivation are applied externally, but the mice deterred from the incorrect exit with electric shock, and the rats in Broadhurst's study deterred from the incorrect exit with a locked gate. Broadhurst himself noted that air deprivation may be more similar to "reward" than "punishment": "While air deprivation shares some aversive features with electric shock ... escape from it has major rewarding aspects akin to the more usual rewards and unlike the negative reward of simple escape from shock" (Broadhurst, 1959, p. 329).

Secondly, the order of application within the experimental procedure is not comparable. In Broadhurst's study, air deprivation was applied to the subjects prior to them making their exit choice, whereas in Yerkes and Dodson (1908) electric shock was applied in response to an incorrect exit choice. The two types of "motivation" were used for different purposes: in Yerkes and Dodson (1908), the electrical shock was used to train the mice to a particular exit passage, whereas in Broadhurst (1957), air deprivation was used to increase swimming speed toward the two possible exits.

### **Conceptual substitution**

Throughout the history of the Yerkes-Dodson law a change in terminology is observed between the original study, the replications, and subsequent citations of the "law" (Corbett, 2015; Hancock & Ganey, 2003; Teigen, 1994). Teigen (1994) argues that this practice of language substitution and the simultaneous development of a number of similar, but distinct, concepts in cognitive psychology aided the transformation of the Yerkes-Dodson law from comparative psychology studies to human psychology.

Right from the early replications, a change in the language used to describe the results is observed (Corbett, 2015; Teigen, 1994). Yerkes and Dodson (1908) described their results in terms of "strength of stimulus" and "habit-formation". Cole (1911) described his conclusions in terms of "strength of stimulus" and "learning", while Dodson (1915) in terms of "unpleasantness of stimuli" and "habit-formation". Other examples of this interchangeable terminology can also be found in descriptions of the law by the same author, years apart. Young (1936) described the Yerkes-Dodson law as an optimum degree of punishment for the learning of every activity, then seven years later as an optimal degree of motivation (Young, 1943). Similarly, Broadhurst (1957) described the Yerkes-Dodson law as a relationship between "motivation" and "learning task", then two years later as a relationship between "motivation" and "performance" (Broadhurst, 1959). Broadhurst (1959) acknowledged this historical practice of conceptual substitution, but dismissed it as insignificant "jargon":

In the jargon of 50 years ago the Law was phrased: "As difficultness of discrimination

increases, that strength of electrical stimulus which is most favorable to habit formation approaches the threshold". In the jargon of to-day we might say: "The optimum intensity of shock varies inversely with the difficulty of discrimination", or, more succinctly [sic] and more generally, "The optimum motivation for a learning task decreases with increasing difficulty." (p. 322)

Alongside this practice of conceptual substitution, a number of cognitive psychology concepts were developed in the 1950s and theorized to function as single inverted-U shaped graphs. These conceptual relationships included: arousal & cue function (Hebb, 1955), autonomic drive and performance (Eysenck, 1955), activation and emotion (Schlosberg, 1954), arousal and performance quality (Duffy, 1957), and drive and proficiency (Easterbrook, 1959). Of these authors, only Eysenck (1955) explicitly referred to the Yerkes-Dodson law (only in the study Appendix, indicating the law's lack of significance regarding his work). The similarity between the U-shaped curves of the habit-formation studies and the inverted-U human cognitive psychology concepts was too great to ignore, with Broadhurst (1957) reformulating the results of his habit-formation study in inverted-U shaped graphs, rather than the traditional U-shaped graphs. Two years later, Broadhurst (1959) synthesized all this information, explicitly noted the connection between the habit-formation studies and human cognitive psychology concepts, and announced the law as "revived".

The practice of conceptual substitution continues today with the Yerkes-Dodson law often described as a curvilinear relationship between a variety of different concepts, with almost any of these similar, yet distinct, concepts interchangeable on the x- or y-axes (Teigen, 1994). Examples of this wide interchangeability of concepts in descriptions of the Yerkes-Dodson law is found across a number of disciplines. In MPA literature, the inverted-U relationship described as arousal and performance (Barbeau, 2011; Brugués, 2009; Kokotsaki & Davidson, 2003; North & Hargreaves, 2008; Wilson, 1997), anxiety and performance (Kirchner, 2002; Rae & McCambridge, 2004; Steptoe & Fidler, 1987; Sweeney, 1981), anxiety and effective realization of a task (Reubart, 1985), stress or tension and performance (Wolfe, 1989), arousal and motor skills (Salmon, 1990), task efficiency and activation (Salmon & Meyer, 1992), or drive and learning (Papageorgi et al., 2007). This lack of agreement in terminology emphasizes an underlying disciplinary belief that some inverted-U relationship relating to performance quality applies to music performance, without agreement on what produces this curvilinear relationship. Similar to the law's presentation in other disciplines and its historical transformation, these modern descriptions of the law attributed to Yerkes and Dodson (1908), demonstrate a lack of engagement with the original study and related literature.

