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Music performance anxiety in classical music students: A matter of challenge and threat?

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pour le Doyen
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Prof. Claudia Bagni

A mes parents, mes références dans la tempête.

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Abstract

To pursue a music career, music students must be able to perform at a high level in front of an audience. However, when it comes to performing on stage, not all music students are equally comfortable. Through this thesis, we aimed to understand how general music performance anxiety (MPA) and audience presence influence a music performance. We first investigated to what extent general MPA level and audience presence influence the hypothalamic-pituitary-adrenal (HPA) axis and the sympathoadrenal system (SAM) activity, the nine flow experience dimensions, and self-rated performance quality throughout the music performance. Based on the biopsychosocial model of challenge and threat (Blascovich, 2008; Seery, 2011), we also investigated to what extent general MPA level and audience presence influence music students' tendency to be in a challenge or threat state during music performance. Finally, we explored to what extent challenge and threat states can influence self-rated performance quality.

For this purpose, we recruited 121 classical music students and asked them to perform twice the same music piece solo: once alone and once in front of an audience of 6 to 8 people. Music students' general MPA levels were measured using an adapted version of the state scale of the State-Trait Anxiety Inventory (STAI - Spielberger, 1983). Students' general MPA levels ranged from 27 (low MPA level) to 76 (high MPA level). Throughout the experiment, 6 salivary samples were collected to analyze salivary cortisol (sC) level, salivary dehydroepiandrosterone (sDHEA) level, anabolic balance level (i.e., sDHEA/sC ratio), considered as HPA axis activity indices, and salivary alpha-amylase activity level, considered as SAM system activity index. Flow experience, self-rated music performance quality, and challenge-threat state were measured via questionnaires.

Our results showed that the general MPA level did not influence the HPA axis and the SAM system activity, however, it did negatively influence some flow dimensions (focus on the task at hand, sense of control, self-reported experience), perceived resources, and self-rated performance quality. The audience presence caused an increase in the perceived demands of the task and an increase in the HPA axis activity, but not the SAM system activity. Our results also showed that during a public performance, music students with a general MPA level between 47 and 57 tended to perceive more ambiguous feedback, to be more aware of the others presence, and to be more in a threat state than in a challenge state. After listening to their performance recordings one week after the end of the last performance, music students tended to rate the quality of their public performance more negatively than the quality of their private performance. Finally, students with a challenge state rated the quality of their performances more positively.

In conclusion, this thesis provides a better understanding of how the general MPA level and the audience presence during a music performance influence the HPA axis and the SAM system activity, the different flow dimensions, the challenge-threat state, and the self-rated performance quality. This thesis results could be a first step towards developing and creating interventions to help music students overcome the challenge of performing on stage.

Résumé

Pour poursuivre une carrière musicale, les étudiant.e.s en musique doivent être capables de réaliser une performance musicale de haut niveau face à un public. Néanmoins, lorsqu'il faut se produire sur scène, les étudiant.e.s en musique n'ont pas tous la même facilité. Au travers de cette thèse, nous avons voulu comprendre de quelle façon l'anxiété de performance musicale (MPA) générale et la présence du public influencent une performance musicale. Nous avons d'abord étudié tout au long de la performance musicale dans quelle mesure le MPA général et la présence du public influencent l'activité de l'axe hypothalamo-hypophyso-surrénalien (HPA) et du système sympatho-surrénalien (SAM), les neuf dimensions de l'expérience du flow et la qualité de performance auto-évaluée. Sur la base du modèle biopsychosocial de défi et de menace (Blascovich, 2008 ; Seery, 2011), nous avons également étudié dans quelle mesure le niveau de MPA général et la présence du public influence la tendance des étudiants en musique à être dans un état de défi ou de menace au cours de la performance musicale. Enfin, nous avons étudié dans quelle mesure un état de défi ou de menace peut influencer la qualité de performance auto-évaluée.

Pour cela, nous avons recruté 121 étudiant·e·s en musique classique qui ont dû jouer le même morceau de musique en solo deux fois : une fois seul·e et une fois face à un public de 6 à 8 personnes. Le niveau de MPA général des étudiant·e·s en musique a été mesuré à l'aide d'une version adaptée du State-Trait Anxiety Inventory (STAI - Spielberger, 1983). Les niveaux de MPA général des étudiant.e.s variaient entre 27 (bas niveau de MPA) à 76 (haut niveau de MPA). Tout au long de l'expérience, 6 échantillons salivaires ont été prélevés pour mesurer le niveau de cortisol, le niveau de déhydroépiandrostérone (DHEA), le niveau de balance anabolique (i.e., ratio sDHEA/cortisol), indicateurs de l'activité de l'axe HPA, ainsi que le niveau d'activité d'alpha-amylase, indicateur de l'activité du système SAM. L'expérience du flow, la qualité de performance musicale auto-reportée et l'état de défi-menace ont été mesuré via des questionnaires.

Les résultats ont montré que le niveau de MPA général n'influençait pas l'activité l'axe HPA et du système SAM, cependant, il influençait négativement certaines dimensions du flow (concentration sur la tâche en cours, sentiment du contrôle, expérience autotélique), les ressources perçues et la qualité de performance auto-reportée. La présence du public provoquait une augmentation du niveau de demandes perçues de la tâche et une augmentation de l'activité de l'axe HPA mais pas du système SAM. Nos résultats montraient également que lors d'une performance publique, les étudiant·e·s en musique ayant un niveau de MPA général entre 47 et 57 avaient tendance à percevoir plus de feedback ambigu, à être plus conscient·e·s de la présence du public, et à être plus dans un état de menace que dans un état de défi. Après avoir réécouté les enregistrements de leurs performances une semaine après la fin de la dernière performance, les étudiant·e·s en musique avaient tendance à évaluer plus négativement la qualité de leur performance publique par rapport à la qualité de leur performance privée. Enfin, les étudiant·e·s ayant généralement un état de défi évaluaient plus positivement la qualité de leurs performances.

En conclusion, cette thèse apportent une meilleure compréhension de l'influence qu'ont le niveau de MPA général et la présence du public au cours d'une performance musicale sur l'activité de l'axe HPA et du système SAM, les dimensions de l'expérience du flow, l'état de défi-menace et la qualité de performance auto-évaluée. Ces résultats pourraient être une première étape vers le développement et la création d'interventions visant à aider les étudiant·e·s en musique à surmonter le défi de jouer sur scène.

Abbreviations

BPSM	Biopsychosocial model
DHEA	Dehydroepiandrosterone
HPA	Hypothalamic-pituitary-adrenal
MPA	Music performance anxiety
MPQ	Music performance quality
TSST	Trier social stress test
sAA	Salivary alpha-amylse
SAM	Sympathoadrenal medullary
sC	Salivary cortisol
sDHEA	Salivary dehydroepiandrosterone

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For all figures, the symbol "★" indicates a *p*-value below 0.05. The symbols "★★" indicates a *p*-value below 0.01. The symbols "★★★" indicates a *p*-value below 0.001.

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1. Introduction

Not all musicians have the same predisposition when it comes to performing in front of an audience. While some excel and flourish on stage, others feel paralyzed and perform below their actual competence level without an audience. With this thesis, we aim to determine how music performance anxiety (MPA) and audience presence may influence classical music students' neuroendocrine activity, flow experience, motivational state, and music performance quality (MPQ) across a music performance. In the following, we will first introduce the concept of general MPA level and the issue of audience presence during a music performance. Then, we will focus on the hypothalamic-pituitary-adrenal (HPA) axis and sympathoadrenal medullary (SAM) system activity in the music performance context. We will also explore the positive aspects of making a music performance, and more specifically, we will look at the flow experience. Finally, we will see how these concepts can be integrated into the biopsychosocial model (BPSM) of challenge and threat (Blascovich, 2008; Seery, 2011) and how, using this framework, general MPA level and audience presence may influence the MPQ.

1.1. Music performance anxiety

1.1.1. Definition[1]

Although there is no consensus to date regarding the definition and origin of music performance anxiety (Kenny, 2011), here we consider the definition proposed by Kenny in 2011. According to this researcher, MPA is "the experience of marked and persistent anxious apprehension related to music performance that has arisen through underlying biological and/or psychological vulnerabilities and/or specific anxiety-conditioning experiences." (Kenny, 2011, p. 433). This apprehension experience can manifest itself through a combination of symptoms: affective (i.e., negative feelings such as anxiety, tension, or panic - Steptoe, 2001), cognitive (e.g., loss of concentration or memory, ruminations, pre-performance catastrophizing - Steptoe, 2001, Nielsen et al., 2018, Haccoun et al., 2020, Sokoli et al., 2022), psychosomatic (e.g., tremors, excessive movements – Sokoli et al., 2022), and biological changes (i.e., respiratory alterations – Studer et al., 2012; Guyon et al., 2020a). This combination of symptoms can manifest differently before, during, and after a music performance (e.g., Kenny, 2011; Studer et al., 2014; Haccoun, 2020). MPA is classified as a subcategory of social anxiety by the Diagnostic and Statistical Manual of Mental Disorders (DSM-V -American Psychology Association, 2013). Social anxiety disorder models highlight numerous differences between non-socially and socially anxious individuals at the level of attention, interpretation, and action (Hiemisch et al., 2002; Hofmann, 2007; Nieuwenhuys and Oudejans, 2012). Compared to non-socially anxious individuals, highly socially anxious individuals exhibit an increased attention to task-irrelevant (threat-related) information, have higher social standards (i.e., expectactions and social goals), perceive poorer task-related skills, view their own emotions and bodily reactions as less controllable, and engage more in information processing that interferes with successful goal selection.

1.1.2. Epidemiology

[1] The chapter 1.1.1. was based on a publish article (Guyon et al., 2022)

MPA is not an unusual phenomenon. The number of musicians reporting high MPA ranges from 16.5% to 60% depending on the study (Fernholz et al., 2019). Studies have found that MPA can be modulated by other factors such as the style of music (Papageorgi, Creech, & Welch, 2013) or the type of instrument used (e.g., Robson and Kenny, 2017; Sokoli et al., 2022) but also by the number of musicians involved in the performance. For example, when performing in an ensemble, musicians generally express lower anxiety levels than when performing solo (e.g., Nicholson et al., 2015; Cohen & Bodner, 2021). Among the factors that may influence the MPA level, gender has often been emphasized. Most research teams have observed that women are more frequently affected and/or have higher MPA scores than men. A few studies reported no gender differences in MPA (Fernholz et al., 2019; Barros et al., 2022). Age has also been long considered as a potential risk factor for MPA; however, the literature is divided. On the one hand, a number of studies show that young musicians are more affected by MPA than older musicians (Huston, 2001; Osborne & Franklin, 2002; Kenny et al., 2014; Butkovic et al., 2021) and on the other hand, either an inverse relationship is found (Zarza-Alzugaray et al., 2018; Sokoli et al., 2022) or no association at all is found between MPA level and age (e.g., Wolfe, 1989; Wesner et al., 1990; van Kemenade et al., 1995; Liston, Forst, & Mohr, 2003; Kobori et al., 2011; Papageorgi, Creech, & Welch, 2013; Dobos, Piko, & Kenny, 2019; Cohen & Bodner, 2021). Some researchers have argued that it is not age that predicts MPA proneness but rather occupational status (Kobori et al., 2011). Indeed, studies have put forward that music students and amateur musicians are generally more likely to have a high MPA level than professionals (Steptoe & Fidler, 1987; Kobori et al., 2011; Biasutti & Concina, 2014). In Switzerland, approximately one-third of university music students consider MPA a problem for them (Studer et al., 2011). For music students, MPA can lead to substance use (medication or drugs) or dropping out of school (Orejudo Hernández, Zarza-Alzugaray, & Casanova, 2018). For these reasons, more and more studies are being conducted on undergraduate music students (Barros et al., 2022).

1.1.3. General music performance anxiety

For the purposes of this thesis, it is crucial to distinguish between what is considered state MPA and trait MPA, also called general MPA. State MPA refers to the temporary state that the musician is in before, during, and after a music performance, whereas general MPA refers to the general tendency of the musician to experience MPA during a music performance. To date, only few studies investigated how the general MPA level may influence musicians' psychophysiological responses in a music performance context. Studies have shown that during a music performance (whether performed in the presence of an audience or not), music students with high general MPA levels report higher levels of anxiety, discomfort, tension, and bodily complaints (e.g., tremors, palpitations, and clammy hands - Craske & Craig, 1984; Fredrikson & Gunnarsson, 1992; Studer et al., 2012; 2014), and higher levels of post-event rumination than music students with low general MPA level after a music performance (Nielsen et al., 2018). Although music students with higher general MPA levels reported more psychophysiological symptoms, the differences at the physiological level were mixed. At the cardiovascular level, general MPA level had no significant effect on heart rate or heart rate variability (Studer et al., 2012; 2014). However, at the respiratory level, it was observed that during a music performance, music students with high general MPA have greater changes in partial pressure end-tidal carbon dioxide ($PetCO_2$ - an index of the presence of hyperventilation) and minute ventilation (i.e., the volume of air inhaled per minute) than

music students with low general MPA. It has also been observed that total respiratory variability (quantified by the coefficient of variation or standard deviation including sighs) in music students with high general MPA levels is lower than in students with low MPA during a music performance (Guyon et al., 2020a). It is important to notice that most of these studies operationalized differently the general MPA level (i.e., continuous vs. categorical) and that the music performance contexts (i.e., with or without an audience) were different from one study to another, however, music performance context may play an important role on music students' psychophysiological response to the situation.

1.2. Music performance

Music performance is considered as a complex activity requiring a high level of cognitive and sensorimotor control, which also necessitates a great sense of aesthetics and interpretation (Zatorre, Chen, & Penhune, 2007; Altenmüller & Ioannou, 2016). Moreover, music performances are performed, for the most part, in front of an audience that will explicitly or implicitly evaluate the quality of that performance. Musicians must, therefore, continually reach a certain level of excellence not to jeopardize their careers.

According to the theory of social self-preservation proposed by Dickerson & Kemeny in 2004, music performances can be seen as social self-threatening situations. The social self is defined as "one's social value, esteem, and status and is largely based on others' perception" (Dickerson & Kemeny, 2004, p.357). Having a high social self means that one exhibits qualities recognized and respected by others, while a low social self means that one exhibits qualities considered undesirable by others and may cause rejection and/or disinterest on their part. Social self-preservation theory (Dickerson & Kemeny, 2004) states that one of our fundamental goals is to preserve this social self at its highest. To do this, we would constantly scan our environment for possible threats to our social self. When we perform a task relevant to our goals that requires the demonstration of our skills, it can be considered a threatening situation because the very fact of failing at this task would result in a negative evaluation by others, a decrease in our social self, and thus a questioning of our abilities to achieve the goal we consider relevant. Among these threatening situations, we can consider the realization of a music performance. If musicians fail to give a high-level music performance, then their social self, and more precisely, their status as a musician is called into question, as is their musical career. According to the theory of social self-preservation, a situation that threatens the social self is even more threatening when the situational conditions are uncontrollable and unpredictable (Dickerson & Kemeny, 2004). In the music performance context, there are many unpredictable and/or uncontrollable factors, such as the audience composition, their reaction to the performance, the room temperature, which can influence the instrument sound or the musician's physiological reactions during the performance. Taken together, these elements can create a certain "pressure" in the musician during public performances that is not present during private performances.

This "pressure" from the public can generate psychophysiological stress responses in musicians (Rohleder et al., 2007; Gomez et al., 2018). On average, musicians tend to report more anxiety, distress, nervousness, bodily complaints, and negative cognitions than when they perform in front of an audience than without an audience (e.g., Craske & Craig, 1984; Fredrikson & Gunnarsson, 1992; Yoshie et al., 2009a; Studer et al., 2012; Larrouy-Maestri & Morsomme, 2014; Fancourt, Aufegger, & Williamon, 2015; Chanwimalueang et al., 2017; Aufegger & Wasley, 2018). Furthermore, at the physiological level, musicians tend to have a

higher heart rate (Neftel et al., 1982; Craske & Craig, 1984; Fredrikson & Gunnarsson, 1992; Brotons, 1994; Hunsaker, 1994; Inesta et al., 2008; Yoshie et al., 2009a; 2009b; Hamart & Theorell, 2010; Endo et al., 2014; Larrouy-Maestri & Morsomme, 2014; Studer et al., 2014;), larger skin conductance (Yoshie et al., 2009a; 2009b, but see Craske & Craig, 1984), higher salivary immunoglobin A (Beck et al., 2000), higher plasma myeloperoxidase and interleukin-6 (Pilger et al., 2014), increased electromyographic activity of arm and shoulder muscles (only for pianist – Yoshie et al., 2009a; 2009b), higher salivary and urinary cortisol levels (Fredrikson & Gunnarsson, 1992; Pilger et al., 2014; Fancourt, Aufegger, & Williamon, 2015; Aufegger & Wasley, 2018), and higher urinary norepinephrine and epinephrine (Neftel et al., 1982; Fredrikson & Gunnarsson, 1992). Nevertheless, very little attention has been paid to the psychophysiological concomitants of general MPA and audience presence together. Studies showed that a high general MPA level was associated with a high state anxiety level during public performance compared to private performance (Craske & Craig, 1984; Guyon et al., 2020a), and that from a private to a public music performance, the skin conductance, the urinary adrenaline, and the noradrenaline levels are not modulated by the general MPA level (Crake & Craig, 1984; Fredrikson & Gunnarsson, 1992).

Up to now, in addition to the restricted number of studies on the MPA-associated psychophysiological differences in the context of music performance, the sample size of these studies was relatively small (Crake & Craig, 1984; Fredrikson & Gunnarsson, 1992) and the number of psychophysiological parameters remains limited. For instance, at the physiological level, even though they are of great interest in stress research, the salivary concentrations of cortisol, dehydroepiandrosterone, and alpha-amylase have not yet been considered in relation to potential MPA-associated differences.

1.3. Hypothalamic-pituitary-adrenal axis

According to Dickerson and Kemeny (2004), in the context of a situation that threatens the social self, there should be a significant increase in the activity of the hypothalamic-pituitary-adrenal (HPA) axis. The HPA axis is a component of the body's adaptive system that allows for the maintenance of functions during changes in the environment; however, its chronic overactivation can lead to numerous diseases such as cardiovascular disease, fatigue, or psychological disorders such as depression or memory loss (Dickerson & Kemeny, 2004; Nicolson, 2008). The HPA system activation is characterized by the hypothalamus activation causing an increase in the secretion of corticoliberin (CRH). The CRH allows the production of corticotrophin (ACTH) by the pituitary gland to increase, which then activates the adrenal glands and causes the secretion of glucocorticoids by the cortex, including cortisol, a catabolic hormone.

1.3.1. Cortisol

Cortisol is one of the most studied hormones in the stress response. Cortisol allows gluconeogenesis (formation of glucose from lipids and proteins), a mechanism that provides energy to the body and allows adequate metabolic functioning (Dickerson & Kemeny, 2004; Marieb & Hoehn, 2019). Dependent on the circadian cycle, cortisol reaches its highest level upon awakening before decreasing throughout the day until the evening (Hucklebridge et al., 2005; Nicolson, 2008). However, acute psychosocial stressors can disrupt the normal circadian pattern of cortisol by causing its increase (Dickerson & Kemeny, 2004; Nicolson, 2008). The

purpose of this rise in cortisol is to mobilize energy to cope with the psychosocial stressor while protecting the body (Munck, 2000). In blood, cortisol can be found under three forms: unbound (or free) cortisol, protein-bound cortisol, and cortisol metabolites. When the cortisol level increases in front of a psychosocial stressor, all the cortisol form levels are increasing and especially, the unbound cortisol, which is the only biologically active hormone. The unbound cortisol levels not only increase in the blood but also in urine and saliva, which allow us to measure reliably the the HPA axis activity (Levine et al., 2007; El-Farhan et al., 2017; Nicol, Anitescu, & Benzon, 2018).

Many studies looking at the cortisol response to an acute psychosocial stressor use the Trier-Social-Stress paradigm (TSST – Kirschbaum, Pirke, & Hellhammer, 1993; Allen et al., 2017 – e.g., Schommer, Hellhammer, & Kirschbaum, 2003; Nater et al., 2005; Rohleder et al., 2006). The TSST takes place in a laboratory. Participants are invited to participate to an interview for the job of their choice. Participants have a short period of time to prepare a speech explaining why they would be the best candidate for this job. Then, they need to present this speech in front of interviewers with a video or voice recorder. During their presentation, participants are interrupted, and asked to do an unexpected mental arithmetic task. Throughout the experiment, the people playing the role of interviewers must adopt a neutral attitude and not help the participants. This paradigm has repeatedly been shown to elevate stress levels in participants and increase their cortisol levels (Allen et al., 2014). These studies have shown that the increase in cortisol levels in response to the onset of a stressor (also known as reactivity) is not immediate and, the peak cortisol concentration in the face of that stressor is not reached until 15-30 min after the onset of the stressor (Ramsay & Lewis, 2003; Mulder, 2011). Furthermore, once this peak concentration is reached, cortisol levels may take up to one hour after the stressor has subsided to return to baseline (also known as recovery – Dickerson & Kemeny, 2004; Nicolson, 2008; Mulder, 2011).

The study of salivary cortisol (sC) concentration in the context of music performance has gained momentum in recent years. While all studies agree that during a public performance, the sC level is higher than during a private music performance in professional singers (Beck et al., 2000; Fancourt, Aufegger, & Williamon, 2015), in orchestra musicians (Halleland et al., 2009; Pilger et al., 2014), and in music students (Aufegger & Wasley, 2018; Tùran et al., 2022), this is not the case concerning the sC temporal pattern. On the one hand, in amateur musicians, one study was able to observe that the sC level was higher before the performance compared to the sC level measured on a day without performance and that the sC level was higher after the performance than before (Everaerd et al., 2020). On the other hand, a study in choral singers observed a significant decrease between pre-performance sC level and post-performance sC level (Schladt et al., 2017; Bowling et al., 2022). Finally, also in choral singers, one study found no significant difference between pre-performance sC level and post-performance sC level (Kreutz et al., 2004). Research has also shown that in music students, peak cortisol elevation can be reached between 10 and 20 minutes after the start of the music performance (Boyle et al., 2013; Aufegger & Wasley, 2018) and that sC recovery after a public performance can take several hours (Gomez et al., 2018).

While these differences can largely be explained by paradigm or population differences, few studies have yet investigated how general MPA level associated with the audience presence may influence the sC response. To date, only Fredrikson & Gunnarson (1992) investigated the effect of general MPA level and type of session together on urinary cortisol levels. In their study, they concluded that cortisol levels were higher during the public performance session compared to the urinary cortisol level during the private performance

session. However, they found no significant difference in urinary cortisol levels between musicians reporting high general MPA levels and those reporting low general MPA levels. In a different study, a significant positive correlation was observed between the cortisol level 10 and 30 min after the performance onset and the musicians' belief that they would be judged negatively if they gave a poor performance (Boyle et al., 2013). In addition, more experienced musicians, also considered to have lower general MPA levels (Huston, 2001; Osborne & Franklin, 2002; Kenny et al., 2014; Butkovic & Modrusan., 2021), have lower sC levels during the recovery phase following a performance than less experienced musicians (Killough, Thompson, & Morgan, 2015).

1.3.2. Dehydroepiandrosterone and anabolic balance

In addition to the cortisol secretion, the HPA axis can also stimulate the adrenal cortex to secrete gonadocorticoids from the zona reticularis, including dehydroepiandrosterone (DHEA) - an anabolic hormone (Mendes et al., 2007a). As cortisol, DHEA is dependent on the circadian cycle with a higher concentration in the morning before decreasing throughout the day (Hucklebridge et al., 2005; Ahn et al., 2007). In the literature, most studies agree that DHEA plays a regenerative and protective role (Theorell, 2008; Maninger et al., 2009). In particular, studies have suggested that low DHEA levels may be associated with lower psychological well-being, with a negative correlation between DHEA levels and depression being observed (Berr et al., 1996; Michael et al., 2000; van Niekerk, Huppert, & Herbert, 2001).

Given the positive role that DHEA may have, more and more studies have focused on the role that DHEA may play during exposure to a psychosocial stressor (Dutheil et al., 2021). Using the TSST paradigm, the majority of these studies have shown that salivary DHEA (sDHEA) levels increase significantly overall immediately after exposure onset to a psychosocial stressor compared to baseline and then decrease significantly up to 60 min after exposure onset to the stressor (Dutheil et al., 2021). In 2008, Izawa et al. measured the level of sC and sDHEA in 33 male students during a TSST paradigm. They were able to observe that both the sDHEA level and the sC level increased significantly during the experiment. Yet, there were a few noteworthy differences in the response patterns of the two hormones. Whereas the cortisol level became significantly higher than the baseline level (after 10 min resting before the TSST beginning) once the exposure to the stressor was over and remained so until 30 min after the end of the exposure, the DHEA level was significantly higher than the baseline level from the beginning of the exposure to the psychosocial stressor until 20 min after the end of the exposure. For some researchers, DHEA, as an anabolic hormone, would have a role to play in reducing cortisol levels by acting as an antagonist (Blauer et al., 1991; Epel, McEwen, & Ickovics, 1998). According to Epel, McEwen, & Ickovics (1998), DHEA may play a crucial role in counter-regulating the effect of catabolic hormones during stress, allowing the organism to return to its baseline state once the stressor disappears. This theory was later supported by the work of Alhaj et al (2006) who noted that DHEA administration leads to a reduction in cortisol concentration suggesting that DHEA may antagonize cortisol activity. For this reason, some authors have advocated not only for the analysis of cortisol and DHEA levels separately but also of the ratio between DHEA and cortisol levels, known as anabolic balance (e.g., Epel, McEwen, & Ickovics, 1998; Mendes et al., 2007b; Jin et al., 2016). As an example of study showing the interest of the anabolic balance, Goodyer et al. (2003) found that persistently depressed individuals had a low DHEA level associated with a high cortisol level compared to non-depressed people.