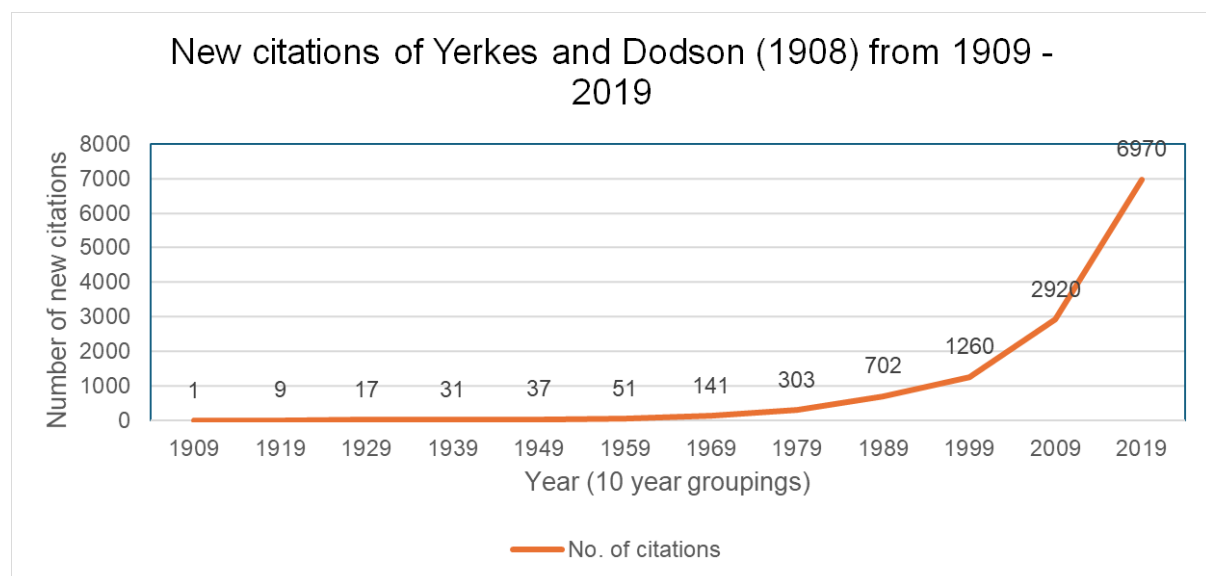
While this conceptual substitution appears common practice throughout the 20th century and beyond, the definitions of terms within psychology have changed over the years. Psychology in the first half of the 20th century was dominated by behaviorism, a school of thought that focused on observable and measurable behavior (Watson, 1913). All behavior, including human behavior, was understood to be conditioned (i.e. learned) via interaction with their environment (i.e. punishment/rewards) and able to be reduced down to a simple stimulus-response association (Hothersall, 1995; Illeris, 2018). In this context, terms such as "learning" and "habit-formation" were understood as analogous. However, divergent views on "learning" began to appear in the 1930s (Bruner, 2004). Further development occurred during the second half of the 20th century, with cognitive, constructivism, and humanism

approaches to learning becoming more prominent (Illeris, 2018). Today, psychology's understanding of terms such as "learning" and "motivation" differs to Yerkes, Dodson, and Cole's understanding of those terms in the early 20th century.

This overview of the key historical events leading to the transformation of the Yerkes-Dodson law reveals: a lack of empirical support, even if Broadhurst (1957) is deemed comparable; and a common practice of conceptual substitution. These themes are likely to have contributed to the law's wide applicability, not only across a number of concepts, but across a number of disciplines. These themes are also found in the presentation of optimal arousal in MPA literature: conditional empirical support, only for a curvilinear relationship between anxiety and performance in highly skilled musicians; little engagement with the original study, the Yerkes-Dodson law and optimal arousal often presented as one of its modern presentations; and acceptance of a commonsense appeal, the concept assumed, no longer questioned, and often presented without citation. Despite the limited evidence, the application of optimal arousal to music performance is also further supported and maintained by other common characteristics of the MPA literature: that MPA suffering is widespread (Bartel & Thompson, 1994; Fishbein et al., 1988; Help Musicians UK, 2014; Wesner et al., 1990; Wilson & Roland, 2002), and there is no guaranteed trait or strategy to avoid its negative effect on performance (Brugués, 2011a; Gómez-López & Sánchez-Cabrero, 2023; Farnbach & Farnbach, 2001; Herman & Clark, 2023; Kenny, 2011; Osborne & Kirsner, 2022; Salmon & Meyer, 1992).