To the best of our knowledge, there are no studies on the DHEA or anabolic balance responses during a music performance in front of an audience, let alone on the effect that the general MPA level might have on these responses. In 2009, Shirotsuki et al. measured the sC and sDHEA levels during the TSST in 22 men who differed in the level of social anxiety. Their results showed that highly anxious individuals had a significantly lower sC response than low anxious individuals while no difference was observed in sDHEA. Furthermore, they observed a significant interaction effect of the anxiety level and time on the anabolic balance (conceptualized as the ratio sC/sDHEA). Socially low anxious participants had a higher anabolic balance level after the exposure to the psychosocial stressor than before the exposure whereas for highly socially anxious participants, there was no significant anabolic level difference. Given the small sample size, the results of this study must be interpreted with great caution.

1.4. Sympathoadrenal medullary system and salivary alpha-amylase

The sympathoadrenal medullary system (SAM) axis is regulated by the locus coeruleus-norepinephrine system located in the brain stem (Kaltsas & Chrousos, 2007). The SAM activation involves the activation of the adrenal medulla allowing the release of norepinephrine and epinephrine into the blood, which help to increase ventricular contractility and dilate blood vessels (Brownley, Hurwitz, & Schneiderman, 2000). To date, it is not possible to measure the activity of the SAM axis in a direct and non-invasive way. Nevertheless, the SAM axis, like the parasympathetic nervous system, is part of the autonomic nervous system that innervates the salivary glands. Thus, when the sympathetic nervous system is activated, it increases salivary protein secretion, whereas when the parasympathetic system is activated, the salivary flow rate increases (Rohleder et al., 2004). It is one of the reasons why in recent years, salivary alpha-amylase (sAA), a salivary enzyme involved in carbohydrate digestion, has been recognized as a marker of autonomic nervous system activity and to some extent, might be used as an index for SAM axis activity (Rohleder, 2014; Warren et al., 2017; Ali & Nater, 2020). The secretion of this enzyme is dependent on the circadian cycle (low level in the morning and then increases until it reaches its peak in the late afternoon – Nater et al., 2007; Nater & Rohleder, 2009). Furthermore, its secretion level also seems to be sensitive to exposure to social-evaluative stressors (e.g., Nater et al., 2007; Filaire et al., 2010; Thoma et al., 2012). Considering the variations related to circadian rhythm, previous studies have shown, using a TSST paradigm that the sAA level was significantly higher when participants were exposed to acute stress compared to a resting condition (Nater et al., 2005, Rohleder et al., 2006). This increase in the sAA level also seems to be associated with the increase in the norepinephrine level in plasma, however, this association is rather weak (Rohleder et al., 2004; Nater et al., 2006). Unlike cortisol, whose concentration increases significantly within minutes of the onset of exposure to an acute stressor such as TSST, the sAA level would appear to increase even before exposure to the TSST task begins (Bosch et al.,1996; Nater et al., 2005; Espin et al., 2019).

Similarly to what was observed in social-evaluative stressor studies, a previous study on MPA showed that the norepinephrine and epinephrine levels in the blood were significantly greater in a public session than in a private session, but that there was no difference between musicians with high or low general MPA levels (Fredrikson & Gunnarson, 1992). Nevertheless, this study includes many possible methodological confounds (e.g., small sample, only string instrument players, stress due to blood collection). Studies examining the

sAA activity evolution in the context of music performances remain scarce even though researchers started to get interested in it (Aufegger & Wasley, 2018; Gomez et al., 2018; Tùran et al., 2022). Notably, in 2018, Gomez et al. observed that sAA activity increased on the day of a public concert and that this elevation in sAA activity extended up to a day after the public performance had ended in music students with moderate to high general MPA levels. The same year, Aufegger and Wasley studied 11 violinists in a private and a public performance session. The authors found a significant interaction between time and type of performance. Interestingly, as opposed to previous studies results using other social-evaluative stressors, the sAA activity was higher during the private performance compared to the public performance 15 min after the end of the performance. They also observed that the sAA activity level across all the performance was higher in private performance than in public performance. Finally, they found that the sAA activity increased after the private performance, whereas it decreased after the public performance. Nevertheless, the limited number of participants in this study makes it difficult to generalize these results. Even though these two last studies suggest that both the general MPA level and the type of performance session may influence the sAA activity, the direction of this influence seem to be mixed.

1.5. Flow experience[2]

Although MPA is a common experience for many musicians, performing in front of an audience can also be associated with pleasant experiences (Beck et al., 2000; Pilger et al., 2014). In recent years, the flow experience has attracted increasing attention in the music performance literature (Biasutti, 2017; Habe, Biasutti, & Kajtna, 2021; Tan & Sin, 2021; Antonini et al., 2022). The term "flow" describes "an almost automatic, effortless, yet highly focused state of consciousness" (Csikszentmihalyi, 1996, p. 110) experienced "when a person's body or mind is stretched to its limits in a voluntary effort to accomplish something difficult and worthwhile" (Csikszentmihalyi, 1990, p. 3). More recently, flow has been defined as "an intrinsically rewarding state of absorption in a task in which control feels effortless" (Norsworthy, Jackson, & Dimmock, 2021, p. 818). In colloquial terms, the state of flow is often referred to as being "on the ball," "in the groove," or "in the zone" (Martin & Jackson, 2008). Flow is a multidimensional concept. Csikszentmihalyi's (1990) original conceptualization of flow consists of nine dimensions. According to this framework (Nakamura & Csikszentmihalyi, 2009), three dimensions are preconditions for flow to occur: (1) "challenge-skill balance," which refers to the perceived balance between the situational challenge represented by the activity and the personal skills necessary to overcome it; (2) "unambiguous feedback," which concerns the clear and immediate feedback regarding the activity's failure or success; and (3) "clear goals," which relates to the clarity of what was expected to complete the task. The other six flow dimensions describe the flow state experience itself: (4) "action-awareness merging," which alludes to the automaticity of actions with no separation of the self from the task; (5) "concentration on task at hand," which refers to the absorption in the activity; (6) "sense of control," which describes the feeling of being in control of the activity; (7) "loss of self-consciousness," which relates to the total immersion of the person in the task to the point of forgetting oneself and becoming one with the activity; (8) "transformation of time," which refers to the time alteration perceived during the activity; and (9) "autotelic experience," which expresses the intrinsically rewarding feeling of the overall experience. The flow

[2] The chapter 1.5 is based on a published article (Guyon et al., 2022)

dimensions may be more or less prominent according to situational and personal factors. For instance, in some sport performances (e.g., figure skating or running) the dimensions "loss of self-consciousness" and "transformation of time" correlate weakly with other flow dimensions (Jackson, 1992; Jackson & Eklund, 2002; Stavrou et al., 2007). In music making, "loss of self-consciousness" and "transformation of time" were also found to be the weakest contributors to the flow state whereas "challenge-skill balance," "sense of control" and "autotelic experience" were considered to be the strongest flow state contributors (Sinnamon et al., 2012; Marin & Bhattacharya, 2013; Wrigley & Emmerson, 2013). Recently, researchers also reported that "action-awareness merging" had the lowest correlation with the other dimensions for musicians while performing in an orchestra (Cohen & Bodner, 2019a). These findings further highlight the importance of assessing the flow construct at the level of the nine dimensions, as opposed to a global flow assessment, in order to fully understand the nature of the flow experience (Jackson & Eklund, 2002).

Experiencing flow may promote musicians' daily practice commitment (O'Neill, 1999; Araújo & Hein, 2019), may be positively related to musical creativity (MacDonald et al., 2006) and could improve MPQ (Kirchner, Bloom, & Skutnick-Henley, 2008; Clark, Lisboa, & Williamon, 2014; Iusca, 2015). Recently, the literature discussed the idea that flow state elicitation may be used to offset the MPA negative effect (Cohen & Bodner, 2019b; Moral-Bofill et al., 2022). Small to moderate negative correlations between dispositional flow (i.e., "the frequency with which people experience flow," Jackson et al., 1998, p. 360) and general MPA level among music students have been reported (Kirchner, Bloom, & Skutnick-Henley, 2008; Cohen & Bodner, 2021). Also, moderate negative correlations were found between flow state and state anxiety among music students (Fullagar et al., 2013) and between flow state and MPA symptoms among classical orchestral musicians (Spahn, Krampe, & Nusseck, 2021). A limitation of these studies is the use of a global score to measure the flow experience. To our knowledge, only one study (Butzer, Ahmed, & Khalsa, 2016) investigated the correlation between the score difference (after minus before a yoga intervention) in general MPA level of music students and the score difference in the different components of dispositional flow in different musical contexts (practice, group, and solo performance). In this study, only weak to moderate significant negative correlations were obtained for the changes in the dimensions "challenge-skill balance," "clear goals," "action-awareness merging," "sense of control," "loss of self-consciousness," and "autotelic experience" with the general MPA level during a practice performance. Weak to moderate significant negative correlations were also observed between the general MPA level and all flow dimensions except "transformation of time" during solo performance. "Action-awareness merging" and "sense of control" had the strongest significant correlation with the general MPA level. Three studies have measured musicians' flow state during performances in front of an audience (Fullagar et al., 2013; Wrigley & Emmerson, 2013; Spahn, Krampe, & Nusseck, 2021). However, these studies did not compare musicians' flow state experiences during the public performances to their flow state experiences during practice or rehearsal. To date, no study has compared flow state experiences in different performing contexts. In sum, it is unknown how the general MPA level and the presence of an audience affect musicians' flow state at the level of its nine dimensions.

1.6. The biopsychosocial model of challenge and threat

One theoretical framework that can offer a possible explanation for individual differences in response to performance situation is the BPSM of challenge and threat (Blascovich, 2008; Seery, 2011). This model focuses on motivated performance situations, which are defined as evaluative situations that may be potentially stressful and require the production of an instrumental response. This instrumental response then allows the achievement of a self-relevant goal that should subsequently lead to well-being and/or personal development (Blascovich, 2008; Seery et al., 2009; Hase et al., 2019). These elements can be found in the context of a music performance as musicians must produce music using their instrument, and the success of this performance will allow them to obtain a certain recognition to maintain their social status as a musician and continue their musical career. Based on Lazarus (1991) and Dienstbier's works (1989), the BPSM of challenge and threat considers that during a motivated performance situation, an individual will adopt a motivational state that can either be deleterious or, on the contrary, be favorable to the situation.

1.6.1. Resources-demands evaluations

According to the BPSM of challenge and threat, when a motivated performance situation involves a goal that is subjectively self-relevant and with an uncertain outcome, it should lead to the engagement in the performance situation (Seery et al., 2011). The BPSM of challenge and threat postulates that parallel to this commitment, individuals would consciously and unconsciously evaluate two elements: on the one hand, the resources they think they have at their disposal to deal with the situation (e.g., do I have the necessary capacities to deal with this situation?), and on the other hand, the demands of the situation they perceive (e.g., is this situation considered difficult? - Blascovich, 2000; Blascovich et al., 2004; Blascovich, 2008; Jamieson et al., 2018; Hase et al., 2019). Based on the outcome of these two evaluations, individuals will tend to be either more in a challenge state, characterized by a higher perceived resources level compared to the perceived demands level, or more in a threat state, characterized by a lower perceived resources level compared to the perceived demands level. These two states are considered as the two ends of a bipolar continuum (Tomaka et al., 1993; Seery et al., 2011; Blascovich, 2013a) as these two states imply a certain degree of approach motivation, but the threat state, unlike the challenge state also includes a certain degree of avoidance motivation (Blascovich, 2013a). Whether a person is more in a challenge state or more in a threat state can be determined thanks to the resources-demands differential. This differential is obtained by subtracting the perceived demands level from the perceived resources level, both obtained via a questionnaire (Tomaka et al., 1993; Moore et al., 2019). When the resources-demands differential is high, the person may be more in a challenge state than in a threat state. Conversely, when the resources-demands differential is low, the person may be more in a threat state than a challenge state. Additionally, it has been shown that challenge and threat states can be differentiated by means of specific cardiovascular patterns (Tomaka et al., 1993; Tomaka et al., 1997; Blascovich, 2008; Moore et al., 2012; Turner et al., 2012; Moore et al., 2013; Turner et al., 2014). However, a systematic review showed that the correlation between the cardiovascular patterns and the perceived resources and demands reported via questionnaire by participants was only weak to moderate. Furthermore, they highlighted the cardiovascular patterns of challenge and threat states obtained in literature were not always distinguishable (Hase et al., 2019).

As the resources and demands evaluations are conscious and unconscious, they can be modulated by cognitive and affective processes (Blascovich, 2000; Blascovich, 2004; Blascovich, 2008). For some authors, the perceived resources evaluation may be influenced by the familiarity of the situation, the knowledge, the skills, dispositional factors, and social support, whereas the perceived demands evaluation may be influenced by the uncertainty and danger of the situation, and the required efforts (Tomaka et al., 1993, Jamieson et al., 2018). Nevertheless, these influences have been questioned as some of them may not only influence one of the evaluations but the two of them (Seery et al., 2011). Another key aspect of the resources and demands evaluations is that they are iterative, meaning that all along the situation individuals may adapt their resources-demands evaluations, and consequently their challenge and threat state level (Blascovich, 2013b). Despite the importance of the challenge and threat state unsteadiness in time, there are few studies that have investigated how the underlying resources-demands evaluations vary across time. In 1993, Tomaka et al., asked college students to perform two similar arithmetic tasks. College students had to report the resources and demands perceived level before and after each task. Based on the pre-task resources-demands evaluation, the researchers classified college students in respectively a challenge or a threat state. The authors observed that the cardiovascular reactivity to the first task for college students classified in the challenge state was significantly different from the cardiovascular reactivity of college students classified in the threat challenge. In the second task, this difference was not significant. Based on these results, the authors concluded that the task repetition may have reduced the environmental uncertainty and may have changed college students' resources-demands evaluations for the task, however, they did not measure if this evaluation change occurred during the task. More recently, Hase (2019) investigated to what extent individual factors, task characteristics, time and their 2-way interactions vary the challenge and threat state at the cognitive and the cardiovascular level. To do so, he recruited university students and staff members and asked them to complete a combination of 4 tasks in a different order once a week for 3 weeks. The results showed that most of the variance in the cognitive challenge-threat state, in the perceived resources, and in the perceived demands was explained by the individual factors alone, but significant parts of the variance were explained by the interaction between the individual factors and task characteristics, and by the interaction between the individual factors and time. These two studies seem to support the hypothesis of the dynamic and iterative nature of resources-demands evaluations; however, they are concerened with changes in the evaluations between different tasks and not with the change taking place during the same task. To our knowledge, there are no studies that have investigated this question.

While previous studies highlighted the importance of individual factors, only one study investigated the effect of social anxiety on resource-demands evaluations. This study looked at challenge and threat using the TSST paradigm with socially anxious and non-anxious individuals (Jamieson et al., 2013). The results showed that those who participated in the TSST considered themselves to have fewer resources to cope than those who performed the same tasks alone. Socially anxious individuals also felt they had fewer resources to cope than non-anxious individuals. In addition, socially anxious individuals viewed the control task as more demanding than non-anxious individuals, and this difference in perceived demand level was even greater between socially anxious and non-anxious individuals for the TSST task. Although these results may suggest social anxiety and social evaluative situation may play a role in the resources-demands evaluations, research to date has not yet investigated how the general MPA level and audience presence may influence the resources-demands evaluations.

1.7. Self-rated music performance quality

To date, most studies investigating the audience presence effects on MPQ used external judges to conduct the MPQ assessment, but their results are mixed. In some studies, judges rated musicians' MPQ higher when an audience was present than when the audience was absent (Hamann & Sobaje, 1983). Another study found the opposite effect, judges rated musicians' MPQ higher during a private performance than during a public performance (Yoshie et al., 2009a). Finally, some studies found no significant difference in MPQ between the private and the public performance (Craske & Craig, 1984; Yoshie et al., 2009b). Only one study considered the general MPA level and observed that judges tended to rate more negatively anxious individuals' MPQ than non-anxious individuals' MPQ. This difference was even greater when the performance was given in front of an audience (Craske & Craig, 1984). The disparity in these results could be explained to methodological differences such as differences in the context of the MPQ assessment (e.g., competition or exam) or in the method used to evaluate MPQ (e.g., using a standardized scale or no). Although there may be a strong significant correlation between the level of MPQ judged by experts and the level of self-assessed MPQ (Kenny, Fortune, & Ackermann, 2013), expert judgment is highly subjective and may be biased by external factors such as fatigue or the order of presentation of musicians, thus potentially leading to validity problems.

Yet very few studies have focused on how the general MPA level and audience presence might influence the self-rated MPQ. In the social anxiety literature, it has been shown that socially anxious individuals tended to evaluate their social performance more negatively than non-anxious individuals whether directly after the performance or a week later regardless of the presence of other people during the performance (Brozovich & Heimberg, 2011; Gavric et al., 2017). Socially anxious individuals tended to minimize the quality of their social performance by focusing their attention primarily on the failed aspects of that performance (Rapee & Lim, 1992; Stopa & Clark, 1993; Wallace & Alden, 1995; Norton & Hope, 2001; Moscovitch & Hofmann, 2007). In line with these results, a study on music students found a negative correlation between general MPA level and self-rated MPQ during private and public performance, but this correlation was only weak. In addition, they also found no significant difference in the self-rated MPQ between the private and the public performance (Studer et al., 2014). Recently, another study found that music students with a high general MPA level tend to rate the quality of their performance more negatively when they perform solo in front of an audience, but this study only investigated the self-rated MPQ during a public performance session (Nielsen et al., 2018).

In sum, thus far, the findings are mixed and to our knowledge few studies have investigated whether the general MPA level and the audience presence can influence the self-rated MPQ for the same performance done once in private and once in front of an audience. On the end, the BPSM of challenge and threat may provide some key explanation for individual differences in response to performance situation.

1.7.1. Relationship between challenge-threat states and music performance quality

The growing interest in the literature for the BPSM challenge and threat is partially due to its link with health. Studies showed that people who tend to be more in a challenge state tend

to have more positive health outcomes (Blascovich, 2008; Jefferson et al., 2010; O'Donovan et al., 2012). Nevertheless, this growing interest is also related to the potential link between the challenge-threat states and performance quality. To date, it can be seen in the literature that individuals having more challenge state have on average better performance than those having more threat state (Behnke & Kaczmareck, 2018; Hase et al., 2019) whether on a number-categorization and pattern recognition (Blascovich et al., 1999), problem-solving (Chalabaev et al., 2009), word finding (Blascovich et al., 2001; Mendes et al., 2002; Mendes et al., 2008; Scheepers, 2009; Frings et al., 2015), arithmetic (Tomaka et al., 1993 ; Tomaka & Blascovich, 1994; Quigley et al., 2002; Schneider, 2008; Kubzansky et al., 2012), visual search (Frings et al., 2014), modified Stroop test (Turner et al., 2012), remote associates task (Seery et al., 2004), information processing task, anchoring-and-adjustment tasks (Kassam et et al., 2009; de Wit et al., 2012), negotiation task (Scheepers et al., 2012), academic performance (Seery et al., 2010), netball shooting among netball players (Turner et al., 2012), batting test among cricketers (Turner et al., 2013), throwing task (Turner et al., 2014), golf putting (Moore et al., 2012, Moore et al., 2013), athletic performance (Blascovich et al., 2004), and car racing video game (Trotman, 2018). Some authors have hypothesized that this difference would be due to the fact that individuals in a challenge state may mobilize more energy, which may allow better performance than those in a threat state (Behnke & Kaczmareck, 2018).

In 2019, Osborne and McPherson asked 36 music students to complete a questionnaire twice: once at the beginning of the semester and once before the end-of-year recital. This questionnaire is designed to measure precompetitive appraisal (Wolf et al., 2015), it includes items on recital relevance, control ability, and perceived available resources, among others. Based on these questionnaires, the researchers inferred the existence of two groups: music students with challenging appraisals and students with threatening appraisals. They were then able to observe that music students who perceived performance as a challenge tended to have less cognitive anxiety and more self-confidence than those who perceived performance as a threat. Nevertheless, they found no significant difference in performance quality rated by expert between music students perceiving performance as a challenge and those perceiving performance as a threat. However, it is possible that this lack of difference has to do with the methodology used to determine the challenge state and threat state since it did not consider the demands evaluation. Nevertheless, there is no other study to date that investigated the potential influence of challenge-threat states on self-rated MPQ.

2. Thesis aims and specific objectives

In chapter 1, we have identified several research gaps in the MPA literature. This thesis aims to fill these research gaps. More specifically, we will examine in a music performance context the following research questions:

1. To what extent do the general MPA level, audience presence, time, and their interaction influence the hypothalamic-pituitary-adrenal axis and the sympathoadrenal medullary system activity?

For this research question, we hypothesized that the sC and sDHEA level would be higher at the beginning of the music performance session than at the end of the music performance session, whereas the sAA level would be lower at the beginning of the music performance session than at the end of the music performance session (**Hypothesis 1.1 –** Significant main

time effect). We expected that the sC and sDHEA level, as well as the sAA activity would be higher during the public performance session than the private performance session (**Hypothesis 1.2** – Significant main performance session effect). We also hypothesized that the sC, sDHEA, and anabolic balance level, as well as the sAA activity would be higher after the public music performance than before the public music performance. The same difference should not be present in the private performance session (**Hypothesis 1.3** – Significant interaction time x performance session effect). We assumed that during the public performance session, music students with higher general MPA level would have a higher sC, sDHEA, and anabolic balance level, as well as higher sAA activity than music students with lower general MPA level (**Hypothesis 1.4** – Significant interaction general MPA level x performance session effect). Finally, we expected that after the music performance session, music students with higher general MPA level would have a higher sC, sDHEA, and anabolic balance, as well as higher sAA activity than music students with lower general MPA level (**Hypothesis 1.5** – Significant interaction general MPA level x time effect).

2. To what extent do the general MPA level, audience presence, and their interaction influence the flow experience at the level of its nine dimensions?

For this research question, we hypothesized that the levels of "challenge-skill balance," "clear goals," "action-awareness merging," "concentration on task at hand," "sense of control," "loss of self-consciousness," and "autotelic experience" would be significantly lower during the public performance session than the private performance session (**Hypothesis 2.1** – Significant main performance session effect). As an autotelic experience is an intrinsically rewarding experience, we considered that it might indirectly index the absence of anxiety. Consequently, we also assumed that the previous expected decrease would be greater in musicians with higher general MPA level than in musicians with lower general MPA level (**Hypothesis 2.2** – Significant interaction general MPA level x performance session effect). For the dimensions "unambiguous feedback" and "transformation of time," we did not have strong theoretical or empirical evidence to support any predictions regarding the effects of audience and general MPA level; we thus treated these questions as exploratory issues.

3. To what extent do the general MPA level, audience presence, time, and their interaction influence the self-rated MPQ?

For this research question, we hypothesized that music students with higher general MPA level would rate their MPQ more negatively than music students with lower general MPA level (**Hypothesis 3.1** – Significant general MPA level effect). Based on the social anxiety literature, we considered that the general MPA level effect will be larger for the public performance session than for the private performance session (**Hypothesis 3.2** – Significant interaction general MPA level x performance session effect). Due to the lack of consensus in the literature regarding the audience presence effect on self-rated MPQ, this question was treated as exploratory issues. The time effect on self-rated MPQ and the 3-way interactions between general MPA x Session x Time was also treated as exploratory since no studies have investigated these questions before.

4. To what extent do the general MPA level, audience presence, time, and their interaction influence the challenge-threat states?

For this research question, we hypothesized that music students with higher general MPA level would have lower resources-demands evaluation differential level and lower perceived resources level than music students with lower general MPA level (**Hypothesis 4.1** – Significant main general MPA level effect). We also assumed that music students would have lower resources-demands evaluation differential and lower perceived resources level during the public performance session than during the private performance session (**Hypothesis 4.2** – Significant main performance session effect). We also expected that during the public performance session, music students with higher general MPA level would have an even lower resources-demands evaluation differential and a higher perceived demands level than the music students with lower general MPA level (**Hypothesis 4.3** – Significant interaction general MPA level x performance session effect). As the oucome evolution of the resources-demands evaluation has never been investigated before, the time effect on the resources-demands evaluation, perceived resources and perceived demands was investigated for exploratory purpose as the 3-way interaction between the general MPA level, the audience presence and the time on resources-demands differential, perceived resources, and perceived demands.

5. To what extent do the challenge-threat states influence the self-rated MPQ at the between-person and within-person levels?

For this last research question, we hypothesized that music students who tend to have higher resources-demands differential level (more challenge across music performances) before the music performance would rate their MPQ more positively than music students who tend to have lower resources-demands differential level (more threat across music performances – **Hypothesis 5.1** – Significant main between-person resources-demands differential effect). We also considered that the music students' within-person changes in resources-demands differential level from the first to the second music performance session would be significantly related to the within-person changes in self-rated MPQ from the first to the second music performance session (**Hypothesis 5.2** – Significant main within-person resources-demands differential effect).

3. Method[3]

3.1. Participants

By means of electronic invitations and posting on social media, we recruited 121 music students between 18 and 35 years old enrolled in a classical music program from Swiss university music schools.

All participants were in general good health. Music students were excluded if they had cardiovascular, neurologic, respiratory, and endocrine diseases, or used drugs with effects on the cardiovascular, nervous, respiratory, and endocrine systems, including recreational drugs, beta-blockers, and anxiolytic medication. Individuals wearing a pacemaker and working night shifts were also excluded. A current diagnosis of panic disorder or eating disorders were additional exclusion criteria. Women were excluded if they were pregnant or lactating. Further sample characteristics are given in table 1. The ethical committee of the canton of

[3] The chapter 3 is based on a published study protocol article (Guyon et al., 2020b).

Vaud, Switzerland, approved the study (protocol number 2019–01222). Eligibility to participate was determined with an online entry questionnaire. Participants received 250 Swiss Francs as compensation if they completed all phases of the study protocol.

3.2. Study protocol

Participation in the study consisted of completing an online entry questionnaire, attending three laboratory sessions (Habituation session, Performance session 1, Performance session 2) and completing a final online questionnaire (figure 1). The study was conducted in French or English depending on participants' preference.

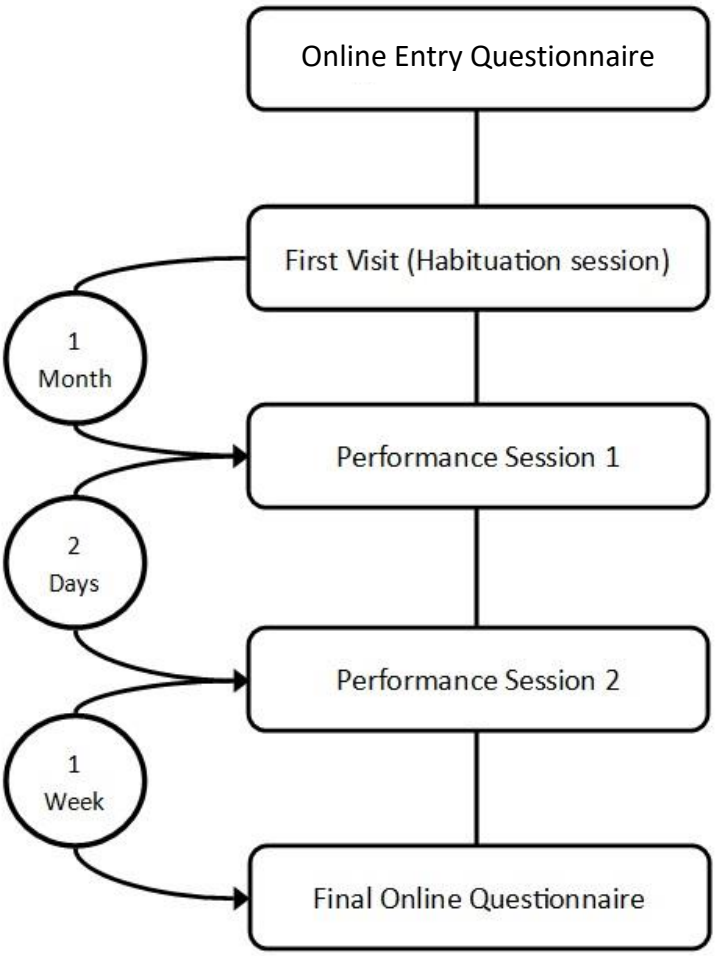

Figure 1. Study protocol

3.3. Online entry questionnaire

In the online entry questionnaire, we collected sociodemographic, academic, music and health-related data as well as the students' general MPA level. Eligible participants were contacted to arrange three appointments (Habituation session, Performance session 1, and Performance session 2). The two performance sessions were scheduled ensuring that the participants had no other public performances neither on the same day of the performance session, nor the day before, or after it.

3.4. Habituation session

Participants were tested individually. Upon arrival to the lab, the experimenter explained the study protocol to the participant and obtained written consent. This was followed by the measurement of participant's body height and weight, which were used to compute the body mass index (BMI). Afterwards, the participant was familiarized with the physiological measurements[4]. The experimenter showed the different instruments and explained their function. Afterwards, the sensors of the four devices Finometer, VU-AMS, BioRadio and Capnostream were applied, and the participant was asked to sit for 8 min alone. After removing the sensors of the Finometer and the Capnostream, the participant was invited to play his/her instrument for a few minutes. The participant was also familiarized with the saliva sampling procedure.

In the second part of the habituation session, the participant was presented with a list of instrument specific music pieces from which he/she had to choose one to perform during the following performance sessions. The pieces belong to the standard repertoire usually required for auditions, competitions, and exams. The piece duration ranged from 2min 36s to 8min 31s (M= 4min 10s, SD= 45s; see supplementary table S1 for the complete list of the pieces). We provided the participants with the exact number of bars to perform and required them to perform the selected pieces by heart and without accompaniment during the two performance sessions. Participants were given up to 2 days to choose their music piece. Finally, the experimenter gave the participant the following information about the upcoming performance sessions: the session order (private before public session or vice versa) and the audience composition (composed of the experimenter and five to seven music connoisseurs including two experts who will rate their MPQ). The experimenter also explained the MPQ Scale to them.

3.5. Private and public performance sessions

After the habituation session, the participant came to our laboratory for the two performance sessions (see table 1 for more information about the days number between the habituation and the first music performance session). For each participant, the two sessions took place 2 days apart (e.g., Monday and Wednesday) at the same time of the day. Participants were scheduled at either to start the experiment at 13h and to perform at 14h02 (early afternoon) or to start the experiment at 15h45 and to perform at 15h47 (late afternoon). The procedures of the two sessions were identical, except for the fact that the participants performed without audience in the private session and in front of an audience of six to eight persons in the public session. Participants were randomly assigned to one of the two possible orders. The procedure of a performance session is shown in figure 2. The day before each performance session, the participants received an electronic reminder in which they were asked to comply with the following requirements: no alcohol intake and no intense physical activity 24 h before the visit, no heavy meal 1h15min before the visit, no caffeine intake (including coffee, tea, or chocolate) 1h15min before the visit, no cigarettes or any products containing nicotine 1 h before the visit, and no food intake 15 min before the visit.

[4] Please note that additional physiological measurements (cardiovascular and respiratory) were performed. The devices used to perform these measurements are mentioned, yet the results will not be presented in this Ph.D. thesis.

The email for the public performance session also reminded the participants of the audience composition.

First, participants were given 5 min to prepare their instrument and warm up. Then, they filled in a first questionnaire (Q1) to verify their compliance with the behavioral instructions (food intake, etc.). After attaching the sensors of the Finometer, VU-AMS, BioRadio and Capnostream and performing the required checks and calibrations, a first saliva sample (S1) was collected followed by an 8-min period during which the participants was sitting alone at a table and required to keep their hands on the table, keep their eyes open, stay quiet and still and not cross their legs. Afterwards, participants filled in a second questionnaire (Q2) and took a second saliva sample (S2). Following the removal of the sensors of the Finometer and of the Capnostream, the participants performed their music piece. After the performance, the participants filled in a third questionnaire (Q3) and took a third saliva sample (S3). The rest of the session consisted of three 5-min sitting periods each followed by questionnaires (Q4, Q5, Q6) and saliva collection (S4, S5, S6). The scheduled timing of the sitting periods, performance, questionnaires, and saliva collection, as well as the content of each questionnaire are given in figure 2. The actual saliva collection timing for the early and late afternoon are reported in tables 2 and 3.

Performances were recorded with a handy recorder Zoom H4 (Zoom North America, Hauppauge, NY, USA) placed on a tripod close to the participant. It was combined with a microphone DPA 4099 (DPA Microphones, Inc., Longmont, CO, USA), which was placed on the participant's instrument with a clip or on a music stand depending on participant's preferences (only on a music stand for singers). Audio recording was started and stopped by the experimenter while participants were completing questionnaire Q2 and Q3, respectively.

3.6. Final online questionnaire

One week after completing the second performance session, participants received the recordings of their two performances via an e-mail containing a link to a final online questionnaire and a Dropbox link to two mp3 audio files named "Recording1" for the first performance session and "Recording2" for the second performance session. Each recording was cut out to remove any noise external to the performance. In the final online questionnaire, participants were asked to listen to these audio files in the same order and rate the MPQ using the MPQ Scale.

Finally, the participants filled in questionnaires assessing their trait anxiety, social anxiety, and depressive symptoms, all of which are potential confounding variables because they can affect the psychophysiological measures.

3.7. Measures of the online entry questionnaire

3.7.1. Sociodemographic data

The sociodemographic data included age, gender, mother tongue, French or English level (on a scale from 1 = Do not speak and do not understand English/French to 5 = Speak and understand perfectly English/French), and night shift work (yes/no).

3.7.2. Academic and music related data

The academic and music-related data included the name of the school, the department, the current academic year, the main instrument, the time they started to play their main instrument, the second instrument, the average number of hours per day of music practice, the number of public solo and ensemble performances given during the past 12 months.

3.7.3. Health-related data

We asked participants to list any known disease and any acute or chronic medication intake and to answer the questions assessing panic disorder and eating disorders from the Patient Health Questionnaire (for English version Spitzer et al., 1999; for French version Carballeira et al., 2007). Women were also asked to indicate whether they were pregnant, lactating or using hormonal contraceptives. Women also indicated the first day and the length of their last period as well as the duration of their menstrual cycle. Moreover, participants had to indicate if they wear a pacemaker, smoke, or take recreational drugs.

3.7.4. General MPA level

The general MPA level was assessed with the state scale of the State-Trait Anxiety Inventory (STAI-S; for English version Spielberger (1983), for French version Spielberger et al. (1993)), which consists of 20 items, e.g., “I am tense,” rated on a 4- point Likert scale (1 “not at all” to 4 “very much so”). The score ranges from 20 (no anxiety) to 80 (severe anxiety). Because anxiety depends on the performance setting (Cox & Kenardy, 1993), we asked students to indicate how they generally feel when they perform solo. We (Studer et al., 2012; Nielsen et al., 2018) and others (e.g., Widmer et al., 1997; Kokotsaki & Davidson, 2003; Kim, 2005) have used this instrument to assess the general MPA level. The Cronbachs’ alpha of this scale in this present study was 0.93 for the English version and 0.92 for the French version.

3.8. Performance session measures

3.8.1. Salivary measures

Saliva samples were obtained via a passive drooling method facilitated by polypropylene straws into low bind polypropylene 2 mL cryovials (Salicap, IBL International, Hamburg, Germany). For each saliva sample, participants were instructed to rinse their mouth with water, swallow the saliva currently in their mouth, accumulate new saliva for 2 min and then transfer all saliva into the tubes. Samples were stored immediately after collection at −20 °C and then shipped on dry ice to the Biochemical Laboratory of the Department of Clinical Psychology, University of Vienna, where they were assayed for sAA, free cortisol and DHEA. SAA activity was measured using reagents provided by DiaSys Diagnostic Systems (Holzheim, Germany). The sC concentration was measured with a Cortisol Saliva Luminescence Immunoassay kit (IBL-Tecan, Hamburg, Germany) and the sDHEA concentration was measured using a DHEA Saliva Luminescence Immunoassay kit (IBL-Tecan, Hamburg, Germany).

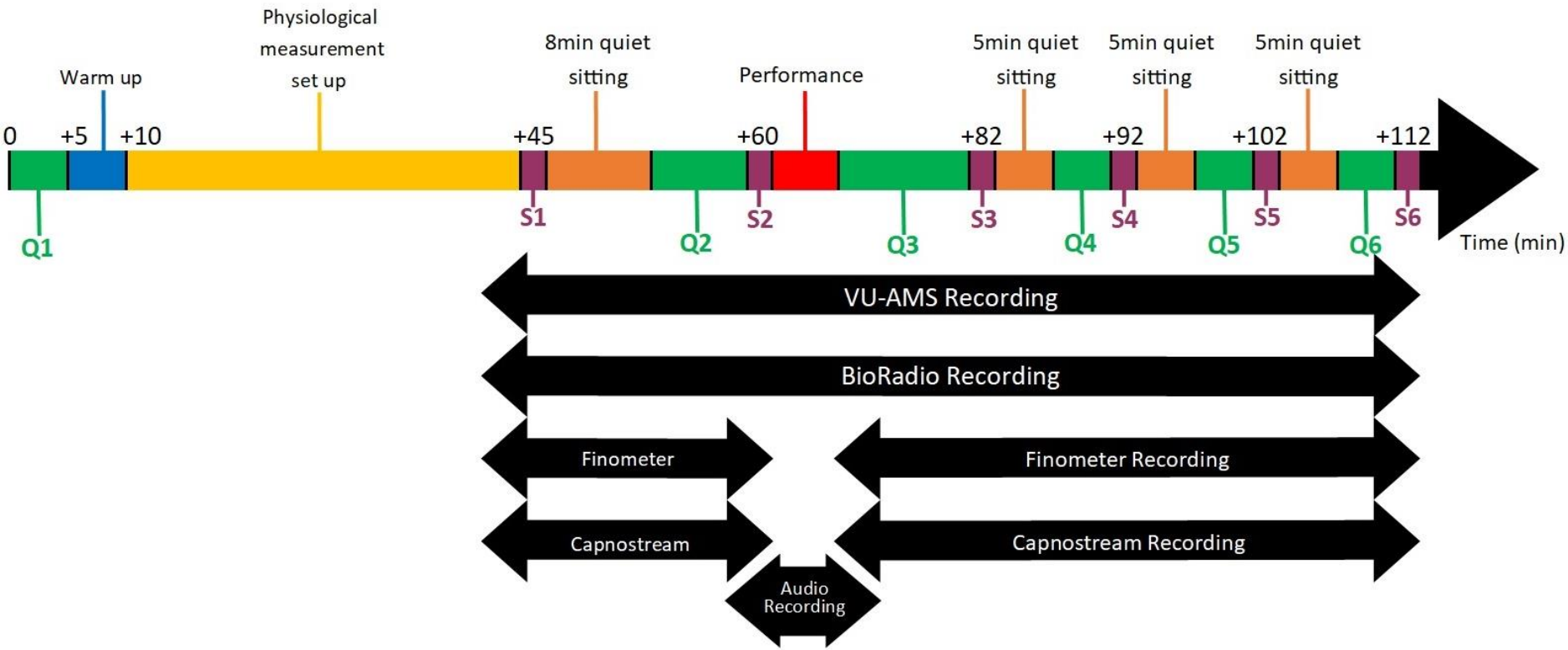

Figure 2. Performance session procedure – (Q = Questionnaire; S = Salivary sample) The quiet sitting periods correspond to a period where the participants are sitting alone at a table and required to keep their hands on the table, keep their eyes open, stay quiet and still and not cross their legs. Q1 consists of questions assessing participants' compliance with the behavioral instructions (food intake, etc.) Q2 includes the questionnaires CSAI-2R (cognitive anxiety, somatic anxiety, and self-confidence), self-reported demands and resources, STAI-6 and SAMq. Q3 includes the questionnaires FSS-2, MPQ Scale, CSAI-2R (somatic anxiety), self-reported demands and resources, STAI-6 and SAMq. Q4 and Q5 include the questionnaires CSAI-2R (somatic anxiety), STAI-6 and SAMq. Q6 includes the questionnaires CSAI-2R (somatic anxiety), STAI-6, SAMq, Post-Music Performance Thoughts Questionnaire, a question about performance engagement and a question about preparation time.

The analyses were performed in duplicate with the exception of the sC analysis for two participants (one at all times points for both performance sessions and one for S1 at the private performance session), the sDHEA analysis for two participants (one for S2 at the private performance session and one for S6 at the public performance session), and both the sC analysis and the sDHEA analysis for one participant (for S4 at the private performance session).

The sC concentration was not detected for four samples from three participants (one participant for S5 at the private performance session; one participant for S6 at the private performance session and for S3 at the public performance session; one participant for S6 at the private performance session). The sDHEA concentration was too low to be detected in one participant across all saliva samples from the private and the public performance session except for the saliva samples for S4 and S6 at the public performance session. The sAA activity was not detected for 3 participants (one participant for S5 at the private performance session; one participant for S5 at the public performance session; one participant for S6 at the public performance session). The intra- and inter-assay coefficients of variation were respectively 3.50 and 2.55 for sAA, 4.69 and 8.07 for sC, and 4.59 and 10.02 for sDHEA.

3.8.2. Flow[5]

Immediately after each performance (Q3), participants filled in the 36-item Flow State Scale-2 (for the English version Jackson & Eklund, 2002**;** for the French version Fournier et al., 2007). This scale quantifies each of the following flow state dimensions (four items per dimension): challenge-skill balance (e.g., “I was challenged, but I believed my skills would allow me to meet the challenge”), unambiguous feedback (e.g., “It was really clear to me how I was going”), clear goals (e.g., “I knew clearly what I wanted to do”), action-awareness merging (e.g., “I did things correctly without thinking about trying to do so”), concentration on task at hand (e.g., “My attention was focused entirely on what I was doing”), sense of control (e.g., “I had a sense of control over what I was doing”), loss of self-consciousness (e.g., “I was not concerned with what others may have been thinking of me”), transformation of time (e.g., “Time seemed to alter (either slowed down or speeded up)”), and autotelic experience (e.g., “I really enjoyed the experience of what I was doing”). For each item, participants expressed their level of agreement on a 5-point Likert scale from 1 “strongly disagree” to 5 “strongly agree” by referring to the just completed performance. For each dimension, a mean score ranging from 1 to 5 was computed. A higher mean score indicates a higher level of the dimension. The Cronbach’s alphas of these nine subscales are reported in the supplementary table S3.

3.8.3. Self-reported demands and resources

Self-reported demands were assessed before the performance (Q2) with the question “How demanding do you expect this music performance to be?” and after the performance (Q3) with the question “How demanding was the music performance situation?”. Self-reported resources were assessed before the performance (Q2) with the question “How able are you to cope with the demands of the music performance?” and after the performance (Q3) with the question “How able were you to cope with the demands of the music

[5] The subsection 3.8.2 is based on a published article (Guyon et al., 2022b)

performance situation?". The participants answered using a 6-point Likert scale ranging from 1 "not at all" to 6 "extremely". These questions were adapted from the cognitive appraisal ratio (Tomaka et al., 1993; Moore et al., 2019). The resources-demands differential for Q2 and Q3 was obtained by subtracting the score of the first question from the score of the second question so that higher scores indicate that the music student had a higher challenge state level than threat state level.

3.8.4. Self-rated music performance quality

Participants rated their MPQ after each performance (Q3) with the MPQ Scale (see supplementary table S2). This scale is a revised version of a MPQ scale used in a previous study (Nielsen et al., 2018). The scale consists of nine dimensions ("tempo", "rhythm", "intonation", "tone", "dynamics", "articulation", "musical understanding and interpretation", "missing notes, wrong notes, and unwritten breaks" and "global appreciation") to be rated on a 21-point scale ranging from 1 (= lowest score) to 6 (= highest score), with 0.25-point intervals to replicate the grading system of French-speaking Swiss schools. A definition was given for each dimension together with the specific aspects to consider in scoring the dimension.

3.8.5. Preparation time

The amount of preparation time for each session performance is a control measure assessed at the end of each performance session (Q6) with the question "How much time have you spent in the last 48 hours specifically preparing the musical piece you have just played?". Participants responded by indicating a numerical value. To compute the variable preparation, which is defined as the number of hours spent practicing the piece between the first and the second performance, we attributed the value 0 to the first performance session and the number of practice hours reported by the participants (e.g., 2 hours) to the second performance session. Then, we centered to the individual mean (e.g., 1 hour). The descriptive statistics are provided in table 1.

3.9. Measures of the final online questionnaire

3.9.1. Depressive symptoms

Depressive symptoms were assessed with the Beck Depression Inventory-II (for English version Beck et al. (1996), for French version Edition du Centre de Psychologie appliquée (1998)). This inventory is a unipolar questionnaire assessing depressive symptoms during the last 2 weeks with 21 items. Each item contains four sentences, which are coded from 0 (less close to depression, e.g., "I do not feel sad") to 3 (closest to depression, e.g., "I am so sad or unhappy that I can't stand it"). The total score can range from 0 to 63 with higher scores indicating more severe depressive symptoms. The Cronbachs' alpha of this scale in the present study was 0.83 for the English version and 0.88 for the French version.

3.9.2. Self-rated music performance quality

Music students listened to the recordings of their performances and evaluated them using the MPQ scale described in chapter 3.8.4.

3.10. Statistical analyses

Statistical analyses were performed with STATA version 16.0 for Windows (Stata Statistical Software; StataCorp LP, College Station, TX). The alpha level was set at 0.05 for all tests.

3.10.1. Preliminary analyses

We tested the relationships between general MPA level and other personal variables prior to the main analyses. For continuous variables (i.e., depressive symptoms, age, number of years and hours of instrument practice, number of solo and ensemble performances), we computed pairwise correlations and for categorical variables (i.e., gender, academic level, instrument type), we performed least-squares linear regressions. We conducted these analyses to determine which variables should be included in the main analyses as control variables.

3.10.2. Research question 1

For this first research question, we investigated to what extent the general MPA level, audience presence, time, and their interaction influence the hypothalamic-pituitary-adrenal axis and the sympathoadrenal medullary system activity.

3.10.2.1. Additional preliminary analyses

We computed a t-test to evaluate the relationship between general MPA level and hormonal contraception use in women as well as a least-squares linear regression to assess the relationship between general MPA level and the cigarette smoking habits. These preliminary analyses were done to determine whether these variables should be included in our analyses as control variables.

3.10.2.2. Main analyses

The measurement unit of sC was the nmol/L, whereas for the sDHEA, it was pg/mL. To compute the anabolic balance, sDHEA measures were converted to have the same unit as sC (nmol/L). To do so, we multiply each sDHEA measure by 0.00347. Then, a ratio score was created by dividing the sDHEA level by the sC level. This ratio score was considered as the anabolic balance.

A logarithmic transformation was applied to the sC, sDHEA, anabolic balance, and sAA data using a natural logarithm function to reduce skewness (see tables 6 to 9). For the transformed sC, sDHEA, anabolic balance, and sAA we fitted two three-level linear mixed models with restricted marginal maximum likelihood estimation, heterogeneous residual variance structure, and with random intercepts for participants and for session.

The model 1 tested the main effect of general MPA level, session (private vs. public) and time (time point at which the saliva sample was collected, i.e., S1 to S6 – see figure 2). The general MPA level was treated as a continuous variable. We controlled for the following

variables: order (order 1: private – public vs. order 2: public – private), hour (early afternoon vs. late afternoon), preparation, gender, depressive symptoms, and time difference. The variable hour refers to the hour at which the music students were expected to start their music performances. The variable preparation represents the amount of preparation time for the piece in hours between the first and the second performance session. The variable time difference refers to the number of days between the habituation session and the first performance session. All continuous predictors were mean-centered.

The model 2 was an extension of the first model. The second model included the main 2-way interactions general MPA level x session, general MPA level x time, and session x time. The following control interactions were also added: general MPA level x hour, general MPA level x order, session x hour, session x order, time x hour, time x order, gender x session, gender x time, gender x hour, gender x order, depressive symptoms x session, depressive symptoms x time, depressive symptoms x hour, depressive symptoms x order, time difference x session, time difference x time, time difference x hour and time difference x order. For each significant 2-way interactions, we only considered the pairwise comparisons of interest. If the main effect time was significant or there was a significant 2-way interaction including the predictor time, we compared each time point (e.g., S4) to the two adjacent time points (e.g., S3 and S5). For significant 2-way interactions, we also compared each time point in the first condition to its equivalent in the second condition. In addition, the following pairwise comparisons between time points were considered: S1 to S3, S3 to S6, and S1 to S6. The purpose of the latter comparisons is to determine whether there is a significant difference between the level of sC, sDHEA, anabolic balance, and sAA at the beginning of the performance session and at the end of the music performance, between the level at the end of the music performance and the level at the end of the performance session, and between the beginning of the performance session and the end of the performance session. Due to the large number of pairwise comparisons tested in significant 2-way interactions, we applied Holm-Bonferroni correction (Holm, 1979) on these comparisons.

Diagnostics for residuals and random effects showed that the overall distributional assumptions were met for all models implying satisfactory model specification. As a certain number of outliers (defined as standardized residuals smaller than -3 and larger than 3) were identified, the first and the second model were tested again after dropping the outliers to evaluate their impact on the results.

3.10.3. Research question 2

In this research question, we aimed to investigate to what extent the general MPA level, audience presence, and their interaction influence the flow experience at the level of its nine dimensions.

3.10.3.1. Additionnal preliminary analyses

We tested the relationship between each of the nine flow dimensions, general MPA level, depressive symptoms, and time difference.

3.10.3.2. Main analyses

Two three-level linear mixed models with restricted marginal maximum likelihood estimation and heterogeneous residual variance structure were fitted for each of the nine flow dimensions. All models included random intercepts for participants and for session.