### **TODAY: CURRENT STANDING AND CRITICISMS OF THE YERKES-DODSON LAW**

Today, the inverted-U curve of the Yerkes-Dodson law describes an almost endless number of relationships across a variety of research fields, including pharmacology/toxicology (Calabrese, 2008), weight management (Johnston et al., 2012), economics (Kuznets, 1955), sport (Hong et al., 2022; Oxendine, 1970; Robazza et al., 1998; Wood, 2016), medical education (Haluck & Krummel, 2000), workplace management (Chong et al., 2012; Corbett, 2015; Mellifont et al., 2016), aviation education (Perry, 2022), classroom education (Keller, 2007), memory (Anderson et al., 1989; Bennion et al., 2013; Clark et al., 1999), personality (Von Gehlen & Sachse, 2015), and relevant to our discussion here, music psychology. Citations of Yerkes and Dodson (1908) have increased exponentially from 1908 to 2019 (see Figure 4), with the law most often presented in its modern form as a relationship between arousal and performance (American Psychological Association, 2018c; Colman, 2014). Despite its wide disciplinary application and exponentially increasing citations, it is rarely acknowledged that the Yerkes-Dodson law has been extensively critiqued, or that divergent views on the concept exist (Teigen, 1994). Published critiques of the Yerkes-Dodson law are aplenty. This section will summarize the published criticisms under three crucial flaws related to the original study: the methodological design, data analysis, and conceptual transformation. These criticisms are significant to the validity of the "law" and, along with the limited empirical evidence for the concept in MPA literature, warrant an evaluation of the concept's application to MPA.



**Figure 4.** Number of new citations recorded for Yerkes and Dodson (1908) on Google Scholar in 10-year intervals between 1909 and 2019. Note: counts are non-cumulative.

The methodological design of Yerkes and Dodson (1908) has been criticized by a number of authors for its: small sample size per condition (Brown, 1965; Calabrese, 2008; Hancock & Ganey, 2003; Teigen, 1994); inconsistent strength and lack of calibration in electrical current (Hancock & Ganey, 2003; Teigen, 1994); criteria chosen for differing levels of difficulty and habit-formation (Baumler, 1992, as cited in Baumler & Lienert, 1993; Brown, 1965); and lack of factorial design (Brown, 1965). Yerkes and Dodson (1908) acknowledged some of these limitations in their study, namely, the small number of mice per condition (affecting the irregularity of the results of Set II), and that for Set I only three strengths of stimulus were used (indicating a possibility that the most favorable strength of electric shock was not found). Despite acknowledging these limitations, Yerkes and Dodson (1908) expressed confidence in their findings given the logical explanation between the three experiments. However, the methodological flaws described above are significant, impacting on the study's external reliability, due to inconsistent and uncalibrated electrical currents; validity, due to criticisms for the criteria chosen for habit-formation; and generalizability, due to the small sample sizes.

The data and analysis of the original study have also been criticized for their limited points of data, only able to determine that the optimum lies between two points (Brown, 1965); amount of inter-mouse variability (Teigen, 1994); and lack of statistical significance (Brown, 1965; Calabrese, 2008; Teigen, 1994). These criticisms impact on the validity of the conclusions drawn by Yerkes and Dodson (1908).

Psychologists Gunther Baumler and Gustav Lienert reclassified Yerkes and Dodson's original data and then re-analyzed the data with modern statistical methods using both Yerkes and Dodson's original learning criterion ("series"), as well as a new ("error") learning criterion. The regrouping of the data decreased the number of categories of difficulty and strengths of electric shock but increased the number of subjects per condition for analysis. These studies found linear relationships (easy task in the "series" criterion and difficult task in "error" criterion), no trend within the data (easy task in "error" criterion), and only one

curvilinear relationship (difficult task in “series” criterion) (Baumler, 1992, as cited in Baumler & Lienert, 1993; Baumler & Lienert, 1993). A further nonparametric and bivariate analysis of the data combined data from both learning criteria found negative linear relationships for both easy and difficult tasks, rejecting the notion of a curvilinear relationship for difficult tasks using the original learning criterion (Lienert & Baumler, 1994). These re-analyses suggest that even the original data do not support an inverted-U result (Hancock & Ganey, 2003; Teigen, 1994). In other words, perhaps Yerkes and Dodson’s original data do not support the common “Yerkes-Dodson law”, and therefore are no longer valid as a conceptual support of optimal arousal to music performance.<sup>2</sup>

The third and final critical flaw of the Yerkes-Dodson law is the conceptual transformation and its breadth of application. While today’s wide application of the “law” is viewed as a mark of its robustness, this aspect of the Yerkes-Dodson law has been criticized (Teigen, 1994). Various authors have noted that the concepts described by the Yerkes-Dodson law and the variables on the accompanying inverted-U graphs appear to be interchangeable (Corbett, 2015; Hancock & Ganey, 2003; Teigen, 1994), despite each having distinct definitions and physiological characteristics (Teigen, 1994). Teigen (1994) argues that this suggests a “conceptual vagueness”, reflecting more on the state of scientific inquiry in the field rather than the strength of the law itself. Hancock and Ganey (2003) describe how it is possible for almost all experimental findings to be captured by parts of the Yerkes-Dodson curve:

... no lost data set in search of interpretation was ever rejected by the ever friendly inverted-U explanation... virtually all response outcomes can be embraced by windowing different locations on the curve and, as long as the author did not pre-specify arousal (whatever that was), an explanation for virtually any data set was forthcoming. (p. 10)

The Yerkes-Dodson law is plagued by an over-generalization without ever a need for any causal explanation (Corbett, 2015). This over-generalization, along with the Yerkes-Dodson law’s explanation by substitution and an immunity against falsification, are characteristics of a “folk model” (Dekker & Hollnagel, 2004), understood in the general population as commonsense explanations of behavior (Andrews et al., 2021; Fernandez Castro, 2020). Folk psychology models are also found in the field of music psychology, for example, musical skill as an innate musical talent (Sloboda, 2000; Sloboda et al., 1994). Despite some authors calling for the Yerkes-Dodson law to be repealed (Brown, 1965) and retired (Neiss, 1988), the Yerkes-Dodson law and its many formulations remain “irrefutable” (Neiss, 1988) and “immune against falsification” (Corbett, 2015; Neiss, 1988; Teigen, 1994).

## DISCUSSION

This study traced and critiqued the origin and transformation of optimal arousal as applied in

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<sup>2</sup> While the methodological design and analysis of Yerkes and Dodson (1908) do not hold up to modern standards of psychological research (Calabrese, 2008; Hancock & Ganey, 2003), many of these criticisms are not the fault of the authors. Psychology as a research field was still in its early days at the beginning of the 20<sup>th</sup> century and Yerkes and Dodson worked within the bounds of knowledge and technology at that time of publication. Methods of statistical analysis were not yet available to them (Brown, 1965; Calabrese, 2008; Teigen, 1994), with methods of calibrating the strength of electric shock only apparent part-way through their experiment. The only accepted criteria for habit-formation at that time was the series criteria used by Yerkes and Dodson (Lienert & Baumler, 1994).

MPA literature. The critical literature review demonstrated that optimal arousal, supported by the Yerkes-Dodson law, is an assumed tenet of MPA, underlying much discussion, research design, and practice in MPA literature. It was also found that the specifics of optimal arousal in MPA literature are inconsistent, with little empirical evidence to support its application to music performance. The Yerkes-Dodson law originated from a 1908 comparative psychology study on the most favorable strength of electric shock for habit-formation in mice. The transformation of this concept, from its origin to its current presentation, is permeated by a lack of empirical support and a common practice of conceptual substitution. It is little-known that the Yerkes-Dodson law has been widely criticized for its methodological flaws, analysis, and conceptual substitution. This critical historical review reveals that many of the inconsistencies and problems with the presentation of optimal arousal in MPA literature are also found within the Yerkes-Dodson law's transformation and current presentation in other disciplines.

This section will discuss the validity of the application of optimal arousal to music performance via an examination of three themes identified from the historical review above: its incomplete presentation, comparability of research design, and conceptual substitution.

### **Incomplete presentation**

The presentation of optimal arousal in MPA literature as a single inverted-U relationship indicates that that some unknown amount of anxiety can improve performance quality for pieces of music at any level of difficulty, and for performers at any level of expertise. While similar to the presentation of the concept in other disciplines, the single inverted-U presentation loses the interaction of task difficulty originally emphasised, including in the experimental replication by Broadhurst (1957). If the Yerkes-Dodson law was empirically sound and applied to music performance in its original conception, with different peaks of optimal performance for different levels of task difficulty, the implications on music performance would differ from its current presentation as a single inverted-U function. Its application to music performance may be conceived as follows: low levels of anxiety would produce optimal performance of a difficult piece of music; medium levels of anxiety for optimal performance of medium difficulty piece of music; and higher levels of anxiety would facilitate optimal performance of easy pieces of music.