Model 1 tested the main effect of the two main factors, namely general MPA level and session (private vs. public). The general MPA level was treated as continuous variable. The performance sessions order was also included as control variable (order 1: private – public vs. order 2: public – private). As the number of days between the habituation session and the first performance session differed between participants (see table 1), we controlled the variable time difference expressed in days. The variable preparation, defined as the amount of preparation time in hours between the first and the second performance session, was included to control for the additional preparation time for the second performance. This variable was computed as follows: First, we attributed the value 0 to the first performance session and the number of practice hours reported by the participants (e.g., 2 h) to the second performance session. Second, we centered to the individual mean (e.g., 1 h). Finally, gender and depressive symptoms were also added. All continuous predictors were mean-centered.

Model 2 was an extension of model 1 including the main interaction general MPA level × session, and the following control interactions: general MPA level × order, order × session, gender × order, gender × session, depressive symptoms × order, depressive symptoms × session, time difference × order, and time difference × session. Diagnostics for residuals and random effects showed that overall distributional assumptions were met for all models implying satisfactory model specification. Nevertheless, we identified a number of outliers defined as standardized residuals smaller than -3 and larger than 3. To evaluate their impact on the results, models 1 and 2 were tested again after dropping the outliers.

3.10.4. Research question 3

In this research question, we investigated to what extent the general MPA level, audience presence, time, and their interaction influence the self-rated MPQ.

3.10.4.1. Additional preliminary analyses

First, we computed pairwise correlations between all the outcome variables and the individual factors (general MPA level, depressive symptoms, preparation, and time difference).

Second, we performed two exploratory factors analyses with principal axis factoring using the MPQ scale dimensions in order to test if the evaluated dimensions were all measuring the same latent variable.

The first exploratory factor analysis included all dimensions from the MPQ scale whereas the second exploratory factor analysis excluded the item intonation, as this item was irrelevant for accordion, piano, and guitar players. We used the Kaiser criterion, the percent variance accounted for each factor, a scree test, a parallel analysis, and a Minimum Average Partial (MAP) test as criterion to determine the number of factors.

3.10.4.2. Main analyses

Based on the factor analyses results, we fitted three three-level linear mixed models with restricted marginal maximum likelihood estimation for the self-rated MPQ. We used a

heterogeneous residual variance structure, and we included random intercepts for participants and for session.

In model 1, we tested the main effect of general MPA level (treated as a continuous variable), session (private vs. public), and time (time 1: performance evaluated directly after the performance vs. time 2: performance evaluated one week after the end of the experiment using a performance recording). As control variables, we included order (order 1: private – public vs. order 2: public - private), time difference (number of days between the habituation session and the first performance session), preparation (amount of preparation time in hours between the first and the second performance), gender (women vs. men), and depressive symptoms. All the continuous predictors were mean-centered.

Model 2 was an extension of model 1 including the main interactions general MPA level x session, general MPA level x time, and session x time. We added the following control interactions: general MPA level x order, order x session, order x time, gender x order, gender x session, gender x time, depressive symptoms x order, depressive symptoms x session, depressive symptoms x time, time difference x order, time difference x session, and time difference x time.

Model 3 was an extension of model 2. It was intended to explore the 3-way interaction: general MPA level x session x time. We added the following three-way control interactions: general MPA level x session x order, general MPA level x time x order, session x time x order, session x time x gender, session x time x depressive symptoms, and session x time x time difference. Each significant interaction was investigated further with post-hoc analyses including post-hoc contrasts.

Diagnostics for residuals and random effects showed that the overall distributional assumptions were met for all models implying satisfactory model specification. As a certain number of outliers (defined as standardized residuals smaller than -3 and larger than 3) were identified, the three models were tested again after dropping the outliers to evaluate their impact on the results.

3.10.5. Research question 4

In this research, we aimed to investigate to what extent the general MPA level, audience presence, time, and their interaction influence the challenge-threat states.

3.10.5.1. Additional preliminary analyses

We performed pairwise correlations to test the relationships between all the outcome variables and the predictors (general MPA level, depressive symptoms, preparation, and time difference).

3.10.5.2. Main Analyses

We fitted separately three three-level linear mixed models with restricted likelihood estimation for each of our outcome variables. These models were fitted with heterogeneous residual variance and with random intercepts for participants and for session.

For each outcome variable, the first model tested the main effect of general MPA level, the main effect of session (private vs. public) and the main effect of time (before vs. during the music performance). The general MPA level was treated as a continuous variable. We

included the following variables as control variables: order (order 1: private - public vs. order 2: public vs. private), preparation (amount of time in hours spent to practice for the music performance in between the first and the second performance session), gender (men vs. women), depressive symptoms and time difference (number of days between the habituation session and the first performance session). All continuous predictors were mean-centered.

The second model was an extension of the first model. It tested the following main 2-way interactions: general MPA level x session, general MPA level x time, and session x time. The following control interactions were also added: general MPA level x order, session x order, time x order, gender x session, gender x time, gender x order, depressive symptoms x session, depressive symptoms x time, depressive symptoms x order, time difference x session, time difference x time, and time difference x order.

The third model was an extension of the second model. It was intended to explore the 3-way interaction general MPA level x session x time. The following control 3-way interactions were added to the model: general MPA level x session x order, general MPA level x time x order, session x time x order, gender x session x time, gender x session x order, gender x time x order, depressive symptoms x session x time, depressive symptoms x session x order, depressive symptoms x time x order, time difference x session x time, time difference x session x order, and time difference x time x order.

Diagnostics for residuals and random effects showed that the overall distributional assumptions were met for all models implying satisfactory model specification. As a certain number of outliers (defined as standardized residuals smaller than -3 and larger than 3) were identified, the three models were tested again after dropping the corresponding outliers to evaluate their impact on the results.

3.10.6. Research question 5

In this research question, we investigated to what extent the challenge-threat states influence the self-rated MPQ.

3.10.6.1. Main analyses

To disaggregate the effect of the resources-demands differential evaluated before the performance into its between- and its within-effect, we first, removed from each value of the resources-demands differential variable, the average of associated individual values. These new values correspond to the within-subject variation. Thus, a participant having indicated a score of 2 before the private session and a score of 4 before the public session will have a within score of -1 for the private session and of 1 for the public session. Second, we calculated the average of the individuals' means for the resources-demands differential variable. We then subtracted this value from each of the individuals' means. The value obtained corresponds to the between subject variation. If the average of the individuals' means is 3, then the participant who had a score of 2 and 4 previously will have a score between 0.

A three-level linear mixed model with restricted marginal maximum likelihood estimation and heterogeneous residual variance structure was fitted for the self-rated MPQ evaluated after the performance. We also included random intercepts for participants and for session.

In this model we tested the main resources-demands between effect and the main resources-demands within effect. As control variables, we included: order (order 1: private –

public vs. order 2: public - private), time difference (number of days between the habituation session and the first performance session), preparation (amount of preparation time in hours between the first and the second performance), gender (women vs. men), and depressive symptoms. All the continuous predictors were mean-centered.

The exact same model was also fitted for the self-rated MPQ evaluated one week after the end of the last performance with recordings.

Diagnostics for residuals and random effects showed that the overall distributional assumptions were met for all models implying satisfactory model specification. As a certain number of outliers (defined as standardized residuals smaller than -3 and larger than 3) were identified, the model was tested again after dropping the outliers to evaluate their impact on the results.

4. Results and discussion

4.1. General descriptive statistics[6]

Descriptive statistics for the sample and predictors are given in table 1.

4.2. Preliminary analyses

The results are given in the tables 4 and 5. There was a significant gender difference in general MPA level (F (1,119) = 10.09, *p*= 0.002). Female participants' general MPA level was significantly higher than male participants' general MPA level (mean difference= 6.23, SE= 1.96). Depressive symptoms and general MPA level were significantly correlated (r= 0.27, p= 0.003). There were no significant differences in general MPA level as a function of academic level and instrument. There were also no significant correlations between general MPA level and years of practice, number of solo performances, number of ensemble performances, time difference, and preparation. Based on these results, gender and depressive symptoms were entered into the main analyses to control for their potential confounding effects.

4.3. Research question 1

4.3.1. Descriptives statistics

The descriptive statistics for the times at which the different salivary samples were taken can be found in the table 2 for the performance session realized during the early afternoon (14h02) and in the table 3 for the performance session realized during the late afternoon (16h47). The descriptive statistics for the salivary parameters are reported in the tables 6 to 9.

[6] The subsections 4.1 and 4.2 is based on a published article (Guyon et al., 2022b).

Table 1 - Sample general descriptive statistics

	M	*SD*	Min-max	Skewness	Kurtosis
Age	24.3	3.2	18 - 33	0.3	2.7
General MPA level	47.7	11.1	27 - 76	0.0	2.2
Depressive symptoms	10.0	7.8	0 - 33	1.0	3.4
Years of practice	15.4	4.1	2 - 22	-0.8	3.6
Hours of daily practice	4.5	1.7	1 - 11	0.7	4.4
Number of solo performances	8.7	11.5	0 - 100	4.8	34.9
Number of ensemble performances	13.3	17.3	0 - 100	3.3	15.1
Time difference	67.8	64.0	6 - 425	2.4	10.7
Preparation	1.4	1.3	0 - 7	1.6	6.3
Menstrual cycle day (Women only)	11.52	9.69	0 - 68	3.9	21.4

	N		N
Gender			
Men	52	Women	69
Language of the questionnaire			
English	13	French	108
Instruments			
Accordion	1	Oboe	12
Bassoon	6	Piano	14
Cello	11	Saxophone	2
Clarinet	7	Trombone	4
Doublebass	4	Trumpet	5
Flute	7	Viola	3
Guitar	5	Violin	13
Horn	4	Voice	23
Academic year			
Year 1	23	Year 5	22
Year 2	18	Year 6	3
Year 3	16	Year 7	6
Year 4	33		
Order			
Private – public	57	Public – private	64
Hour			
Early afternoon	62	Late afternoon	59

Note of Table 1 - Years of practice = years spent playing their instrument. Hours of daily practice = hours spent daily to practice their instruments. Number of solo performances = number of solo performances done during the previous year. Number of ensemble performances = number of ensemble performances done during the previous year. Time difference = days between the habituation session and the first performance session. Preparation = hours spent to practice the piece between the first and the second performance. Mentrual cycle day = Number of days for women between the beginning of the last period and the day of the first musicl performance. Hour = hour at which the participant should have started the music performance (early afternoon = 14h02, late afternoon = 16h47).

Table 2 - Descriptive statistics of the saliva sampling time collected from music students who participated to the experiment during the early afternoon

PRIVATE PERFORMANCE						
Time point	**N**	**Mean**	**Median**	**SD**	**Min**	**Max**
S1	62	13:45:55	13:45:31	00:02:54	13:40:00	14:03:10
S2	62	14:02:34	14:01:54	00:03:21	13:57:00	14:17:38
S3	62	14:25:18	14:22:54	00:04:52	14:22:00	14:46:31
S4	62	14:36:01	14:33:46	00:05:26	14:32:00	14:59:57
S5	62	14:46:31	14:44:28	00:05:48	14:42:00	15:10:34
S6	62	14:59:33	14:57:55	00:06:35	14:52:00	15:24:16
PUBLIC PERFORMANCE						
Time point	**N**	**Mean**	**Median**	**SD**	**Min**	**Max**
S1	62	13:45:54	13:45:23	00:03:02	13:40:00	14:04:26
S2	62	14:02:33	14:01:58	00:03:17	13:57:10	14:17:56
S3	62	14:25:17	14:22:42	00:05:02	14:21:55	14:46:55
S4	62	14:35:58	14:33:40	00:05:24	14:32:00	14:59:31
S5	62	14:46:22	14:44:10	00:05:50	14:42:00	15:10:30
S6	62	14:59:30	14:57:53	00:06:46	14:52:00	15:24:59

Table 3 - Descriptive statistics of the saliva sampling time collected from music students who participated to the experiment during the late afternoon

PRIVATE PERFORMANCE						
Time point	**N**	**Mean**	**Median**	**SD**	**Min**	**Max**
S1	59	16:30:26	16:30:21	00:01:38	16:21:09	16:35:17
S2	59	16:46:58	16:46:43	00:02:08	16:41:07	16:53:11
S3	59	17:09:12	17:07:58	00:02:52	17:05:12	17:17:17
S4	59	17:19:55	17:18:24	00:03:23	17:16:30	17:29:15
S5	59	17:30:19	17:28:28	00:04:06	17:25:40	17:42:24
S6	59	17:43:20	17:41:27	00:05:12	17:36:35	17:59:15
PUBLIC PERFORMANCE						
Time point	**N**	**Mean**	**Median**	**SD**	**Min**	**Max**
S1	59	16:30:29	16:30:28	00:01:40	16:21:10	16:35:32
S2	59	16:46:53	16:46:41	00:02:04	16:41:07	16:53:23
S3	59	17:09:19	17:08:00	00:02:58	17:05:22	17:17:37
S4	59	17:19:59	17:18:44	00:03:21	17:16:35	17:29:00
S5	59	17:30:23	17:28:53	00:04:09	17:25:40	17:42:35
S6	59	17:43:30	17:42:13	00:05:16	17:36:35	17:59:11

Table 4 - Preliminary analyses – Pearson correlations between the general MPA level and seven other personal variables (N = 121)

	General MPA level
Age	0.02
Depressive symptoms	**0.27**
Years of practice	-0.01
Hours of daily practice	-0.04
Number of solo performance	-0.07
Number of ensemble performance	-0.06
Time difference	-0.11
Preparation	-0.03

Note of table 4 - Years of practice = years spent playing their instrument. Hours of daily practice = hours spent daily to practice their instrument. Number of solo performances = number of solo performances done during the previous year. Number of ensemble performances = number of ensemble performances done during the previous year. Time difference = number of days between the habituation session and the first performance session. Preparation = hours spent to practice the piece between the first and the second performance. Significant correlations ($p < 0.05$) are written in bold.

Table 5 - Preliminary analyses – One-way analyses of variances with general MPA level as dependent variable (N = 121)

	Sum of squares	df	Mean Square	F	*p*	R-squared
Gender	**1151.92**	**1**	**1151.92**	**10.09**	**0.002**	**0.08**
Academic level	379.74	6	63.29	0.50	0.81	0.03
Instrument	271.11	4	67.78	0.54	0.70	0.02

Note of table 5 – Academic level = current academic year of the music students. Instrument = type of the main music instrument played by the music students. The musical instruments were divided into five groups: 1) piano and accordion players, 2) woodwind players, 3) brass players, 4) string players, and 5) singers.

Table 6 - Descriptive statistics for sC

	sC (nmol/L)									
	Private session					Public session				
Time points	N	*M (SD)*	Min-max	Skewness	Kurtosis	N	*M (SD)*	Min-max	Skewness	Kurtosis
S1	121	2.59 (1.59)	0.62 - 12.06	2.40	12.91	121	3.49 (2.15)	0.30 - 11.62	1.35	4.84
S2	121	2.23 (1.38)	0.52 - 10.08	2.18	11.22	121	2.99 (1.77)	0.43 - 9.34	1.32	4.92
S3	121	2.03 (1.49)	0.43 - 13.16	3.81	27.46	120	4.33 (2.95)	0.54 - 15.31	1.41	4.78
S4	121	1.80 (1.16)	0.35 - 9.49	2.73	17.66	121	3.87 (2.77)	0.62 - 15.86	1.79	6.74
S5	120	1.61 (0.95)	0.30 - 6.99	1.88	10.54	121	3.24 (2.12)	0.55 - 12.77	1.73	7.07
S6	119	1.60 (1.10)	0.33 - 8.93	3.09	19.24	121	2.69 (1.51)	0.52 - 9.20	1.35	5.70
	Log sC (nmol/L)									
	Private session					Public session				
Time points	N	*M (SD)*	Min - max	Skewness	Kurtosis	N	*M (SD)*	Min - max	Skewness	Kurtosis
S1	121	0.80 (0.54)	-0.47 - 2.49	0.13	2.99	121	1.07 (0.62)	-1.19 - 2.45	-0.29	3.49
S2	121	0.65 0.56	-0.66 - 2.31	0.09	2.85	121	0.93 0.59	-0.85 2.23	-0.18	2.88
S3	121	0.52 0.61	-0.83 - 2.58	0.03	3.16	120	1.25 0.66	-0.61 2.73	-0.11	2.88
S4	121	0.41 0.61	-1.04 - 2.25	-0.24	2.88	121	1.14 0.65	-0.48 2.76	0.10	2.74
S5	120	0.32 0.59	-1.19 - 1.95	-0.30	2.74	121	0.99 0.62	-0.61 2.55	-0.08	2.82
S6	119	0.29 0.61	-1.12 - 2.19	-0.12	3.11	121	0.84 0.57	-0.66 2.22	-0.30	2.97

Table 7 - Descriptive statistics for sDHEA

	sDHEA(pg/mL)										
	Private session					Public session					
Time points	N	*M (SD)*	Min-max	Skewness	Kurtosis	N	*M (SD)*	Min-max	Skewness	Kurtosis	
S1	120	344.22 (223.40)	51.67 - 1421.66	2.16	8.68	120	380.87 (201.44)	104.63 - 1304.31	1.72	7.59	
S2	120	315.68 (204.13)	93.66 - 1718.14	3.43	21.14	120	361.11 (183.08)	105.23 - 1276.31	1.78	8.36	
S3	120	313.18 (192.95)	56.07 - 1554.41	2.94	16.85	120	432.31 (223.85)	54.71 - 1490.04	1.76	8.16	
S4	120	305.07 (190.84)	22.16 - 1359.44	2.39	11.51	121	390.87 (198.94)	92.26 - 1258.45	1.47	6.13	
S5	120	288.56 (178.46)	20.33 - 1275.22	2.42	11.35	120	380.08 (204.62)	99.29 - 1239.79	1.71	6.62	
S6	120	299.71 (203.83)	95.31 - 1525.93	2.94	14.84	121	349.21 (190.36)	18.67 - 1146.62	1.56	6.01	
	Log sDHEA (nmol/L)										
	Private session					Public session					
Time points	N	*M (SD)*	Min - max	Skewness	Kurtosis	N	*M (SD)*	Min - max	Skewness	Kurtosis	
S1	120	5.69 (0.54)	3.94 - 7.26	0.39	3.58	120	5.82 (0.49)	4.65 - 7.17	0.05	2.97	
S2	120	5.62 (0.50)	4.54 - 7.45	0.53	3.89	120	5.78 (0.47)	4.66 - 7.15	0.04	2.99	
S3	120	5.61 (0.50)	4.03 - 7.35	0.31	3.88	120	5.95 (0.51)	4.00 - 7.31	-0.43	4.37	
S4	120	5.57 (0.56)	3.10 - 7.21	-0.35	5.43	121	5.85 (0.49)	4.52 - 7.14	-0.05	2.94	
S5	120	5.52 (0.55)	3.01 - 7.15	-0.38	6.09	120	5.82 (0.49)	4.60 - 7.12	0.15	3.12	
S6	120	5.55 (0.52)	4.56 - 7.33	0.70	3.79	121	5.72 (0.56)	2.93 - 7.04	-0.94	7.40	

Table 8 - Descriptive statistics for anabolic balance

	Anabolic balance									
	Private session					Public session				
Time points	N	*M (SD)*	Min-max	Skewness	Kurtosis	N	*M (SD)*	Min-max	Skewness	Kurtosis
S1	120	0.57 (0.46)	0.15 - 2.70	2.65	11.29	120	0.50 (0.43)	0.06 - 2.80	3.23	15.68
S2	120	0.65 (0.64)	0.17 - 4.15	3.51	16.76	120	0.55 (0.46)	0.06 3.26	3.42	18.10
S3	120	0.74 (0.78)	0.12 - 5.08	3.74	18.92	120	0.49 (0.41)	0.07 - 2.70	2.91	14.10
S4	120	0.77 (0.73)	0.16 - 5.03	3.27	16.20	121	0.50 (0.42)	0.08 - 2.69	2.57	11.26
S5	119	0.80 (0.74)	0.13 - 4.71	3.30	16.07	120	0.55 (0.49)	0.11 - 3.24	2.91	13.81
S6	119	0.87 (0.87)	0.16 - 5.71	3.58	17.52	121	0.59 (0.52)	0.08 - 3.09	2.65	11.03
	Log anabolic balance									
	Private session					Public session				
Time points	N	*M (SD)*	Min - max	Skewness	Kurtosis	N	*M (SD)*	Min - max	Skewness	Kurtosis
S1	120	-0.79 (0.63)	-1.92 - 0.99	0.59	3.17	120	-0.92 (0.65)	-2.82 - 1.03	0.29	3.69
S2	120	-0.69 (0.65)	-1.79 - 1.42	0.93	4.18	120	-0.83 (0.64)	-2.77 - 1.18	0.30	3.78
S3	120	-0.58 (0.67)	-2.09 - 1.63	0.91	4.34	120	-0.97 (0.69)	-2.63 - 1.00	0.16	3.13
S4	120	-0.52 (0.66)	-1.85 - 1.61	0.76	3.65	121	-0.95 (0.70)	-2.53 - 0.99	0.21	3.00
S5	119	-0.47 (0.65)	-2.00 - 1.55	0.65	3.76	120	-0.85 (0.69)	-2.25 - 1.18	0.31	3.12
S6	119	-0.40 (0.65)	-1.85 - 1.74	0.79	4.29	121	-0.78 (0.70)	-2.53 - 1.13	0.25	3.29

Table 9 - Descriptive statistics for sAA

	sAA (U/mL)									
	Private session					Public session				
Time points	N	*M (SD)*	Min-max	Skewness	Kurtosis	N	*M (SD)*	Min-max	Skewness	Kurtosis
S1	121	85.85 (67.27)	5.71 - 341.04	1.49	5.12	121	85.78 (72.97)	5.58 - 459.99	2.07	9.36
S2	121	93.61 (72.83)	6.15 - 404.82	1.65	6.29	121	103.35 (75.62)	3.59 - 381.93	1.22	4.48
S3	121	102.18 (73.69)	6.98 - 392.72	1.16	4.38	121	113.79 (82.34)	5.61 - 387.38	1.04	3.67
S4	121	82.79 (73.67)	3.84 - 609.58	3.50	23.49	121	85.68 (70.96)	4.64 - 478.82	2.49	12.26
S5	120	79.46 (75.21)	4.36 - 627.86	3.73	25.46	120	75.66 (64.54)	3.19 - 544.86	3.57	24.82
S6	121	89.05 (75.08)	4.35 - 452.94	2.06	9.02	120	86.64 (69.51)	11.33 - 486.10	2.52	12.51
	Log sAA (U/mL)									
	Private session					Public session				
Time points	N	*M (SD)*	Min - max	Skewness	Kurtosis	N	*M (SD)*	Min - max	Skewness	Kurtosis
S1	121	4.15 (0.83)	1.74 - 5.83	-0.39	2.87	121	4.10 (0.90)	1.72 - 6.13	-0.48	2.87
S2	121	4.25 (0.80)	1.82 - 6.00	-0.32	2.89	121	4.33 (0.87)	1.28 - 5.95	-0.83	3.87
S3	121	4.34 (0.81)	1.94 - 5.97	-0.46	2.71	121	4.44 (0.84)	1.72 - 5.96	-0.56	3.05
S4	121	4.10 (0.84)	1.35 - 6.41	-0.45	3.37	121	4.16 (0.81)	1.53 - 6.17	-0.47	3.49
S5	120	4.04 (0.85)	1.47 - 6.44	-0.29	3.14	120	4.03 (0.81)	1.16 - 6.30	-0.54	3.70
S6	121	4.15 (0.88)	1.47 - 6.12	-0.47	2.98	120	4.20 (0.75)	2.43 - 6.19	-0.23	3.00

4.3.2. Preliminary results

The general MPA level of women using hormonal contraception did not significantly differ from women who are not using hormonal contraception ($t(63)= -0.64$, $p= 0.53$). Consequently, we decided to use the control variable gender without distinguishing between the two groups of women.

Among our music students, there were 81 non-smokers, 31 occasional smokers (smoking less than 1 cigarette per day), and 9 regular smokers (smoking more than 1 cigarette per day). Smoking habits were not considered among the control variables since no significant general MPA level differences were found between non-smokers and occasional smokers ($F(1,110)= 0.93$, $p= 0.34$), non-smokers and regular smokers ($F(1,88)= 0.04$, $p= 0.84$), and occasional smokers and regular smokers ($F(1,38)= 0.17$, $p= 0.68$).

4.3.3. Main results

The estimated models for the sC, sDHEA, anabolic balance, and sAA are reported in tables 10 to 13. The models without the outliers are given in the supplementary materials (supplementary tables S4 to S7).

4.3.3.1. Model 1

In model 1, no significant general MPA level effect was found for any of the outcome variables, but there was a significant session effect for sC, sDHEA, and anabolic balance. The sC and sDHEA levels were significantly higher during the public performance session than during the private performance session, whereas the anabolic balance was significantly lower during the public performance session than during the private performance session.

A significant time effect was found for sC ($\chi^2= 387.67$, $p < 0.001$), sDHEA ($\chi^2= 71.61$, $p <0.001$), anabolic balance ($\chi^2= 148.04$, $p <0.001$), and sAA ($\chi^2= 209.12$, $p <0.001$ – see supplementary figures S1 to S4). Post-hoc contrasts showed that the sC level was significantly higher at S1 than at S2 ($p <0.001$). The sC level was lower at S2 than at S3 ($p=0.001$). The sC level was higher at S3 than at S4 ($p <0.001$). The sC level was higher at S4 than at S5 ($p<0.001$). The sC level was higher at S5 than at S6 ($p <0.001$). The sC level was not significantly different between S1 and S3 ($p = 0.074$), but it was significantly higher at S3 than at S6 ($p <0.001$), and significantly higher at S1 than at S6 ($p <0.001$). For sDHEA, the level was higher at S1 than at S2 ($p= 0.008$), lower at S2 than at S3 ($p <0.001$), higher at S3 than at S4 ($p <0.001$), and higher at S4 than at S5 ($p= 0.011$), but there was no significant difference between S5 and S6 ($p= 0.14$). The sDHEA level was not significantly different between S1 and S3 ($p = 0.22$), but it was significantly higher at S3 than at S6 ($p <0.001$), and significantly higher at S1 than at S6 ($p <0.001$). For anabolic balance, the level was significantly lower at S1 than at S2 ($p= 0.002$), lower at S3 than at S4 ($p= 0.034$), lower at S4 than at S5 ($p <0.001$), and lower at S5 than at S6 ($p= 0.004$), but there was no significant level difference between S2 and S3 ($p= 0.59$). The anabolic balance level was significantly lower at S1 than at S3 ($p <0.001$), lower at S3 than at S6 ($p <0.001$), and lower at S1 than at S6 ($p <0.001$). For sAA, the activity level was significantly lower at S1 than at S2 ($p<0.001$), lower at S2 than at S3 ($p= 0.001$), higher at S3 than at S4 ($p<0.001$), higher at S4 than at S5 ($p= 0.001$), and lower at S5 than at S6 ($p <0.001$). The sAA level was lower at S1 than at S3 ($p <0.001$), higher at S3 than at S6 ($p <0.001$), and there was no significant different between S1 and S6 ($p= 0.21$).

Table 10 - Estimated linear mixed models for sC

	sC					
	Model 1			*Model 2*		
	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*
Main effects						
General MPA level	-0.00	0.00	0.64	-0.00	0.01	0.95
Session	**0.64**	**0.05**	**<0.001**	0.16	0.12	0.20
Time			**<0.001**			**<0.001**
Order	**-0.23**	**0.09**	**0.011**	-0.26	0.15	0.082
Hour	**-0.25**	**0.09**	**0.006**	-0.48	0.14	**0.001**
Preparation	-0.03	0.03	0.25	-0.03	0.04	0.46
Gender	**0.21**	**0.10**	**0.029**	-0.06	0.18	0.74
Depressive symptoms	-0.00	0.01	0.75	0.01	0.01	0.23
Time difference	0.01	0.01	0.24	0.02	0.01	0.19
Interactions						
General MPA level x session				0.00	0.00	0.86
General MPA level x time						0.69
General MPA level x hour				0.01	0.01	0.49
General MPA level x order				-0.00	0.01	0.92
Session x time						**<0.001**
Session x hour				0.13	0.10	0.16
Session x order				0.00	0.14	0.98
Time x hour						0.91
Time x order						0.59
Gender x session				0.11	0.10	0.31
Gender x time						**0.013**
Gender x hour				0.30	0.20	0.13
Gender x order				0.15	0.20	0.45
Depressive symptoms x session				-0.00	0.01	0.52
Depressive symptoms x time						0.94
Depressive symptoms x hour				-0.01	0.01	0.59
Depressive symptoms x order				-0.02	0.01	0.17
Time difference x session				0.01	0.01	0.25
Time difference x time						0.71
Time difference x hour				-0.01	0.02	0.36
Time difference x order				-0.02	0.02	0.31

Note of Table 10 - Model 1 tested the main effect of our factors and Model 2 tested the interactions of our factors. Significant main effects in Model 1 and significant interaction effect in Model 2 are written in bold. Reference categories for categorical predictors were as follows: session: private performance session; time: S1; hour: early afternoon; order: private performance session first – public performance session second; gender: women. For continuous predictors, coefficients express the change in the outcome measure per unit (unit for Preparation is hour and unit for Time difference is day).

Table 11 - Estimated linear mixed models for sDHEA

	sDHEA					
	Model 1			*Model 2*		
	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*
Main effects						
General MPA level	-0.00	0.00	0.69	0.00	0.01	0.82
Session	**0.24**	**0.03**	**<0.001**	0.12	0.07	0.10
Time			**<0.001**			**<0.001**
Order	0.00	0.09	0.98	0.02	0.13	0.88
Hour	-0.07	0.09	0.39	-0.11	0.13	0.39
Preparation	-0.03	0.01	0.071	-0.02	0.02	0.47
Gender	0.02	0.09	0.79	0.03	0.17	0.84
Depressive symptoms	-0.00	0.01	0.79	0.01	0.01	0.53
Time difference	0.00	0.01	0.81	0.02	0.01	0.15
Interactions						
General MPA level x session				-0.00	0.00	0.23
General MPA level x time						0.97
General MPA level x hour				0.00	0.01	0.72
General MPA level x order				-0.00	0.01	0.71
Session x time						**<0.001**
Session x hour				0.00	0.05	0.96
Session x order				0.04	0.08	0.59
Time x hour						0.37
Time x order						0.62
Gender x session				-0.01	0.06	0.85
Gender x time						0.18
Gender x hour				0.08	0.19	0.68
Gender x order				-0.06	0.19	0.77
Depressive symptoms x session				-0.00	0.00	0.38
Depressive symptoms x time						0.66
Depressive symptoms x hour				0.00	0.01	0.90
Depressive symptoms x order				-0.01	0.01	0.30
Time difference x session				-0.00	0.00	0.92
Time difference x time						0.76
Time difference x hour				-0.01	0.01	0.55
Time difference x order				**-0.03**	**0.01**	**0.034**

Note of Table 11 - Model 1 tested the main effect of our factors and Model 2 tested the interactions of our factors. Significant main effects in Model 1 and significant interaction effect in Model 2 are written in bold. Reference categories for categorical predictors were as follows: session: private performance session; time: S1; hour: early afternoon; order: private performance session first – public performance session second; gender: women. For continuous predictors, coefficients express the change in the outcome measure per unit (unit for Preparation is hour and unit for Time difference is day).

Table 12 - Estimated linear mixed models for anabolic balance

	Anabolic balance					
	Model 1			*Model 2*		
	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*
Main effects						
General MPA level	0.00	0.01	0.98	0.00	0.01	0.85
Session	**-0.35**	**0.04**	**<0.001**	-0.07	0.09	0.46
Time			**<0.001**			**<0.001**
Order	**0.23**	**0.11**	**0.031**	0.27	0.17	0.12
Hour	0.18	0.11	0.093	0.37	0.16	**0.023**
Preparation	0.00	0.02	0.83	0.02	0.03	0.49
Gender	-0.17	0.12	0.13	0.09	0.21	0.57
Depressive symptoms	0.00	0.01	0.92	-0.01	0.01	0.57
Time difference	-0.01	0.01	0.49	0.00	0.02	0.95
Interactions						
General MPA level x session				-0.00	0.00	0.29
General MPA level x time						0.82
General MPA level x hour				-0.00	0.01	0.83
General MPA level x order				-0.00	0.01	0.82
Session x time						**<0.001**
Session x hour				-0.11	0.07	0.13
Session x order				0.07	0.11	0.53
Time x hour						0.36
Time x order						0.59
Gender x session				-0.12	0.08	0.13
Gender x time						**0.009**
Gender x hour				-0.20	0.24	0.41
Gender x order				-0.19	0.24	0.44
Depressive symptoms x session				0.00	0.00	0.77
Depressive symptoms x time						0.44
Depressive symptoms x hour				0.01	0.02	0.59
Depressive symptoms x order				0.00	0.02	0.77
Time difference x session				-0.01	0.01	0.051
Time difference x time						0.99
Time difference x hour				0.00	0.02	0.87
Time difference x order				-0.01	0.02	0.47

Note of Table 12 - Model 1 tested the main effect of our factors and Model 2 tested the interactions of our factors. Significant main effects in Model 1 and significant interactions in Model 2 are written in bold. Reference categories for categorical predictors were as follows: session: private performance session; time: S1; hour: early afternoon; order: private performance session first – public performance session second; gender: women. For continuous predictors, coefficients express the change in the outcome measure per unit (unit for Preparation is hour and unit for Time difference is day).

Table 13 - Estimated linear mixed models for sAA

	sAA					
	Model 1			*Model 2*		
	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*
Main effects						
General MPA level	0.00	0.01	0.88	-0.01	0.01	0.63
Session	0.04	0.03	0.21	-0.11	0.08	0.16
Time			**<0.001**			**<0.001**
Order	-0.06	0.14	0.67	-0.19	0.20	0.35
Hour	-0.02	0.14	0.87	-0.05	0.20	0.79
Preparation	-0.02	0.02	0.18	-0.01	0.02	0.58
Gender	0.17	0.15	0.25	0.05	0.26	0.86
Depressive symptoms	0.01	0.01	0.58	0.02	0.02	0.30
Time difference	-0.02	0.01	0.11	0.00	0.02	0.83
Interactions						
General MPA level x session				-0.00	0.00	0.69
General MPA level x time						0.81
General MPA level x hour				0.00	0.01	0.98
General MPA level x order				0.02	0.01	0.24
Session x time						0.16
Session x hour				0.10	0.06	0.12
Session x order				0.03	0.09	0.72
Time x hour						0.18
Time x order						0.50
Gender x session				0.01	0.07	0.83
Gender x time						**<0.001**
Gender x hour				0.06	0.31	0.85
Gender x order				0.35	0.31	0.25
Depressive symptoms x session				0.00	0.00	0.26
Depressive symptoms x time						0.14
Depressive symptoms x hour				0.01	0.02	0.79
Depressive symptoms x order				0.01	0.02	0.71
Time difference x session				0.00	0.00	0.53
Time difference x time						0.61
Time difference x hour				-0.01	0.02	0.53
Time difference x order				-0.04	0.03	0.087

Note of Table 13 - Model 1 tested the main effect of our factors and Model 2 tested the interactions of our factors. Significant main effects in Model 1 and significant interactions in Model 2 are written in bold. Reference categories for categorical predictors were as follows: session: private performance session; time: S1; hour: early afternoon; order: private performance session first – public performance session second; gender: women. For continuous predictors, coefficients express the change in the outcome measure per unit (unit for Preparation is hour and unit for Time difference is day).

In model 1, there was also a significant order effect on sC and on anabolic balance. The sC level was higher in order 1 (private performance session then public performance session) than in order 2 (public performance session then private performance session), whereas the anabolic balance level was lower in order 1 than in order 2. A significant hour effect was found for sC. The sC level was higher at the early afternoon session than at the late afternoon session. Finally, there was a significant gender effect for sC. Women had a lower sC level than men.

4.3.3.2. Model 2

In model 2, we did not observe a significant interaction either between general MPA level and session or between general MPA level and time for any outcome variables. In contrast, a significant interaction between session and time was found for sC (χ^2= 150.65, *p* <0.001), sDHEA (χ^2= 51.95, *p* <0.001), and anabolic balance (χ^2= 76.41, *p* <0.001), but not for sAA (χ^2= 7.96, *p*= 0.16 - see figures 3 to 6).

The post-hoc contrasts with Holm-Bonferroni correction showed that there was a significant difference in sC level between the public and the private performance at each time point (*corrected p* <0.001 – see supplementary table S8). The sC level was always higher during the public performance session than during the private performance session (see figure 3). The time effect on sC was present for both the private performance session (χ^2= 439.39, *p* <0.001) and the public performance session (χ^2= 265.49, *p* <0.001).

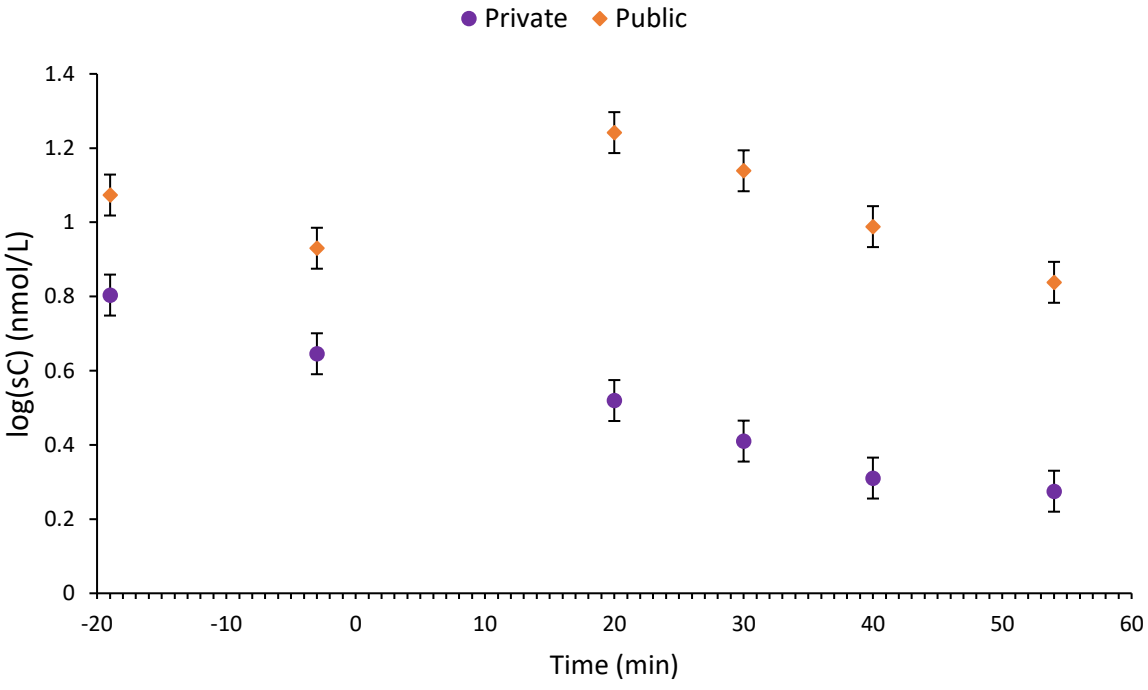

Figure 3. Model-predicted marginal means for log(sC) along the time for the private and for the public performance sessions – The reference point (0) for calculating the time is the beginning of the performance. Bars represent SEs.

Post-hoc contrasts showed that during the private performance session, the sC level was significantly higher at S1 than at S2 (*corrected p*= 0.004), higher at S2 than at S3 (*corrected p*= 0.003), higher at S3 than at S4 (*corrected p* <0.001), and higher at S4 than at S5 (*corrected*

p <0.001). There was no significant level difference between S5 and S6 (*corrected p*= 0.17). The sC level was higher at S1 than at S3 (*corrected p* <0.001), higher at S3 than at S6 (*corrected p* <0.001), and higher at S1 than at S6 (*corrected p* <0.001). During the public performance session, the sC level was significantly higher at S1 than at S2 (*corrected p*= 0.006), lower at S2 than at S3 (*corrected p* <0.001), higher at S3 than at S4 (*corrected p* <0.001), higher at S4 than at S5 (*corrected p* <0.001), and higher at S5 than at S6 (*corrected p* <0.001). The sC level was significantly lower at S1 than at S3 (*corrected p* <0.001), higher at S3 than at S6 (*corrected p* <0.001), and higher at the S1 than at the S6 (*corrected p* <0.001).

For sDHEA, post-hoc contrasts with Holm-Bonferroni correction showed there was a significant difference between the public and private performance session at each time point (*corrected p* <0.001-0.001 – see supplementary table S9). The sDHEA level was always higher during the public performance session than during the private performance session (see figure 4). The time effect on sDHEA was significant both during the private performance session (χ^2= 45.28; *p* <0.001) and during the public performance session (χ^2= 83.26, *p* <0.001). For the private performance session, the sDHEA level was not significantly different between any time points (*corrected p*= 0.16 - 0.80). The sDHEA level at S1 was not significantly different from sDHEA level at S3 (*corrected p*= 0.13), and the sDHEA level at S3 was not significantly different from the sDHEA level at S6 (*corrected p*= 0.20). The sDHEA level was significantly higher at S1 than at S6 (*corrected p* <0.001). For the public performance session, the sDHEA level was lower at S2 than at S3 (*corrected p* <0.001), higher at S3 than at S4 (*corrected p*= 0.012), higher at S5 than at S6 (*corrected p*= 0.011). The sDHEA level was not significantly different between the other time points (*corrected p*= 0.38 - 0.39). The sDHEA level was significantly lower at S1 than at S3 (*corrected p* <0.001), higher at S3 than at S6 (*corrected p* <0.001), and higher at S1 than at S6 (*corrected p*= 0.020).

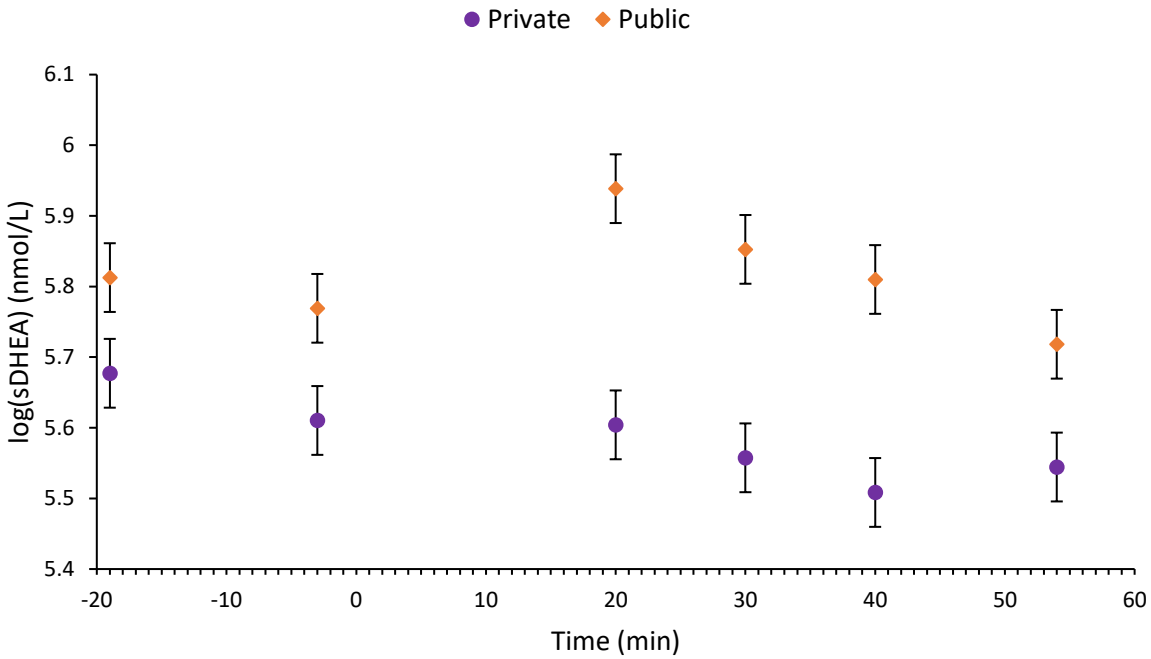

Figure 4. Model-predicted marginal means for log(sDHEA) along the time for the private and for the public performance sessions – The reference point (0) for calculating the time is the beginning of the performance. Bars represent SEs.

The time effect on the anabolic balance was also found for both the private performance session (χ^2= 253.05, *p* <0.001) and for the public performance session (χ^2= 54.36, *p* <0.001 - see figure 5). Post-hoc contrasts with Holm-Bonferroni correction showed that there was no significant difference between the anabolic balance level during the private and the public performance at S1 and at S2 (*corrected p*= 0.060 and 0.090 respectively - see supplementary table S10). From S3 to S6, the anabolic balance level was significantly higher during the private performance session than during the public performance session (*corrected p* <0.001). Furthermore, during the private performance session, the anabolic balance level was significantly lower at S2 than at S3 (*corrected p* <0.001), lower at S1 than at S3 (*corrected p* <0.001), lower at S3 than at S6 (*corrected p* <0.001), and lower at S1 than at S6 (*corrected p* <0.001). The anabolic balance level was not significantly different between the other time points during the private performance session (*corrected p*= 0.11 – 0.16) During the public performance session, the anabolic balance level was higher at S2 than at S3 (*corrected p* <0.001), lower at S3 than at S6 (*corrected p* <0.001), and lower at S1 than at S6 (*corrected p* <0.001). The anabolic balance level was not significantly different between the other time points (*corrected p* = 0.11 – 0.52).

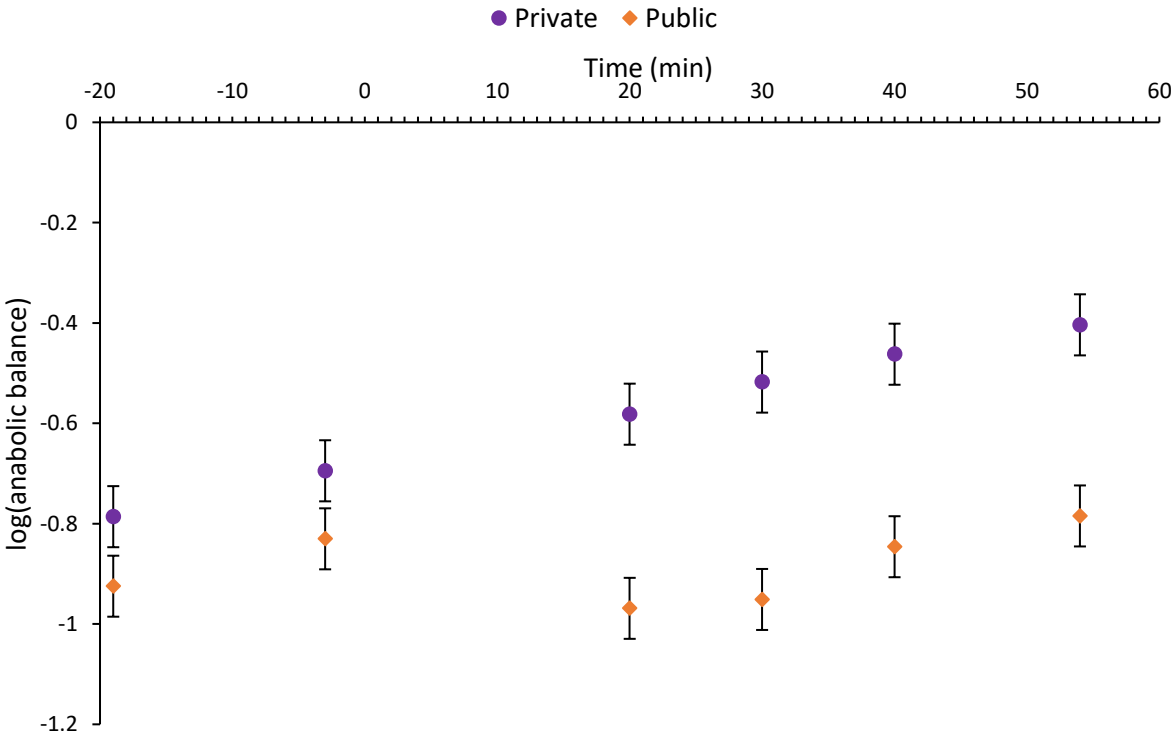

Figure 5. Model-predicted marginal means for log(anabolic balance) along the time for the private and for the public performance sessions – The reference point (0) for calculating the time is the beginning of the performance. Bars represent SEs.

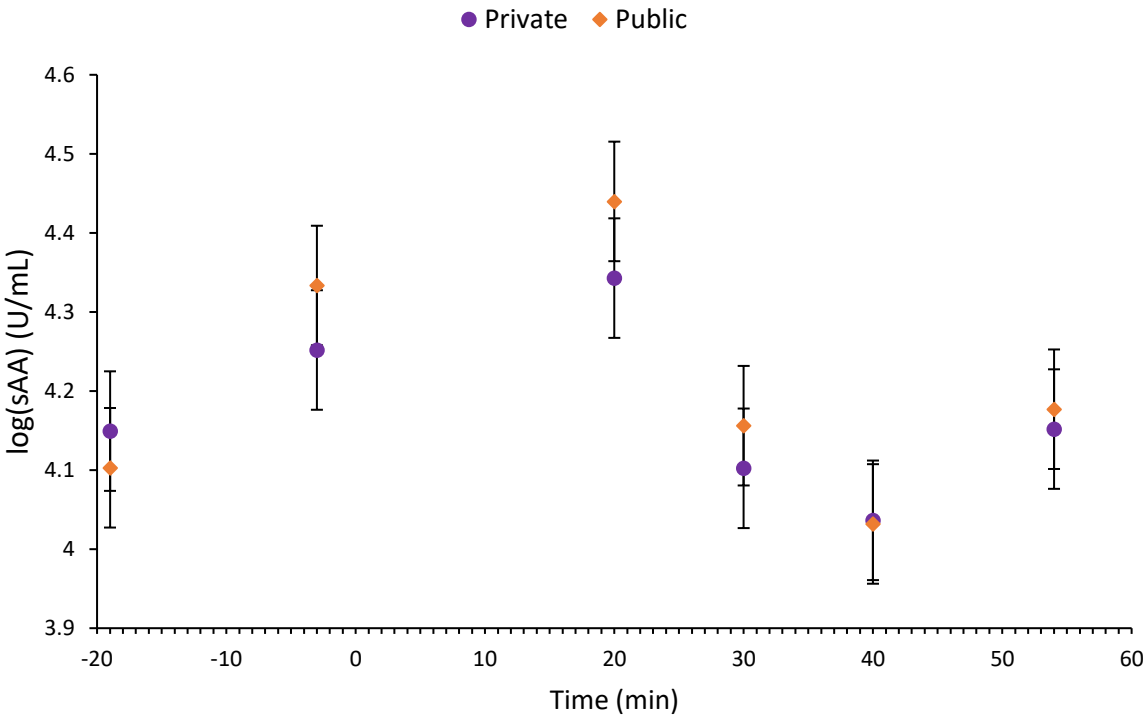

Figure 6. Model-predicted marginal means for log(sAA) along the time for the private and for the public performance sessions – The reference point (0) for calculating the time is the beginning of the performance. Bars represent SEs.