However, "difficulty", as related to musical performance, is complex and subjective, raising a number of questions that impact on the outcome of a "difficulty" conceptual application of the Yerkes-Dodson law to music performance. Is the "difficulty" of musical repertoire objective? Can pieces of music be ranked in an agreed order of increasing difficulty? The difficulty of a piece of music not only lies within the range, complexity, and coordination of the notes, but also depends on the articulation or expressive qualities required (Chernow, 2019; Giorgio, 2020; Herlihy, 2019; Stead, 2019). Evidence of the subjectivity of repertoire grading can be found in the many published graded repertoire collections and exam syllabi which differ in the number and division of levels (ANZCA Music Examinations, 2022; Australian Music Examinations Board, 2022; Koenen, 2010; The Royal Conservatory of Music, 2022). The same repertoire is sometimes found to be graded differently across different collections. For example, Grieg's 'Alfedans' from Lyric Pieces Op. 12, No. 4 is graded in various syllabi as level four (of 12) in AMEB (Australian Music Examinations Board, 2022), level seven (of 14 levels) in The Royal

Conservatory (The Royal Conservatory of Music, 2022), level three (of 11) in ANZCA (ANZCA Music Examinations, 2022), and level four on Henle's repertoire grading (Koenen, 2010). However, despite this subjectivity, some authors have developed instruments for measuring the difficulty of vocal repertoire based on various measurable characteristics (Christensen, 2023; Ralston, 1999).

This "difficulty" application of the Yerkes-Dodson law to music performance becomes even more complex when player expertise is also considered. Individual perceptions of the "difficulty" of a piece of music would differ depending on an individual's expertise, both overall and on specific skills. The perception of "difficulty" of a particular piece of music may not be fixed, with the level of perceived difficulty varying depending on one's familiarity with the piece. The impact of these considerations likely alters the outcome of the anxiety-performance relationship beyond the simple, single, inverted-U graph. A difficulty-based conception of the Yerkes-Dodson law would raise more questions than it answers when applied to music performance. However, more conclusive evidence for the concept and its application to music performance is needed before it is necessary to address these questions.

### **Comparability of research design**

A comparison of the methodological design of the original study and the theorized function of optimal arousal in MPA literature reveals some elements that are experimentally incongruent. These elements include the comparison of the equivalency and manipulation of motivational concepts, as well as the equivalency and measurement of the dependent variables.

The motivating force in Yerkes and Dodson (1908) was physical punishment, in the form of electric shock, externally applied after an incorrect choice made by the subject. If the subject continued to select the correct choice, punishment was avoided, the purpose being to train or "learn" a particular behavior. On the other hand, the motivating force in MPA is anxiety, an internally driven response to a potential or anticipated danger, catastrophe, or misfortune (American Psychological Association, 2018b). The physiological and cognitive symptoms of anxiety may occur between hours or weeks before the performance (Irie et al., 2023; Van Kemenade et al., 1995; Zakaria et al., 2013). For mouse subjects, the correct exit choice ensures a positive response: the absence of punishment. However, for human subjects in MPA studies, the subject is likely to typically experience anxiety before the performance has been carried out, no matter whether they perform "correctly" or not. The positive response in this case being only a reduction, not absence, of anxiety (Irie et al., 2023; Yoshie et al., 2008). The source of the motivation (external punishment vs. internal anxiety) and the order in which they are applied in the experimental conditions (punishment after an incorrect choice vs. anxiety prior performance) differ between the two contexts, raising the question of whether these two concepts are comparable.