The interaction between gender and time was significant for sC (χ^2= 14.41, *p*= 0.013), anabolic balance (χ^2= 15.11, *p*= 0.010), and sAA (χ^2= 26.98; *p* <0.001 - see figures 7 to 9). This interaction was not significant for sDHEA (χ^2= 7.67, *p*= 0.18).

Post-hoc contrast analyses with Holm-Bonferroni correction showed that the sC level between men and women was not significantly different at any time point (*corrected p*= 0.050-0.45). However, there was a significant effect of time for both women (χ^2= 85.45, *p* <0.001) and men (χ^2= 112.65, *p* <0.001) (see figure 7 and supplementary table S11). For women, the sC level was significantly higher at S3 than at S4 (*corrected p* <0.001) and higher at S4 than at S5 (*corrected p* <0.001). The sC level was significantly higher at S1 than at S6 (*corrected p* <0.001) and higher at S3 than at S6 (*corrected p* <0.001). The sC level was not significantly different between the other time points (*corrected p*= 0.072 - 0.64). For men, the sC level was significantly higher at S1 than at S2 (*corrected p*= 0.012), lower at S2 than at S3 (*corrected p* <0.001), higher at S3 than at S4 (*corrected p* <0.001), higher at S4 than at S5 (*corrected p* <0.001), and higher at S5 than at S6 (*corrected p* <0.001). The sC level was higher at S1 than at S6 (*corrected p* <0.001) and higher at S3 than at S6 (*corrected p* <0.001). There was no significant difference in sC level between S1 and S3 (*corrected p*= 0.70).

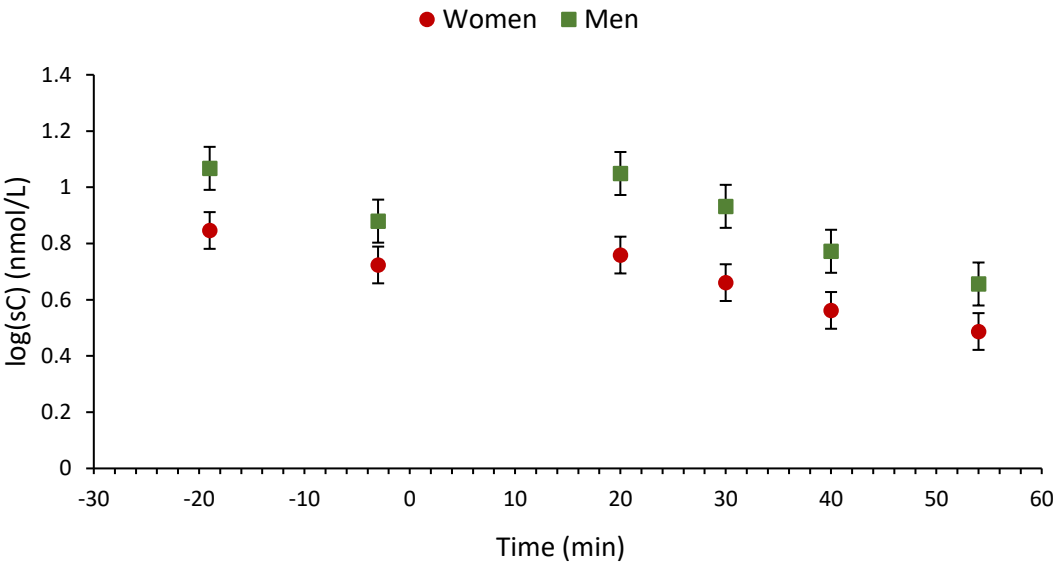

Figure 7. Model-predicted marginal means for log(sC) along the time for women and men – The reference point (0) for calculating the time is the beginning of the performance. Bars represent SEs.

For anabolic balance, the post-hoc analyses and contrasts with Holm-Bonferroni correction showed that there was no significant difference between women and men at any time point (*corrected p*= 0.30 – 1.52 - see supplementary table S12). We found a significant effect of time for both women (χ^2= 44.43, *p* <0.001) and men (χ^2= 67.04, *p* <0.001) (see figure 8). For women, the anabolic balance level was lower at S1 than at S3 (*corrected p* <0.001), lower at S3 than at S6 (*corrected p* <0.001), and lower at S1 than at S6 (*corrected p* <0.001). There was no other significant difference in anabolic balance level between any time point (*corrected p*= 0.15 – 0.59). For men, the anabolic balance level was lower at S4 than at S5 (*corrected p*= 0.017), and lower at S5 than at S6 (*corrected p*= 0.032). The anabolic balance level was lower at S1 than at S6 (*corrected p* <0.001) and lower at S3 than at S6 (*corrected p* <0.001). The anabolic levels at S1 and at S3 were not significantly different from each other (*corrected p*= 0.59). There was no other significant difference in anabolic balance level between any time point (*corrected p* = 0.15 -1.02).

For sAA, post-hoc contrast with Holm-Bonferroni correction showed that there was no significant difference between women's and men's sAA activity level for any time point (*corrected p*= 0.88 - 0.95 - see figure 9 and supplementary table S13), but there was a significant effect of time for both women (χ^2= 167.58, *p*<0.001) and men (χ^2= 33.26, *p*<0.001). For women, the sAA activity level was lower at S1 than at S2 (*corrected p* <0.001), lower at S2 than at S3 (*corrected p* <0.001), higher at S3 than at S4 (corrected *p*<0.001), higher at S4 than at S5 (*p* <0.001), and lower at S5 than at S6 (*corrected p* <0.001). The sAA activity level was also lower at S1 than at S3 (*corrected p* <0.001), and higher at S3 than at S6 (*corrected p* <0.001), but there was no significant different in the sAA activity level between S1 and S6 (*corrected p*= 0.90). For men, the sAA activity level was higher at S3 than at S4 (*corrected p* <0.001). There was no significant difference between the other time points (*corrected p*= 0.098 – 1.82).

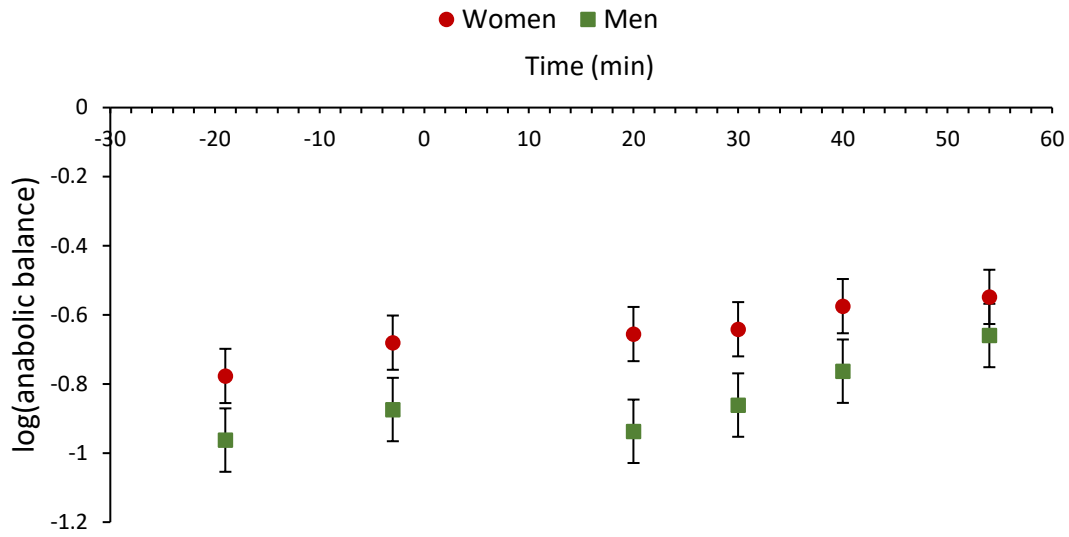

Figure 8. Model-predicted marginal means for log(anabolic balance) along the time for women and men – The reference point (0) for calculating the time is the beginning of the performance. Bars represent standard errors means.

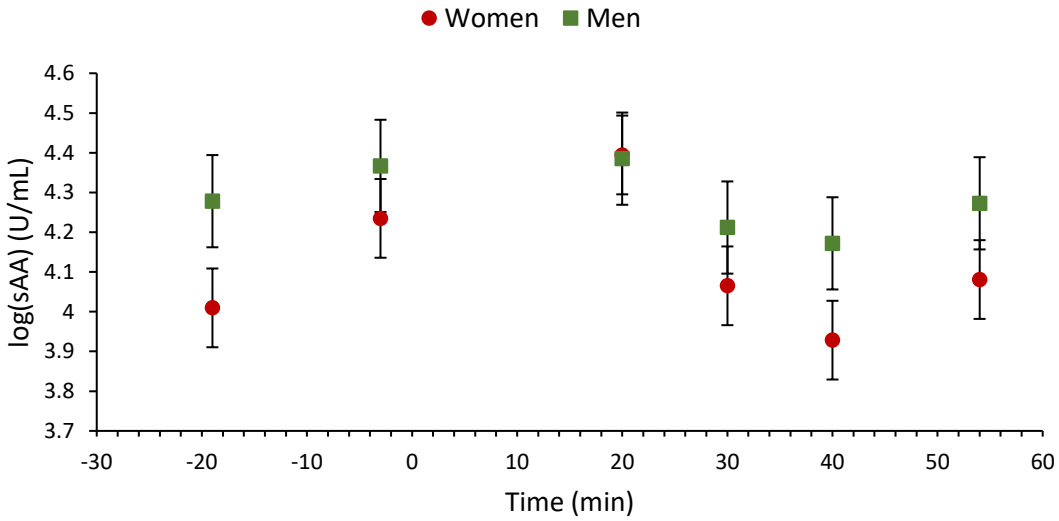

Figure 9. Model-predicted marginal means for log(sAA) along the time for women and men – The reference point (0) for calculating the time is the beginning of the performance. Bars represent SEs.

We also found a significant interaction between time difference and order for sDHEA (see supplementary figure S5). There was no significant effect of time difference either in order 1 (Coefficient = -0.00, SD= 0.01, *p*=0.96) or in order 2 (coefficient = - 0.02, SD= 0.02, *p*= 0.12). The sDHEA level was significantly higher when music students started with the private performance session than when they started with the public performance session but only when there were more than 203 days in between the habituation session and the first performance session.

4.3.4. Main analyses without outliers

The main analyses were based on 1448 observations for sC, 1442 observations for sDHEA, 1440 observations for anabolic balance, and 1449 observations for sAA. In model 1, we dropped 28 observations for sAA, 8 observations for sC, 20 observations for sDHEA, and 16 observations for anabolic balance. In model 2, we dropped 20 observations for sAA, 6 observations for sC, 19 observations for sDHEA, and 16 for anabolic balance.

Without the outliers, the results did not significantly change from the original analyses except for sAA, for which the interaction between time and hour became significant (χ^2= 13.35, *p*= 0.020).

4.3.5. Discussion

The purpose of this research question was to investigate how general MPA, audience presence, and time may influence the HPA axis activity (using sC, sDHEA, and anabolic balance as indexes) and SAM system activity (using sAA as an index).

Based on the literature, sC, sDHEA, and sAA secretions should be dependent on the circadian cycle (Hucklebridge et al., 2005; Ahn et al., 2007; Nicolson, 2008), so we first hypothesized that the sC and sDHEA level would be higher at the beginning of the music performance sessions (S1) than at the end of the music performance sessions (S6), whereas the sAA level would be lower at the beginning of the music performance sessions (S1) than at the end of the music performance sessions (S6 - **Hypothesis 1.1**). As expected, our results showed that the sC and sDHEA levels were higher at the beginning than at the end of the music performance sessions, whereas the sAA activity was not significantly different at the beginning and at the end of the music performance sessions. Contrary to what has been observed in the literature (Nater et al., 2007), our results do not allow us to observe an influence of the circadian cycle on the sAA activity level. This lack of effect of the circadian cycle can be explained by the difference in time between the salivary samples. In their study, Nater et al (2007) observed that diurnal changes in sAA activity would be subtle and only visible over long periods of time with salivary samples spaced approximately one hour apart. In our study, music performance sessions lasted no longer than 2h. It is therefore possible that this is not a long enough time to be able to observe variations in sAA activity related to the circadian cycle. While the sC level, and sDHEA level seem to be influenced by the circadian cycle, only the sC level was significantly different depending on the scheduled hour of the experiment. Our results revealed that music students who performed during the early afternoon had a higher sC level than the music students who performed during the late afternoon. We speculate that this difference could be related to the speed at which sC decreases during the day compared to the speed at which sDHEA level decreases, respectively. It is possible that the sC level decreases more rapidly and creates a bigger gap difference between music students who performed during the early afternoon and music students who performed during the late afternoon. This interpretation may also explain why we found that the anabolic balance level was lower at the music performance session beginning than at the end. If the sC level decreases faster than the sDHEA level over the course of the day, then it may be legitimate that the ratio sDHEA on sC increases over a certain time. Nevertheless, it would be necessary to test this hypothesis over a longer period and on a larger sample.

In our second hypothesis, we postulated that the sC and sDHEA level, as well as the sAA activity would be higher during the public performance session than the private

performance session (**Hypothesis 1.2**). This hypothesis was supported for sC and sDHEA. As observed in previous studies on music performance (e.g., Pilger et al., 2014; Fancourt, Aufegger, & Williamon, 2015; Aufegger & Wasley, 2018), when the audience was present during the music performance, music students had a higher sC level, and in agreement with studies on psychosocial stressors (Dutheil et al., 2021), the sDHEA level was higher when the audience was present than when it was absent. These results are in line with the social self-preservation theory (Dickerson & Kemeny, 2004), which postulates that in unpredictable and/or uncontrollable situations threatening the social self, there should be an increase in the HPA axis activity compared to a non-threatening situation. As previously observed (e.g., Fancourt, Aufegger, & Williamon, 2015; Aufegger & Wasley, 2018; Guyon et al., 2020a), the audience presence seems to act as a psychosocial stressor that generates a physiological stress response in music students.

In contrast, we observed that the sAA activity was not significantly different between the private performance session and the public performance session. To understand these results, we consider previous studies conducted in the sport context showing that not only the sAA level may increase when facing a psychosocial stressor (e.g., Nater et al., 2007; Filaire et al., 2010; Thoma et al., 2012) but also during intense exercise such as cycling (Bishop et al., 2009; Wunsch et al., 2019). In addition to being a source of stress, the music performances are complex activity requiring significant sensorimotor control, it is therefore possible that the sAA reactivity was due to the physical effort required by the music performance and not to the audience presence. In 2014, Studer et al. showed that the physical activation increased significantly during a music performance compared to before and after and there was no significant difference between the private and the public session. This latter possibility is reinforced by our results which reported a higher sAA activity after the end of the music performance than at the beginning or end of the music performance session (also contradicting part of **Hypothesis 1.3**). Until now, only two studies investigated sAA activity during a music performance, and their results are contradictory (Aufegger & Wasley, 2018; Tùran et al., 2022). Yet in these studies, one to three weeks could pass between the first and the second performance, whereas in our study, the two music performances were separated by 48h. Some studies showed that moderate to intense physical activity before the exposure to a psychosocial stressor may have an impact on sAA activity (Wunsch et al., 2019). It is therefore possible that the difference in results obtained between the previous studies (Aufegger & Wasley, 2018; Tùran et al., 2022) and our study is related to the time between the two types of music performance. Nevertheless, further investigation needs to be done to test this hypothesis.

Interestingly, our results showed that the sC level was significantly lower when music students performed first in public and second in private than when they performed first in private and second in public. Previous studies on intense physical activity also highlighted that moderate to intense physical activity before being exposed to a psychosocial stressor provoked a decrease in sC response to the psychosocial stressors (Klaperski et al., 2014; Wunsch et al., 2019; Caplin et al., 2021). Based on this literature, we may speculate that performing a second performance in private after being exposed to an audience for the first performance session decrease the sC response because of the physical effort associated with it. We also might argue that the difference in the number of uncontrollable parameters in the private performance situation that might trigger a stressful response (Dickerson & Kemeny, 2004) after having already played in public is perhaps more important than when performing music in the opposite order.

In line with the previous hypothesis (hypothesis 1.2), we assumed that the sC, sDHEA, and anabolic balance level, as well as the sAA activity would be higher after the public music performance (S3) than before the public music performance (S1), but no difference would be found for the private performance session (**Hypothesis 1.3**). Our results did support the hypothesis for sC and sDHEA level, but not for sAA activity level. Our results showed that only during the public performance session, the sC and sDHEA level was significantly higher after the music performance than at the beginning or the end of the public performance session, whereas this increase was present in both performance sessions (private and public) for the sAA activity. As observed in previous studies on music performance (Schladt et al., 2017; Aufegger & Wasley, 2018; Everared et al., 2020), the sC level increased after being exposed to a psychosocial stressor. Our study was also the first to demonstrate that the sDHEA level increases in response to a public music performance. Taken together, these results indicate that audience presence modulates the HPA axis response, and this response is not due to physical activity. In contrast, the sAA activity changes appeared to be related to the physical activity of the performance and not to the presence of the audience.

As supported by our results, when music students were exposed to a public music performance, the normal circadian sC pattern was disrupted. This increase was justified as a way to help music students coping with the stressful situation by providing them more energy (Dickerson & Kemeny, 2004; Nicolson, 2008). On the other side, it had been argued that the sDHEA normal circadian pattern was also disrupted after a psychosocially stressful situation in order to counterbalance the potential negative effect that can happen if the sC level is high for a long period of time (Epel, McEwen, & Ickovics, 1998). Our results showed that sDHEA and sC had a similar temporal pattern across the public music performance session. We also observed that the anabolic balance was also decreasing after the public music performance, however, the anabolic balance level was higher at the end of the public music performance session than at the beginning of the public performance session. We may therefore infer that the increase in sDHEA level did counterbalance the increase in sC. Nevertheless, previous studies showed that sDHEA was secreted at the beginning of the psychosocial stressor exposure (Izawa et al., 2008, Dutheil et al., 2021), whereas the sC level only started to increase 15 to 30min after the psychosocial stressor (Ramsay & Lewis, 2003; Mulder, 2011). Furthermore, research on music performance showed that the peak cortisol elevation was reached 10 to 20 min after the music performance start (Aufegger & Wasley, 2018; Boyle et al., 2013). In a future study, it might be interesting to investigate more precisely this temporal difference and especially when this peak level of concentration occurs in sC and sDHEA.

In addition, we hypothesized that during the public performance session, music students with higher general MPA level would have a higher sC, sDHEA, and anabolic balance level, as well as higher sAA activity than music students with lower general MPA level (**Hypothesis 1.4**). We also expected that after the music performance session, music students with higher general MPA level would have a higher sC, sDHEA, and anabolic balance, as well as higher sAA activity than music students with lower general MPA level (**Hypothesis 1.5**). None of these two hypotheses were supported by our results. Contrary to what previous studies may have suggested (Fredrikson & Gunnarsson, 1992; Shirotsuki et al., 2009; Gomez et al., 2018), the general MPA level does not appear to influence the level of sC, sDHEA, anabolic balance, or sAA activity whether it is before or after the music performance or whether it is during a private or public performance. To date, the number of studies investigating the psychophysiological effects of general MPA level remains limited. However, most of them seem to show that the level of general MPA has more effects on psychological

components than on physiological ones (e.g., more anxiety, more discomfort, more tension, or body complaints - Craske & Craig, 1984; Fredrikson & Gunnarsson, 1992; Studer et al., 2012; 2014). Nevertheless, Gomez et al. (2018) found that the sAA recovery after a public performance could take longer time in music students with moderate to high general MPA level and that a higher general MPA level was related to a smaller amount sC over one week. It is therefore possible that the general MPA level effect during public performance was not visible during the music performance session but had an impact on the longer term.

Finally, we observed that woman music students had lower sC level than man music students. In addition, we found that the level of sC and anabolic balance, as well as the sAA activity was significantly different depending on the gender and the time. Although Tùran et al. (2022) also found a similar main gender effect, it is difficult to explain these results. To date, the effects of gender on sC and sAA during exposure to a psychosocial stressor are very divergent. On the one hand, some studies postulate the existence of a difference while others consider that there is none (for review see Liu et al., 2017; Espin et al., 2019). Although these discrepancies can be largely explained by differences in methodology (e.g., psychosocial task differences), it is also possible that these discrepancies are related to the phase of the women's menstrual cycle. In this study, we asked the women to tell us the length of their cycle and the date of their last menstrual period so that they would all perform the experiment at the same phase of their cycle. Nevertheless, each woman has a different menstrual cycle that varies constantly. It is therefore possible that this variation in response between men and women is related to hormonal differences.

Based on our results, we can conclude that the general MPA level does not influence the response of the HPA axis and the SAM system of music students. The realization of a music performance disturbs the circadian rhythm of the SAM system, but only the presence of an audience during the music performance modulates the response of the HPA axis.

4.4. Research question 2

4.4.1. Descriptive statistics

Descriptive statistics for the predictors are given in table 1. For the nine flow dimensions, please see table 14.

4.4.2. Results

4.4.2.1. Preliminary analyses

The correlations between general MPA level, depressive symptoms, time difference, and each nine flow dimensions for the private and public performance sessions are given in the supplementary tables S14 and S15.

4.4.2.2. Main analyses

The estimated models for the nine flow dimensions with all observations are reported in tables 15–17. The models without the outliers are given in the supplementary tables S16–S18.

Table 14 - Descriptive statistics for the nine flow dimensions variables

	Private session					Public session				
Flow state dimensions	***M***	***SD***	**Min-max**	**Skewness**	**Kurtosis**	***M***	***SD***	**Min-max**	**Skewness**	**Kurtosis**
Challenge-skill balance	3.75	0.75	1.5 - 5	-0.6	3.3	3.73	0.75	1.5 - 5	-0.5	3.3
Unambiguous feedback	3.89	0.58	2.25 - 5	-0.5	3.1	3.78	0.67	1.75 - 5	-0.3	3.3
Clear goals	3.64	0.79	1.75 - 5	-0.4	2.6	3.62	0.80	1.5 - 5	-0.3	2.8
Action-awareness merging	3.51	0.67	1.75 - 5	-0.5	2.9	3.44	0.72	1.25 - 5	-0.3	2.8
Concentration on task at hand	3.33	1.08	1 - 5	-0.3	2.1	3.52	1.00	1 - 5	-0.3	2.1
Sense of control	3.31	0.85	1.25 - 5	-0.4	2.5	3.10	0.92	1 - 5	-0.0	2.5
Loss of self-consciousness	3.96	1.08	1 - 5	-1.0	3.1	3.12	1.12	1 - 5	0.1	1.9
Transformation of time	2.84	1.05	1 - 5	0.1	2.4	3.25	1.05	1 - 5	-0.5	2.6
Autotelic experience	3.48	0.94	1.5 - 5	-0.3	2.1	3.47	0.96	1 - 5	-0.3	2.5

Table 15 - Estimated linear mixed models for the dimensions challenge-skill balance, unambiguous feedback, and clear goals

	Challenge-skill balance						**Unambiguous feedback**						**Clear goals**					
	Model 1			*Model 2*			*Model 1*			*Model 2*			*Model 1*			*Model 2*		
	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*
Main effects																		
General MPA level	-0.01	0.01	0.16	-0.00	0.01	0.77	**-0.01**	**0.00**	**0.009**	-0.00	0.01	0.58	-0.01	0.01	0.14	-0.01	0.01	0.29
Session	-0.04	0.06	0.50	0.03	0.13	0.82	**-0.12**	**0.06**	**0.034**	-0.02	0.11	0.87	-0.04	0.07	0.62	0.26	0.15	0.083
Order	-0.04	0.12	0.74	0.11	0.19	0.58	-0.11	0.10	0.24	0.13	0.16	0.42	-0.15	0.12	0.21	0.44	0.20	0.026
Preparation	**0.10**	**0.03**	**0.002**	0.08	0.05	0.092	0.05	0.03	0.077	-0.00	0.05	0.99	**0.09**	**0.04**	**0.020**	-0.04	0.06	0.49
Gender	0.20	0.13	0.12	0.37	0.20	0.070	0.01	0.10	0.89	0.10	0.16	0.55	**0.30**	**0.13**	**0.023**	0.58	0.20	0.005
Depressive symptoms	**-0.02**	**0.01**	**0.046**	-0.01	0.01	0.25	-0.01	0.01	0.20	-0.01	0.01	0.28	-0.00	0.01	0.77	0.01	0.01	0.48
Time difference	0.01	0.01	0.39	0.01	0.01	0.43	0.01	0.01	0.46	-0.00	0.01	0.82	-0.01	0.01	0.62	-0.01	0.01	0.57
Interactions																		
General MPA level x order				-0.01	0.01	0.63				-0.00	0.01	0.72				-0.00	0.01	0.82
General MPA level x session				-0.00	0.01	0.62				**-0.01**	**0.01**	**0.025**				0.01	0.01	0.40
Order x session				-0.09	0.19	0.65				-0.27	0.17	0.11				**-0.64**	**0.22**	**0.004**
Gender x order				-0.24	0.27	0.37				-0.23	0.21	0.26				**-0.66**	**0.26**	**0.013**
Gender x session				-0.06	0.13	0.68				0.10	0.12	0.43				0.11	0.16	0.50
Depressive symptoms x order				-0.01	0.02	0.55				-0.00	0.01	0.99				-0.01	0.02	0.48
Depressive symptoms x session				0.01	0.01	0.48				0.00	0.01	0.52				-0.01	0.01	0.46
Time difference x order				0.01	0.02	0.78				0.01	0.02	0.65				-0.02	0.02	0.28
Time difference x session				-0.01	0.01	0.52				0.01	0.01	0.26				0.02	0.01	0.15

Note of table 15 - Model 1 tested the main effect of our factors and Model 2 tested the interactions of our factors. Significant main effects in Model 1 and significant interactions in Model 2 are written in bold. Reference categories for categorical predictors were as follows: session: private performance session; order: private performance session first – public performance session second; gender: women. For continuous predictors, coefficients express the change in the outcome measure per unit (unit for Preparation is hour and unit for Time difference is day).

Table 16 - Estimated linear mixed models for the dimensions action-awareness merging, concentration on task at hand, and sense of control

	Action-awareness merging						**Concentration on task at hand**						**Sense of control**					
	Model 1			*Model 2*			*Model 1*			*Model 2*			*Model 1*			*Model 2*		
	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*
Main effects																		
General MPA level	-0.01	0.01	0.07	-0.01	0.01	0.098	**-0.02**	**0.01**	**0.008**	-0.01	0.01	0.26	**-0.02**	**0.01**	**0.001**	-0.02	0.01	0.019
Session	-0.08	0.07	0.25	-0.12	0.14	0.39	0.17	0.11	0.099	0.18	0.22	0.41	**-0.20**	**0.09**	**0.032**	-0.12	0.19	0.53
Order	0.08	0.11	0.44	0.15	0.18	0.39	-0.08	0.15	0.61	0.04	0.26	0.89	0.21	0.12	0.078	0.51	0.21	0.014
Preparation	0.01	0.04	0.79	-0.00	0.06	0.99	**0.13**	**0.06**	**0.017**	0.15	0.09	0.077	**0.16**	**0.05**	**0.001**	0.13	0.07	0.090
Gender	0.11	0.11	0.36	0.07	0.18	0.71	0.08	0.16	0.62	0.31	0.26	0.23	**0.27**	**0.13**	**0.032**	0.50	0.20	0.015
Depressive symptoms	-0.00	0.01	0.57	-0.01	0.01	0.44	**-0.02**	**0.01**	**0.042**	-0.03	0.02	0.04	-0.01	0.01	0.21	-0.01	0.01	0.65
Time difference	-0.00	0.01	0.96	0.00	0.01	0.68	**0.03**	**0.01**	**0.026**	0.03	0.02	0.10	0.01	0.01	0.19	0.00	0.01	0.75
Interactions																		
General MPA level x order				0.01	0.01	0.45				0.00	0.02	0.98				0.02	0.01	0.12
General MPA level x session				-0.00	0.01	0.78				-0.01	0.01	0.27				-0.01	0.01	0.15
Order x session				-0.04	0.21	0.86				0.07	0.32	0.84				-0.20	0.28	0.47
Gender x order				-0.14	0.23	0.55				-0.34	0.33	0.30				-0.47	0.25	0.059
Gender x session				0.14	0.15	0.33				-0.09	0.23	0.69				0.06	0.20	0.74
Depressive symptoms x order				0.01	0.01	0.55				-0.00	0.02	0.94				-0.01	0.02	0.68
Depressive symptoms x session				0.00	0.01	0.78				0.02	0.01	0.095				-0.01	0.01	0.60
Time difference x order				-0.03	0.02	0.071				0.01	0.03	0.68				0.02	0.02	0.26
Time difference x session				0.01	0.01	0.52				-0.01	0.02	0.53				-0.00	0.01	0.84

Note of table 16 - Model 1 tested the main effect of our factors and Model 2 tested the interactions of our factors. Significant main effects in Model 1 and significant interactions in Model 2 are written in bold. Reference categories for categorical predictors were as follows: session: private performance session; order: private performance session first – public performance session second; gender: women. For continuous predictors, coefficients express the change in the outcome measure per unit (unit for Preparation is hour and unit for Time difference is day).

Table 17 - Estimated linear mixed models for the dimensions loss of self-consciousness, transformation of time, and autotelic experience

	Loss of self-consciousness						**Transformation of time**						**Autotelic experience**					
	Model 1			*Model 2*			*Model 1*			*Model 2*			*Model 1*			*Model 2*		
	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*
Main effects																		
General MPA level	**-0.02**	**0.01**	**0.032**	0.00	0.01	0.88	0.01	0.01	0.16	-0.01	0.01	0.63	**-0.01**	**0.01**	**0.034**	-0.01	0.01	0.47
Session	**-0.90**	**0.12**	**<0.001**	-0.65	0.22	0.003	**0.47**	**0.11**	**<0.001**	-0.29	0.21	0.17	-0.03	0.09	0.75	0.32	0.19	0.084
Order	**0.41**	**0.16**	**0.013**	0.96	0.28	<0.001	-0.03	0.17	0.88	-1.01	0.28	<0.001	0.00	0.14	0.99	0.36	0.24	0.14
Preparation	0.06	0.06	0.32	-0.08	0.09	0.37	**-0.17**	**0.06**	**0.003**	0.11	0.08	0.19	0.06	0.05	0.19	-0.04	0.07	0.56
Gender	0.29	0.18	0.096	0.35	0.28	0.21	0.21	0.19	0.26	-0.11	0.29	0.71	0.23	0.15	0.14	0.41	0.25	0.096
Depressive symptoms	**-0.03**	**0.01**	**0.021**	-0.02	0.02	0.27	-0.00	0.01	0.68	-0.02	0.02	0.35	-0.01	0.01	0.13	-0.01	0.01	0.58
Time difference	0.02	0.01	0.20	0.02	0.02	0.20	0.01	0.01	0.32	-0.01	0.02	0.79	0.01	0.01	0.54	0.00	0.02	0.94
Interactions																		
General MPA level x order				-0.01	0.02	0.72				0.03	0.02	0.14				0.00	0.01	0.89
General MPA level x session				**-0.03**	**0.01**	**0.002**				0.01	0.01	0.52				-0.01	0.01	0.17
Order x session				**-0.76**	**0.33**	**0.019**				**1.44**	**0.31**	**<0.001**				**-0.55**	**0.28**	**0.045**
Gender x order				-0.40	0.36	0.27				0.61	0.38	0.10				-0.18	0.31	0.57
Gender x session				0.36	0.23	0.13				-0.02	0.22	0.93				-0.14	0.20	0.49
Depressive symptoms x order				0.00	0.02	0.84				0.02	0.02	0.44				-0.02	0.02	0.31
Depressive symptoms x session				-0.02	0.01	0.18				-0.00	0.01	0.91				0.01	0.01	0.68
Time difference x order				0.03	0.03	0.24				0.02	0.03	0.53				0.01	0.03	0.62
Time difference x session				**-0.04**	**0.02**	**0.036**				0.02	0.02	0.15				0.01	0.01	0.70

Note of table 17 - Model 1 tested the main effect of our factors and Model 2 tested the interactions of our factors. Significant main effects in Model 1 and significant interactions in Model 2 are written in bold. Reference categories for categorical predictors were as follows: session: private performance session; order: private performance session first – public performance session second; gender: women. For continuous predictors, coefficients express the change in the outcome measure per unit (unit for Preparation is hour and unit for Time difference is day).

4.4.2.2.1. Effects of general MPA level, session, and their interaction

In model 1, a significant general MPA level effect was present for unambiguous feedback, concentration on task at hand, sense of control, loss of self-consciousness, and autotelic experience (see figures 10 to 13). With increasing general MPA level, the level of these five dimensions decreased significantly. There was a significant main effect of session for unambiguous feedback, sense of control, and loss of self-consciousness (see figures 10 to 13). The level of these three dimensions was significantly higher during the private performance session than the public performance session.

In model 2, a significant interaction between the general MPA level and session was observed for unambiguous feedback and loss of self-consciousness (see figures 12 and 13). Post-hoc contrast analyses showed that the level of unambiguous feedback was higher for the private performance session than for the public performance session for general MPA levels higher than 47 (*p*s= 0.002–0.049). The effect of the general MPA level was not significant for the private performance session (coefficient= −0.01, *SE*= 0.01, *p*= 0.31) and significant for the public performance session (coefficient= −0.02, *SE*= 0.01, *p*= 0.001). The level of loss of self-consciousness was significantly higher for the private performance session than for the public performance session for general MPA levels higher than 32 (*p*s= <0.001–0.050). The effect of the general MPA level was not significant for the private performance session (coefficient= −0.00, *SE*= 0.01, *p*= 0.89) and significant for the public performance session (coefficient= −0.03, *SE*= 0.01, *p* <0.001).

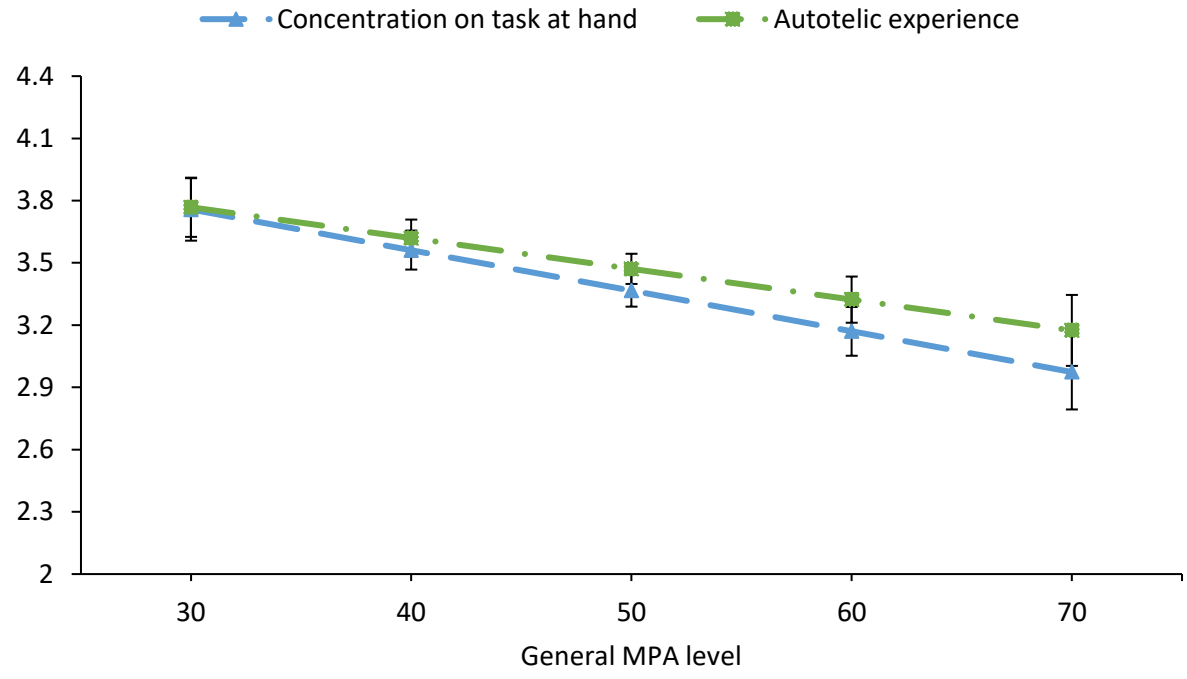

Figure 10. Model-predicted marginal means along the general MPA level for concentration on task at hand and autotelic experience

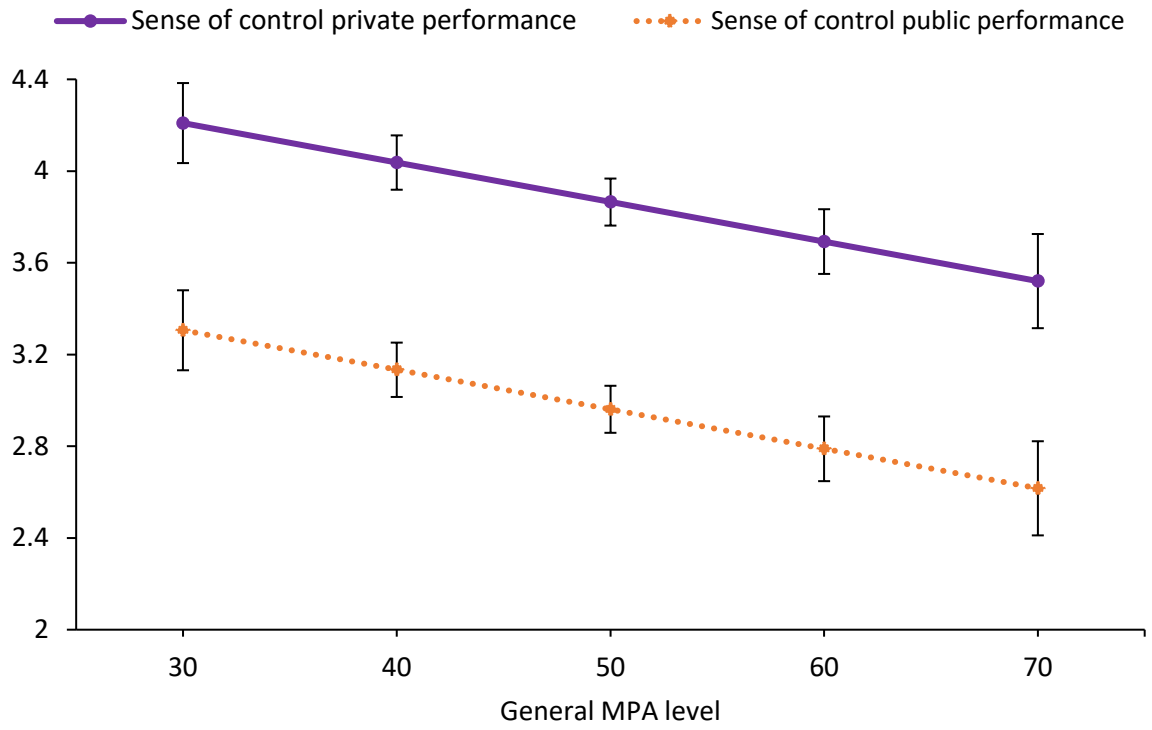

Figure 11. Model-predicted marginal means along the general MPA level for sense of control for the private and for the public performance sessions

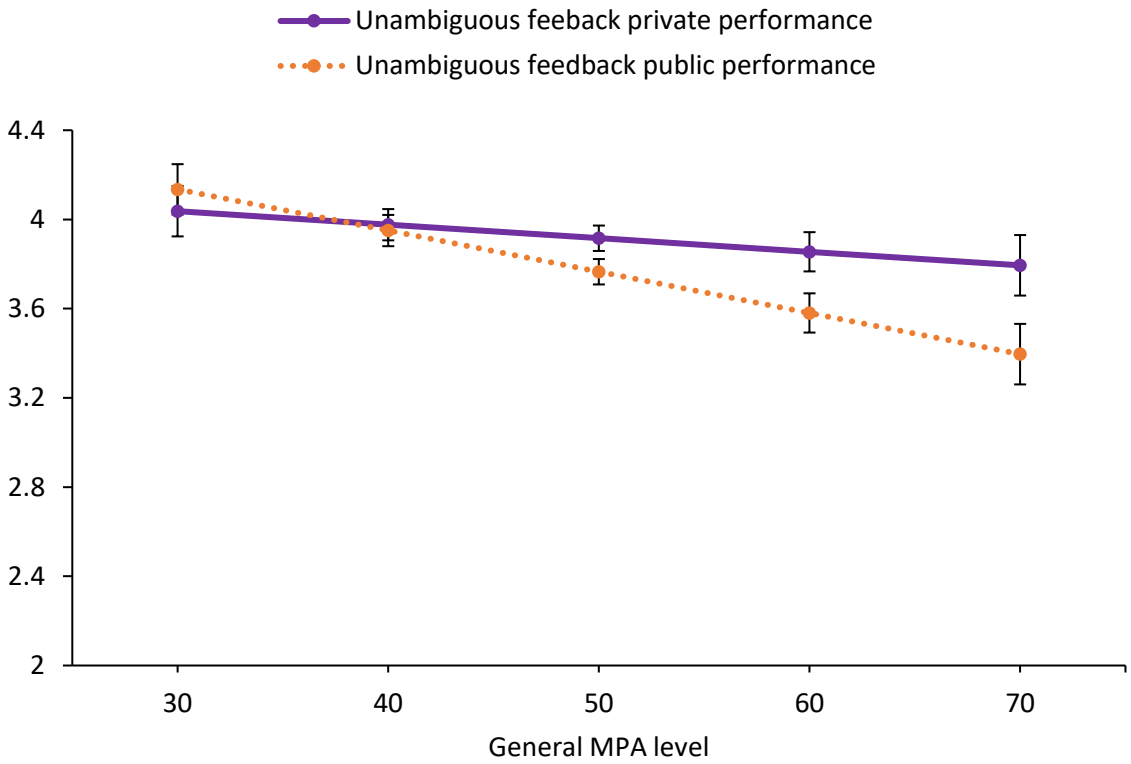

Figure 12. Model-predicted marginal means along the general MPA level for unambiguous feedback for the private and for the public performance sessions

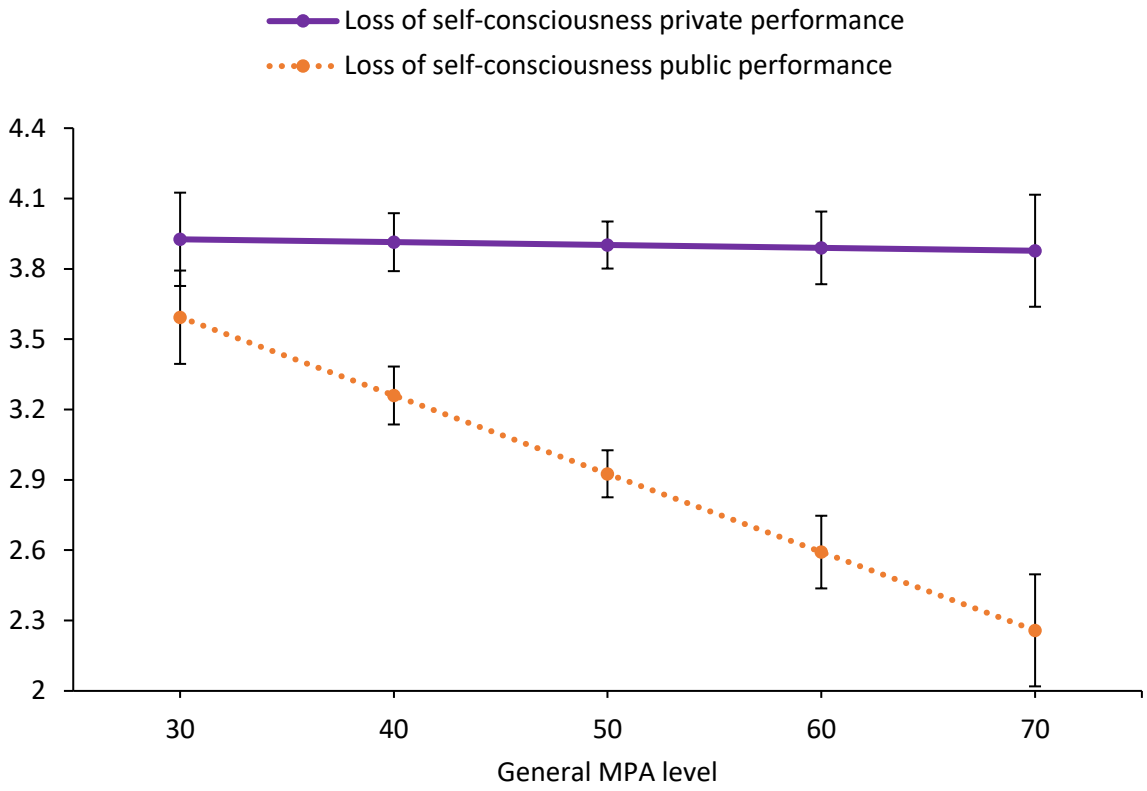

Figure 13. Model-predicted marginal means along the general MPA level for loss of self-consciousness for the private and for the public performance sessions

4.4.2.2.2. Effects of the control variables

Participants with order 1 (private–public) had a significantly higher level of loss of self-consciousness than participants with order 2 (public–private). The levels of challenge-skill balance, clear goals, concentration on task at hand and sense of control increased significantly with an increase in the amount of preparation, whereas the level of transformation of time decreased significantly with an increase in the amount of preparation. Women reported significantly lower levels of clear goals and sense of control than men. The lower the level of depressive symptoms was, the higher the levels of challenge-skill balance, concentration on task at hand and loss of self-consciousness. The higher the amount of time between the habituation session and the first performance session was, the higher the level of concentration on task at hand.

A significant interaction order × session was found for clear goals, loss of self-consciousness, transformation of time and autotelic experience (see figures 14 to 17). To understand these interactions, we tested the session effect for each order separately and the order effect for each session separately. Moreover, we tested whether the levels of these four dimensions during the first performance and the second performance differed significantly from each other. The level of clear goals was higher for the public performance session than the private performance session in order 1 (coefficient =0.30, *SE*= 0.14, *p*= 0.028), whereas the level of clear goals was lower for the public performance than the private performance in order 2 (coefficient= −0.34, *SE*= 0.13, *p*= 0.007). The level of clear goals during the public performance was lower in order 2 than in order 1 (coefficient= −0.48, *SE*= 0.16, *p*= 0.003), but

the order effect was not significant for the private performance (coefficient= 0.16, *SE*= 0.16, *p*= 0.33). The level of clear goals was significantly lower during the first performance session than the second performance session (coefficient= −0.32, *SE*= 0.11, *p*= 0.004). The level of loss of self-consciousness was lower for the public performance session than the private performance session in order 1 (coefficient= −0.50, *SE*= 0.20, *p*= 0.014) and in order 2 (coefficient= −1.26, *SE*= 0.19, *p* <0.001).

The level of "loss of self-consciousness" was higher during the private performance in order 2 than during the private performance in order 1 (coefficient= 0.79, *SE*= 0.23, *p*= 0.001), but the order effect was not significant for the public performance (coefficient= 0.03, *SE*= 0.23, *p*= 0.90). The level of "loss of self-consciousness" was significantly lower during the first performance session than during the second performance session (coefficient= −0.38, *SE*= 0.16, *p*= 0.019). The level of "transformation of time" was higher for the public performance session than for the private performance session in order 2 (coefficient= 1.14, *SE*= 0.18, *p* <0.001). No significant difference was found between the two performance sessions in order 1 (coefficient= −0.30, *SE* = 0.19, *p* = 0.12). The level of "transformation of time" during the private performance session was lower in order 2 than in order 1 (coefficient= −0.74, *SE*= 0.23, *p*= 0.001), whereas the level of "transformation of time" during the public performance session was higher in order 2 than in order 1 (coefficient= 0.70, *SE*= 0.23, *p*= 0.003). The level of "transformation of time" was significantly higher during the first performance session than the second performance session (coefficient= 0.72, *SE*= 0.15, *p*< 0.001). For both orders, the levels of "autotelic experience" for the private and public performance sessions did not significantly differ from each other (coefficient= 0.26, *SE*= 0.17, *p*= 0.13 for order 1 and coefficient= −0.29, *SE*= 0.15, *p*= 0.068 for order 2). For both performance sessions, the order effect was not significant (coefficient= 0.28, *SE*= 0.20, *p*= 0.16 for the private performance session; coefficient= −0.27, *SE*= 0.20, *p*= 0.17 for the public performance session). The level of "autotelic experience" was significantly higher during the second performance session than the first performance session (coefficient= 0.28, *SE*= 0.14, *p*= 0.045).

For "clear goals," the interaction gender × order was significant. Men had a higher level of "clear goals" than women in order 1 (coefficient= 0.63, *SE*= 0.19, *p*= 0.001), whereas the gender difference was not significant in order 2 (coefficient= −0.03, *SE*= 0.18, *p*= 0.89). Men in order 2 had a significantly lower level of "clear goals" than men in order 1 (coefficient= −0.54, *SE*= 0.20, *p*= 0.006). In contrast, women in order 1 and women in order 2 did not significantly differ in their levels of "clear goals" (coefficient= 0.12, *SE*= 0.17, *p*= 0.46).

The interaction time difference × session was significant for "loss of self-consciousness". The effect of time difference was significant for the private performance session (coefficient= 0.03, *SE*= 0.02, *p*= 0.034) and non-significant for the public performance session (coefficient= −0.00, *SE*= 0.01, *p*= 0.97). The level of "loss of self-consciousness" during the public performance session was significantly higher than during the private performance session for all time differences (*p*s <0.001).