A further incongruity between the two concepts is the ability of the motivating force to be controlled or manipulated experimentally. Unlike at the time of Yerkes and Dodson (1908), the strength of electrical current can be precisely measured and controlled today (e.g., Anagnostaras et al., 2010; Fucich & Morilak, 2018; Khataei et al., 2021; Macheda et al., 2020), enabling studies to be replicated more reliably. MPA, on the other hand, is internally driven and often attributed to the fight or flight response (Farnbach & Farnbach, 2001; Kirchner et al., 2008; Salmon & Meyer, 1992; Wilson & Roland, 2002), taking effect immediately, and

unable to be controlled and measured experimentally. It is possible, however, to measure changes of some of the physiological symptoms of anxiety from a baseline level, such as heart rate, blood pressure, skin conductance, and sweat rate (Bellinger et al., 2023; Moreno-Gutierrez et al., 2023; Spahn et al., 2010; Yoshie, Kudo, et al., 2009). Various symptoms of anxiety are also able to be measured before, during (retrospectively reported), and after musical performance via self-report questionnaires (Barbeau, 2011; Cox & Kenardy, 1993; Kenny et al., 2004; Osborne & Kenny, 2005; Papageorgi et al., 2013). However, these responses vary both quantitatively and qualitatively according to different levels of anxiety from person to person (Irie et al., 2023; Kenny, 2011; Papageorgi et al., 2013), and would therefore be extremely difficult to manipulate to specific levels of anxiety for experimental purposes.

The differences between dependent variables in both types of studies also raise questions about comparability in terms of their equivalency and measurement. The dependent variable in Yerkes and Dodson (1908) was habit formation, exiting via a particular colored passageway, whereas when optimal arousal is applied to music performance, the dependent variable is often quality of music performance. Yerkes and Dodson (1908) were concerned with the number of repetitions to acquire a habit, while optimal arousal in music performance is concerned with the reproduction of an already learned skill (or habit), often in front of an audience. If anything, perhaps the context of music performance in reproducing an already learned skill is more comparable with experiments on learning/habit-retention in mice.

Like the comparison of motivational forces, the measurement of the dependent variables between the two types of studies are also incongruent. The number of times a mouse correctly or incorrectly enters a passageway can be counted and analyzed (and repeated). Likewise, there are other fields where performance can be clearly determined by measuring reaction time (Anderson et al., 1989), finger temperature (Bregman & McAllister, 1982), performance on word-search puzzles (Sodhi et al., 2016), counting word-recall (Clark et al., 1999), or correct responses to a letter transformation task (Eysenck, 1985). However, the assessment of music performance is not judged on countable aspects such as correct notes, but subjective expert judgements made on a variety of aspects such as intonation and pitch, rhythmic accuracy, technical competence, phrasing, expression and dynamics, tone quality and touch, memory, and articulation (Craske & Craig, 1984; Hamann, 1982; Hamann & Sobaje, 1983; Hoffman & Hanrahan, 2012; Yoshie, Kudo, et al., 2009; Yoshie, Shigemasu, et al., 2009). The subjective and complex nature of the assessment of musical performance makes it difficult to determine a piece of music has been “learned”. There is also no one right answer to when something is “learned”. What might be considered “learned” to one performer, audience member, or judge, may not be considered complete by another.

This comparison of the equivalency, manipulation, and measurement of the variables in the two fields demonstrates a number of incongruities between the two types of supposedly related concepts, providing further evidence to suggest that optimal arousal has been misapplied to music performance.

### **Conceptual substitution**

Today, the Yerkes-Dodson law can be found to be applied to a number of disciplines, explaining the relationship between any number of concepts (Corbett, 2015; Teigen, 1994). Despite conceptual substitution occurring throughout the history of the Yerkes-Dodson law,

each concept represented in the curvilinear relationship has distinct physiological and cognitive effect on the body. Broadhurst (1959) dismissed the conceptual substitution around the Yerkes-Dodson law in the 1950s as insignificant “jargon” (Broadhurst, 1959) as it was initially thought that all arousal states behave in a similar way. “Arousal” was then understood as: “an energy axis from 'low' to 'high', in the sense that examining one arousal state reveals the nature of them all (with differences only in intensity)” (Hanoch & Vitouch, 2004, p. 432). However, this unitary theory of arousal has since been considered untenable, and it is understood that various types of arousal affect behavior in “nontrivial” ways across different situations (Norman, 2016). Donald Hebb, who published the first theoretical presentation of the arousal construct, even alluded to this possibility: “it may be reasonably anticipated that arousal will eventually be found to vary qualitatively as well as quantitatively” (Hebb, 1955, p. 249). Today, arousal is defined as “a state of physiological activation or cortical responsiveness, associated with sensory stimulation and activation of fibers from the reticular activating system” and often linked to an emotion (American Psychological Association, 2018a).

MPA literature generally agrees that the physiological effects of anxiety experienced by musicians during or prior to performance are a result of the activation of the fight or flight response, an autonomic response to anticipated fear (Farnbach & Farnbach, 2001; Kirchner et al., 2008; Salmon & Meyer, 1992; Wilson & Roland, 2002). It is understood that the effect is instantaneous; blood flow is increased to the body’s large muscle groups and decreased to those not essential for action (digestive system, skin, face, genitals, kidneys), increasing physical vitality to fight or run away from life-threatening danger (Kirchner et al., 2008; Lehrer, 1987; Roland, 1997; Rosset i Llobet & Odam, 2007; Salmon & Meyer, 1992; Wilson & Roland, 2002). Physiological symptoms of MPA documented in musicians include dry mouth, increased heart rate, rise of blood pressure, shallow breathing, shaking, muscle tension, sweating, nausea and “butterflies” in the stomach (Abel & Larkin, 1990; Arneson, 2010; Bonetti, 2003; Egilmez, 2012; Ely, 1991; Henderson, 1985; Nideffer & Hessler, 1978; Plaut, 1990; Roland, 1997; Steptoe, 1989; Wilson & Roland, 2002). Cognitive and behavioral symptoms have also been reported in musicians up to days or even weeks in the lead up to a performance: self-doubt, negative thoughts, distraction, memory blanks, mental confusion, worry and fear of mistakes, pacing, speaking more quickly, avoiding practice, procrastination, inability to sleep, and loss of appetite (Bonetti, 2003; Boyett, 2019; Klickstein, 2009; Lehrer, 1987; Reubart, 1985; Roland, 1997; Rosset i Llobet & Odam, 2007). While dry mouth, shallow breathing, increased heart rate, nausea, and sweating prepare the body to escape or fight for their life, these symptoms are not helpful to the skills required for musical performance (Lehrer, 1987, Rosset i Llobet & Odam, 2007; Wilson and Roland, 2002). For example, shallow breathing in a singer or wind player could result in a shaky, vibrato sound, affecting the quality of sound produced (Bonetti, 2003). Shaking fingers in a pianist could result in mis-judging keys or a shallow depression of the keys, also affecting the intended sound quality (Furuya & Kinoshita, 2008; Yoshie, Kudo, et al., 2009; Yoshie et al., 2008).

The adaptive effects of anxiety on sport performance have been cited in MPA literature as support for the application of optimal arousal to music performance (Drinkwater & Klopper, 2010; McGrath, 2012; Wilson, 1997; Yoshie, Shigemasu, et al., 2009). However, when drawing upon the sport psychology literature, MPA authors have focused only on studies in sport that demonstrate the adaptive effects of anxiety (for example, rugby (Neil et

al., 2012; Robazza & Bortoli, 2007), judo (Papacosta et al., 2016), and anaerobic aspects of basketball (Parfitt & Pates, 1999)) and not integrated findings for sports in which anxiety has been shown to impair performance (for example, in darts (Williams & Cumming, 2012), golf (Bum & Shin, 2015; Chambers & Marshall, 2017; Hassmen et al., 2004; Hellstrom, 2009), archery (Lim, 2016, 2018), and rifle shooting (Hanton et al., 2000; Sade et al., 1990)). Sports, such as rugby, where anxiety has been found to enhance performance generally require use of the larger muscle groups, those muscles which are enhanced by the activation of the fight or flight response. Sports, such as darts and archery, where the effects of anxiety are detrimental to performance, make use of the fine motor skills (or slower movements of the large muscles groups). Music performance is one of the most highly skilled and detailed fine motor activities humanly possible (Altenmuller et al., 2015; Zatorre et al., 2007). Therefore, it would follow that anxiety would be similarly detrimental to music performance, like those sports that rely on fine motor skills (McGrath et al., 2017). Despite this more congruent comparison, studies on the detrimental effects of anxiety on performance for sports that use fine motor skills do not feature in MPA literature. Perhaps it is not “anxiety” that could have a facilitative effect on performance, but a more general “arousal” (Gannon, 2019; Kenny, 2009; Salmon, 1990).

This synthesis of literature from theoretical psychology, sport psychology, and music performance anxiety, demonstrates that the practice of conceptual substitution found throughout the history of the Yerkes-Dodson law does not hold true for the concept of anxiety as applied to music performance. Together with the incomplete application of the “law” and the methodological incongruities, there is an argument for the misapplication of optimal arousal, conceptualized as anxiety, to music performance.

### **LIMITATIONS**

This study followed a transdisciplinary approach to selecting literature, the studies selected for their ability to explain the current understanding and use of the Yerkes-Dodson law within MPA literature. A complete understanding of the historical transformation of the Yerkes-Dodson law can be found via a synthesis of studies by Calabrese (2008), Hancock and Ganey (2003), Hanoch and Vitouch (2004), Staal (2004) and Teigen (1994).

Limitations to this method of inquiry include no scope for systematically reviewing the literature or systematically evaluating the reliability and validity of the empirical studies pertinent to maintaining widespread application of the Yerkes-Dodson law, nor those found within MPA literature. Future studies concerned with the validity of optimal arousal with MPA literature could address this limitation by systematically reviewing empirical evidence for the Yerkes-Dodson law in general, or the empirical evidence for optimal arousal within MPA literature. Such inquiries would help to further corroborate the findings of this narrative historical inquiry.

### **AREAS FOR FUTURE RESEARCH**

Despite its limitations, this historical critique has shed light on a rarely questioned phenomenon in MPA literature. This critical review provides a starting point for further research into the examination of optimal arousal as applied to MPA, potentially opening several new lines of research inquiry, with practical implications. Without conceptual support

for the “need” for anxiety in music performance, academic research could investigate aspects of Western musical culture that assumes anxiety will be synonymous with musical performance. This would expand research inquiry from symptom management and ask questions such as: Why is MPA so pervasive in Western musical culture? How does MPA develop? How is MPA maintained (and why is there not much evidence for it alleviating with experience and age (for exceptions see Kenny et al. (2014) and Sokoli et al. (2022)))? Is it possible for there to be music making environments where MPA is not the expectation? How do they differ from current performance and music making environments? Is it possible to reduce the incidence of MPA associated with music making and performance? What are the implications for music education? Given the controversial nature of the transformation and current standing of the Yerkes-Dodson law, it is recommended that other fields of research similarly review the application of the Yerkes-Dodson law as well as the validity of the empirical and conceptual support within their field.

### **IMPLICATIONS FOR EDUCATION AND PRACTICE**

A critical analysis of the concept of optimal arousal and questioning the inevitability of MPA also has implications for educators and practitioners. Sharing the knowledge that we have no good evidence that fear or anxiety are in any way helpful for high-quality music performance can help shift the focus to an approach that values arousal (possibly in the form of excitement or joy), but not anxiety. Some pedagogical approaches (for example, Bodkin-Allen et al., 2019; Pike, 2017; Bačlija Susić, 2018; West, 2007) that remove the traditional paradigm’s emphasis on evaluation and have an underlying belief in all human beings have a natural desire to make music have the potential to change the narrative around the expectation and inevitability of anxiety around music making. Further widespread application of such pedagogical approaches could lead to the welcome relief of MPA for current sufferers and positively impact on how the general population (i.e. those not professional or student musicians) feel about making music (Australia Council for the Arts, 2010, 2017, 2020; Rivera et al., 2024, West, 2007). Widespread relief of MPA could eventually positively impact on the physical and mental health of student and professional musicians (currently poor compared to other professions (Ballenberger et al., 2023; Rodríguez-Gude et al., 2022; Vaag et al., 2016)).

### **CONCLUSION**

This study has identified and critiqued the historical origin and transformation of the Yerkes-Dodson law, a major support for the concept of optimal arousal found in MPA literature. There is evidence that optimal arousal is a currently assumed concept with MPA literature, embedded within our understanding, research, and practice around MPA. This assumption limits the extent of current research inquiry to managing or controlling anxiety and its related symptoms, instead of questioning widespread MPA as a systemic problem. It may also give musicians, teachers and researchers a justification for maintaining anxiety-inducing environments.

The synthesis of literature from the concept’s origin to its current understanding describes a complex and controversial historical transformation, leaving us unsure of the validity or application of the “law” to music performance. The short critique of empirical evidence for optimal arousal within MPA literature shows only conditional support for an

inverted-U shaped relationship between anxiety and music performance. A detailed examination of a “difficulty” application of the concept, the comparability of research design, and the efficacy of conceptual substitution when applied to music performance also supports a case for the misapplication of optimal arousal, when conceptualized as anxiety, to music performance. Until optimal arousal has been given robust testing with strong conclusions regarding the relationship between anxiety and performance quality, it is recommended that researchers reflect on the extent of their own assumption of the concept and its influence on research inquiry and design, and exercise caution in including it in theoretical or applied models. The common operationalization of “optimal arousal” as “optimal anxiety” contributes to a Western music performance culture that expects and celebrates fear as desirable, which may undercut lay music participation and lead to burnout in musicians. We need to give this cost-benefit balance careful consideration, as a field, before continuing to build a literature base on the foundation of a shaky inverted-U.

#### DECLARATION OF INTEREST STATEMENT

No potential competing interest was reported by the authors.

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