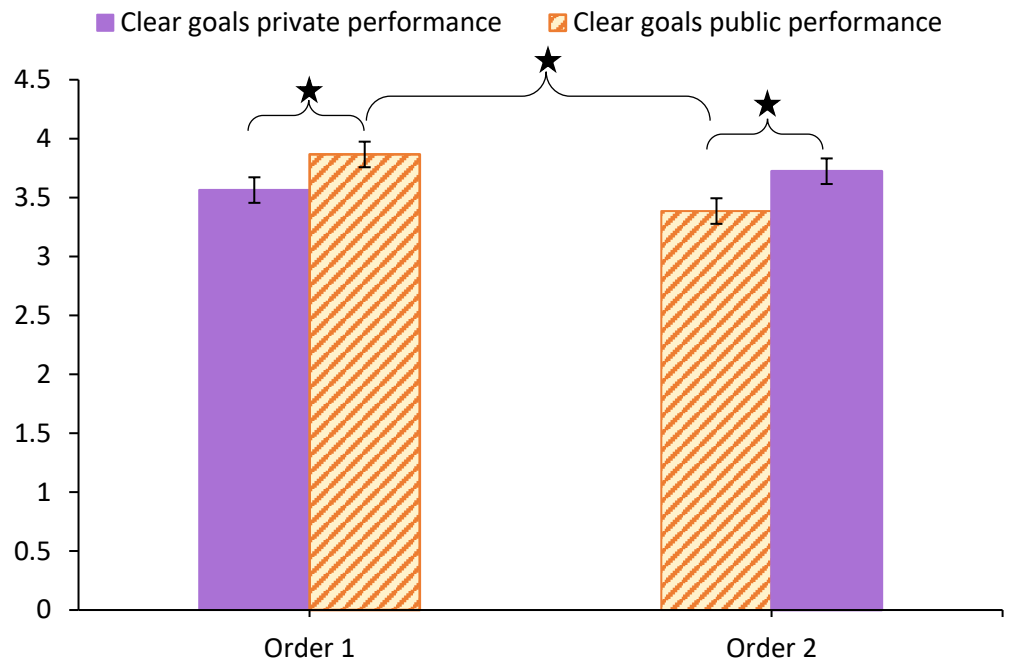

Figure 14. Model-predicted marginal means for order 1 (private session performed first then public session) and order 2 (public session performed first then private session) for clear goals.

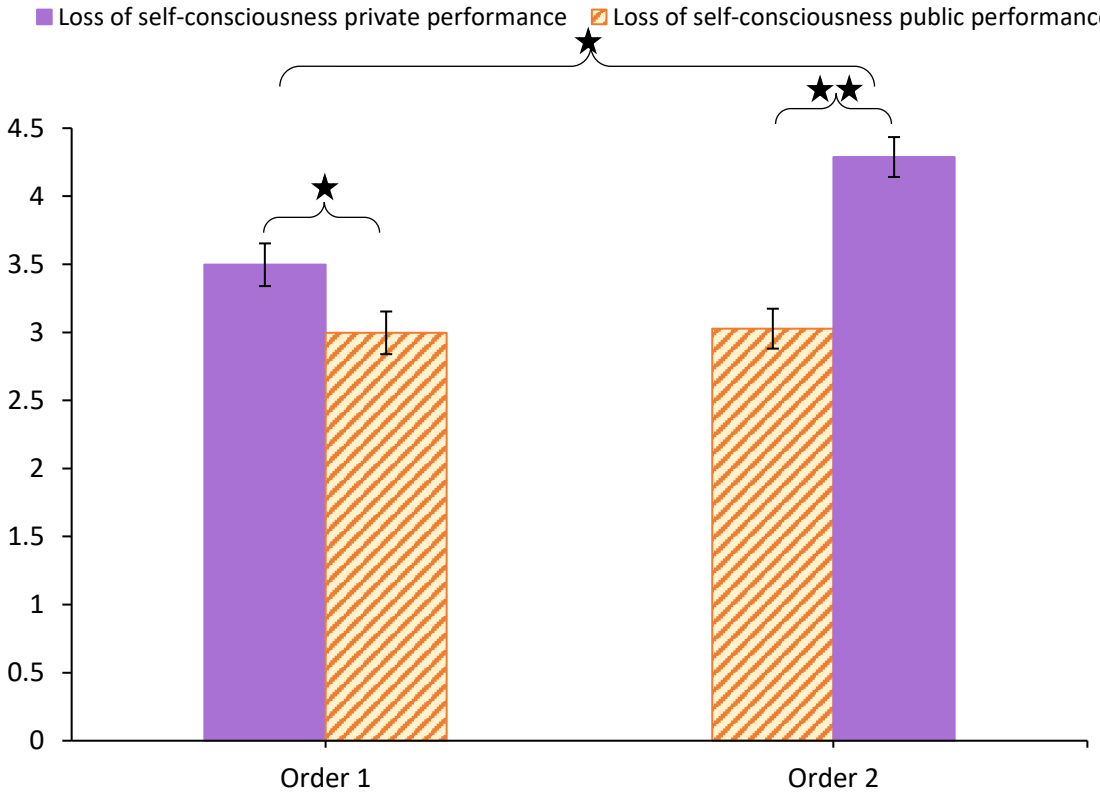

Figure 15. Model-predicted marginal means for order 1 (private session performed first then public session) and order 2 (public session performed first then private session) for loss of self-consciousness

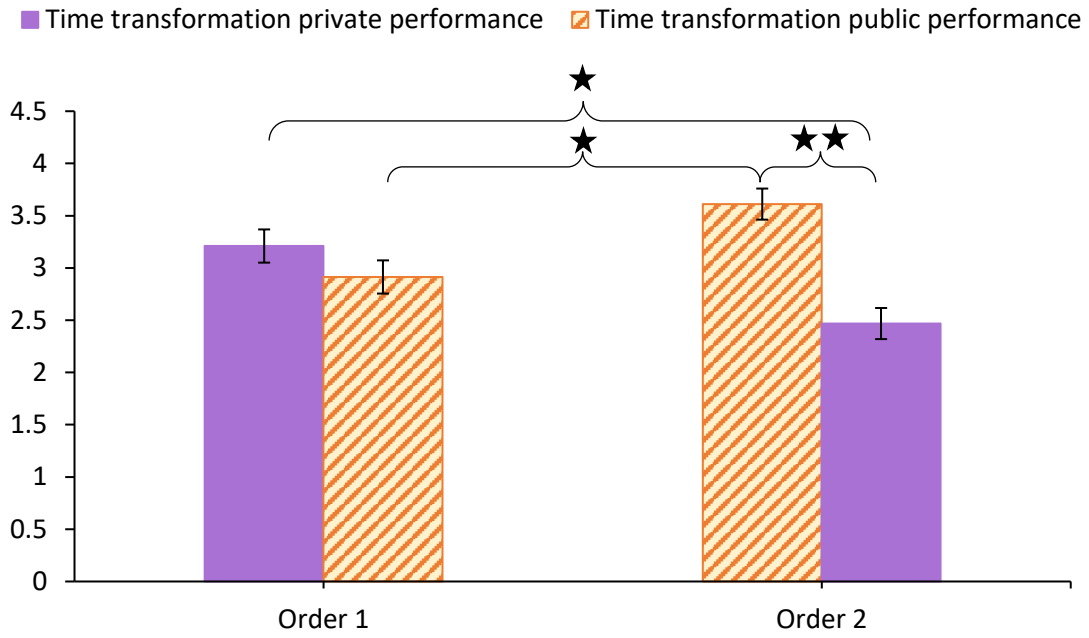

Figure 16. Model-predicted marginal means for order 1 (private session performed first then public session) and order 2 (public session performed first then private session) for transformation of time

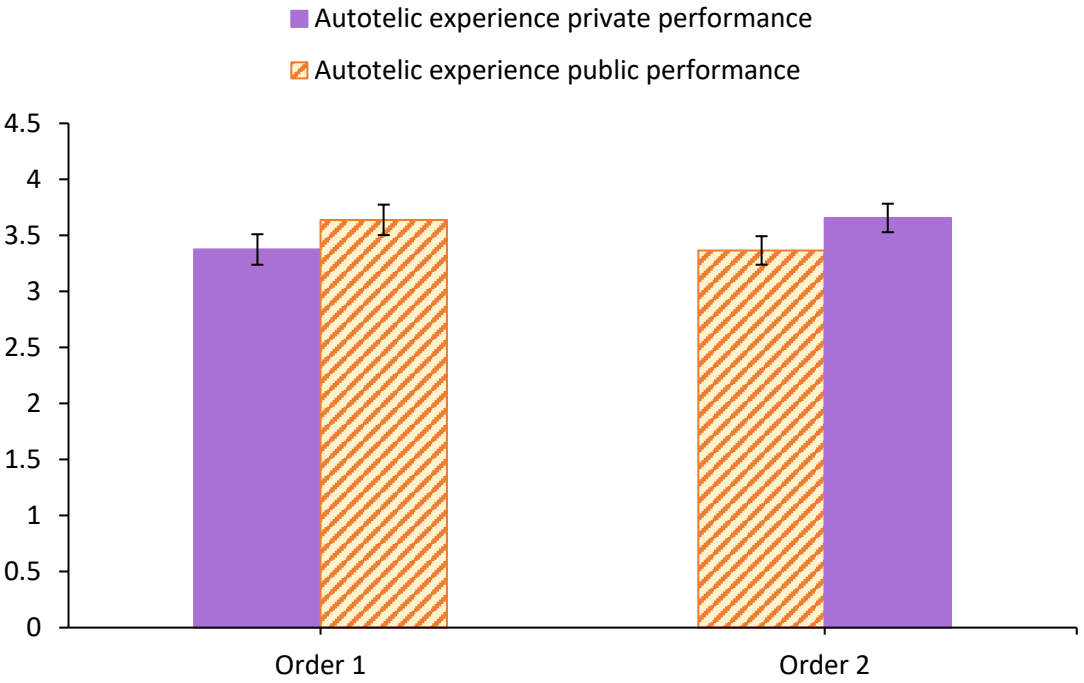

Figure 17. Model-predicted marginal means for order 1 (private session performed first then public session) and order 2 (public session performed first then private session) for autotelic experience

4.4.3. Main analyses without outliers

Of the 968 total observations for each of the nine flow dimensions, we dropped the following number of observations considered as outliers: challenge-skill balance, 17 for models 1 and 2; unambiguous feedback, 4 for model 1, 3 for model 2; clear goals, 2 for model 1, 3 for model 2; action-awareness merging, 5 for models 1 and 2; concentration on task at hand, 9 for models 1 and 2; sense of control, 0 for models 1 and 2; loss of self-consciousness, 18 for models 1 and 2; transformation of time, 14 for model 1, 15 for model 2; and autotelic experience, 2 for models 1 and 2. Cronbach's alphas were significantly increased for all dimensions after discarding the outliers (see supplementary table S3).

As can be seen in the supplementary tables S15–S18, overall, dropping the outliers did not significantly change the results compared to the analyses with all observations. Only the significant main effect of depressive symptoms for challenge-skill balance became non-significant.

4.4.4. Discussion

In this study, we investigated how music students' flow state experience defined in terms of its nine dimensions is influenced by the audience's presence and by students' general MPA level. Based on the social self-preservation theory (Dickerson & Kemeny, 2004) and on empirical research on music performance (e.g., Guyon et al., 2020a), we had hypothesized that the levels of challenge-skill balance, clear goals, action-awareness merging, concentration on task at hand, sense of control, loss of self-consciousness and autotelic experience would be lower during the public performance session than during the private performance session. These hypotheses were confirmed for sense of control and loss of self-consciousness. Sense of control was significantly lower during the public performance than the private performance for all music students. For loss of self-consciousness, the session effect was significant for all music students except for those with a general MPA level lower than 32. Contrary to our hypotheses, the audience's presence did not negatively affect music students' perceived competence to meet the situational demands, their sense of what they want to do, their ability to act spontaneously, their focus on the task and their enjoyment. Furthermore, an unanticipated significant session effect was found for unambiguous feedback. Similarly to loss of self-consciousness, this dimensions level was significantly lower during the public performance than during the private performance for participants with a general MPA level higher than 47. We speculate that this effect might be partly linked to the higher self-consciousness due to the audience's presence observed among music students with higher general MPA level compared to music students with lower general MPA level. Music students with higher general MPA level may have reduced resources to properly monitor and evaluate their public performance's progress due to their increased preoccupation with the audience's judgement and the associated higher attentional focus on the audience. Finally, the level of transformation of time was higher during the public performance session than during the private performance session, yet, only for music students whose first performance session was public and not for music students whose first performance session was private.

Drawing from the social anxiety models (Hiemisch et al., 2002; Hofmann, 2007; Nieuwenhuys & Oudejans, 2012) and empirical research on MPA (e.g., Guyon et al., 2020a), we had also hypothesized that the above-mentioned session effects would be larger for music students with higher general MPA level than for music students with lower general MPA level.

We found that the general MPA level significantly affected the levels of unambiguous feedback, concentration on task at hand, sense of control, loss of self-consciousness and autotelic experience. For concentration on task at hand, sense of control and autotelic experience, the general MPA level had a main effect; their levels decreased significantly with increasing general MPA level independently of the performance session. In contrast, the levels of unambiguous feedback and loss of self-consciousness decreased significantly with increasing general MPA level during the public performance only. The general MPA level did not significantly modulate music students' perceived competence to meet the situational demands, their sense of what they want to do and their ability to act automatically. Thus, the general MPA level effect during the public performance session was found for concentration on task at hand, sense of control, loss of self-consciousness and autotelic experience as expected and additionally for unambiguous feedback. Considering that sense of control and autotelic experience emerged as two of the strongest contributors to the global flow experience in music making (Sinnamon et al., 2012; Marin & Bhattacharya, 2013; Wrigley & Emmerson, 2013), the observed general MPA level effect on these two dimensions can be considered to be in agreement with the negative correlation between flow and general MPA level found in previous studies (Kirchner, Bloom, & Skutnick-Henley, 2008; Fullagar et al., 2013; Cohen & Bodner, 2019a). It is important to note that compared to music students with lower general MPA level, music students with higher general MPA level reported a poorer focus and a lower feeling of control on the task as well as less enjoyment during both performance sessions. These findings extent a previous study's results, which showed that musicians with higher general MPA level exhibited more anxiety, more negative self-statements, and less self-efficacy than musicians with lower general MPA level not only when performing in front of an audience but also when performing alone (Craske & Craig, 1984).

The levels of clear goals, loss of self-consciousness and autotelic experience were significantly higher during the second performance session than during the first performance session, whereas the level of transformation of time was significantly lower. These effects cannot be explained by the amount of preparation time between first and second performance sessions, as this variable was included in the models. We interpret these findings as being in line with the idea that the first performance session allowed the music students to habituate themselves to the performance situation (e.g., same experimental environment, instructions, music piece during both performance sessions; Groves & Thompson, 1970).

With increasing amount of preparation time between the two performance sessions, the levels of challenge-skill balance, clear goals, concentration on task at hand, and sense of control increased, wherease the level of transformation of time decreased. These findings extend previous research by Marin & Bhattacharya (2013) who showed that pianists' daily amount of practice was positively associated with their global dispositional flow. Furthermore, Butkovic et al. (2015) have observed that the amount of weekly music practice does not correlate positively with the general flow proneness but with flow proneness that is specific to activities in the musical field.

Compared to male music students, female music students reported less sense of control and less clear goals. The majority of studies on dispositional flow among musicians did not find any significant gender effect (Marin & Bhattacharya, 2013; Habe, Biasutti, & Kajtna, 2019; Cohen & Bodner, 2021 but see Valenzuela et al., 2018). Similarly, two studies assessing the global flow state reported no significant differences between male and female musicians (Wrigley & Emmerson, 2013; Spahn, Krampe, & Nusseck, 2021). Our significant gender effect for sense of control could be understood from the perspective of the personal control theory

according to which women tend to consider that their actions have less impact on the environment than men (Ross & Mirowsky, 2002). This factor is thought to contribute to a stronger sense of uncontrollability among women (Barlow, 2002). With regard to the gender effect on clear goals, we caution against overinterpreting this finding because the gender difference emerged only among music students who started with the private performance session.

Finally, the more depressive symptoms music students reported, the lower were the levels of challenge-skill balance, concentration on task at hand and loss of self-consciousness, independently of the performance session. These findings extend the results of Mosing et al. (2018), who found a significant, although small, negative correlation between depressive symptoms and flow proneness during music activities in the general population. Our findings are consistent with the fact that decreased ability to concentrate and low self-esteem are two of the depressive symptoms assessed with the Beck Depression Inventory-II (Beck et al., 1996; American Psychiatric Association, 2013).

The direction of the session and preparation effects on transformation of time was opposite to the direction of the effects observed for all other flow dimensions. Previous studies showed that transformation of time correlates poorly with the other flow dimensions and is the weakest predictor of the overall flow experience in music making (Sinnamon et al., 2012; Marin & Bhattacharya, 2013; Wrigley & Emmerson, 2013). We also found very low correlations between transformation of time and all other dimensions during both performance sessions (see supplementary tables S14 and S15). Tempo and rhythm and thus accurate time awareness play a prominent role in music making. A good music performance hinges on respecting the tempo and rhythm requirements of the music piece. Thus, having the sense that time passes in a way that is different from normal during a music performance does not seem to be a desirable experience for a musician. Knowing that the flow state positively correlates with optimal performance (Jackson & Csikszentmihalyi, 1999; Norsworthy, Gorczynski, & Jackson, 2017), it seems reasonable to conclude that during music performances low levels of transformation of time would be more consistent with the flow experience than high levels.

4.5. Research question 3

4.5.1. Descriptive statistics

Descriptive statistics for the predictors are given in Tables 18 and 19.

4.5.2. Preliminary analyses

The correlation tables are given in the supplementary tables S19 to S22. Factor analyses summaries are given in the supplementary tables S23 and S24. The two factor analyses indicated that most of the percentage of variance (>70%) was explained by only one factor. The scree plot test, parallel analysis and MAP test also suggested that all the dimensions may refer to only one latent variable. These analyses suggested that our music performance scale was measuring only one latent variable that we can interpret as MPQ. Considering all dimension together, the Cronbach's alpha of the MPQ scale was 0.93 for the french version and 0.92 for the English version.

Table 18 - Descriptive statistics of the self-rated MPQ dimensions for the private performance session

	After the music performance						One week after the experiment ending					
	M	***SD***	**Min**	**-**	**Max**	**Skewness**	**Kurtosis**	***M***	***SD***	**Min**	**-**	**Max**	**Skewness**	**Kurtosis**
Tempo	16.79	3.03	8	-	21	-0.74	2.74	16.51	3.34	5	-	21	-1.17	3.99
Rhythm	16.99	3.06	8	-	21	-0.95	3.25	16.83	3.35	7	-	21	-1.12	3.62
Intonation	15.76	3.30	5	-	21	-0.74	3.54	15.86	3.65	1	-	21	-1.31	5.38
Tone	15.99	3.59	1	-	21	-1.49	6.84	16.49	3.73	1	-	21	-1.58	6.15
Dynamics	14.76	3.36	5	-	21	-0.91	3.68	15.50	3.47	5	-	21	-0.84	3.09
Articulation	15.59	3.32	5	-	21	-0.88	3.21	15.81	3.57	1	-	21	-1.31	5.10
Musical understanding	16.15	3.10	7	-	21	-0.69	2.75	16.44	3.13	5	-	21	-1.14	4.14
Missing notes	15.00	4.38	1	-	21	-0.81	3.28	15.13	4.24	1	-	21	-0.94	3.43
Global appreciation	15.44	3.17	4	-	20	-1.12	4.46	15.69	3.31	1	-	21	-1.39	5.72

Table 19 - Descriptive statistics of the self-rated MPQ dimensions for the public performance session

	After the music performance						One week after the experiment ending					
	M	***SD***	**Min**	**-**	**Max**	**Skewness**	**Kurtosis**	***M***	***SD***	**Min**	**-**	**Max**	**Skewness**	**Kurtosis**
Tempo	16.45	2.96	8	-	21	-0.82	3.28	16.15	3.41	5	-	21	-1.06	3.76
Rhythm	16.74	3.01	8	-	21	-0.89	3.41	16.69	3.24	7	-	21	-0.98	3.45
Intonation	15.68	3.48	5	-	21	-1.16	4.28	15.25	3.74	5	-	21	-0.65	2.68
Tone	15.79	3.86	1	-	21	-1.32	4.93	15.63	3.82	1	-	21	-1.27	4.72
Dynamics	15.09	3.53	5	-	21	-0.78	3.33	15.05	3.44	4	-	21	-0.74	2.96
Articulation	15.31	3.28	7	-	21	-0.60	2.87	15.57	3.53	3	-	20	-1.22	4.47
Musical understanding	16.56	3.05	5	-	21	-0.83	3.60	16.25	3.20	7	-	21	-0.82	3.07
Missing notes	15.18	4.83	2	-	21	-0.84	2.88	15.01	4.60	2	-	21	-0.74	2.74
Global appreciation	15.45	3.13	5	-	20	-0.86	3.48	15.07	3.40	5	-	20	-0.64	2.74

4.5.3. Main analyses

The estimated models for the self-rated MPQ with all observations (N =4276) are reported in table 20. The models without the outliers are given in the supplementary table S25.

Table 20 - Estimated linear mixed models for self-rated MPQ

	Model 1			*Model 2*			*Model 3*		
	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*
Main effects									
General MPA level	**-0.06**	**0.02**	**0.006**	-0.07	0.03	0.043	-0.08	0.03	0.020
Session	-0.23	0.17	0.18	0.52	0.35	0.14	0.41	0.37	0.26
Time	0.01	0.07	0.85	0.24	0.14	0.090	0.13	0.18	0.45
Order	-0.03	0.42	0.94	0.51	0.63	0.42	0.39	0.63	0.54
Preparation	**0.34**	**0.09**	**<0.001**	0.12	0.14	0.38	0.12	0.14	0.38
Gender	0.05	0.45	0.91	0.37	0.68	0.59	0.37	0.69	0.59
Depressive symptoms	-0.05	0.03	0.056	-0.04	0.04	0.30	-0.05	0.04	0.19
Time difference	0.00	0.03	0.93	-0.00	0.04	0.95	0.00	0.04	0.96
2-way interactions									
General MPA level x session				-0.01	0.02	0.70	0.01	0.03	0.82
General MPA level x time				-0.01	0.01	0.37	0.00	0.01	0.58
General MPA level x order				0.03	0.04	0.48	0.05	0.05	0.24
Session x time				**-0.39**	**0.14**	**0.007**	-0.17	0.25	0.49
Session x order				**-1.10**	**0.51**	**0.031**	-0.87	0.53	0.10
Time x order				0.24	0.14	0.094	0.47	0.20	0.022
Gender x session				0.07	0.37	0.85	0.05	0.40	0.90
Gender x time				**-0.38**	**0.16**	**0.015**	-0.39	0.22	0.073
Gender x order				-0.22	0.91	0.81	-0.22	0.91	0.81
Depressive symptoms x session				0.02	0.02	0.49	0.04	0.02	0.16
Depressive symptoms x time				**-0.04**	**0.01**	**<0.001**	-0.02	0.01	0.25
Depressive symptoms x order				-0.01	0.06	0.83	-0.01	0.06	0.83
Time difference x session				-0.01	0.03	0.80	-0.02	0.03	0.53
Time difference x time				**-0.03**	**0.01**	**0.030**	-0.04	0.02	0.024
Time difference x order				0.06	0.07	0.39	0.06	0.07	0.39
3-way interactions									
General MPA level x session x time							0.00	0.01	0.86
General MPA level x session x order							-0.02	0.03	0.45
General MPA level x time x order							-0.03	0.01	0.058
Session x time x order							-0.45	0.29	0.12
Session x time x gender							0.05	0.31	0.86
Session x time x depressive symptoms							-0.04	0.02	0.064
Session x time x time difference							0.03	0.02	0.23

Note of table 20 - Model 1 tested the main effect of our factors. Model 2 tested the 2-way interactions of our factors. Model 3 tested the 3-way interactions of our factors. Significant main effects in Model 1 and significant interactions in Models 2 and 3 are written in bold. Reference categories for categorical predictors were as follows: session: private performance session; time: evaluation after the music performance; order: private performance session first – public performance session second; gender: women. For continuous predictors, coefficients express the change in the outcome measure per unit (unit for Preparation is hour and unit for Time difference is day).

In model 1, we obtained a significant main effect of general MPA level and a significant main effect of preparation on the self-rated MPQ. The higher the general MPA level, the lower the self-rated MPQ, whereas the more time music students reported to spend practicing between the two music performance sessions, the higher the self-rated MPQ.

In model 2, a significant interaction effect of session x time on self-rated MPQ was found (see figure 18).

Post-hoc analyses showed that for the private performance, the self-rated MPQ was significantly higher when it was evaluated with the recording than when it was evaluated after the performance (coefficient= 0.21, SE= 0.10, *p*= 0.041). For the public performance, the self-rated MPQ was not significantly different when it was evaluated after the performance or when it was evaluated with the recording (coefficient= -0.18, SE= 0.10, *p*= 0.080). The self-rated MPQ was significantly higher for the private performance than the public performance when the performance was evaluated one week after the last performance end recording (Coefficient= -0.42, SE= 0.18, *p*= 0.022). There was no significant difference between the music performance rating between the private and the public performance when it was evaluated just after the music performance (Coefficient= -0.03, SE= 0.18, *p*= 0.86).

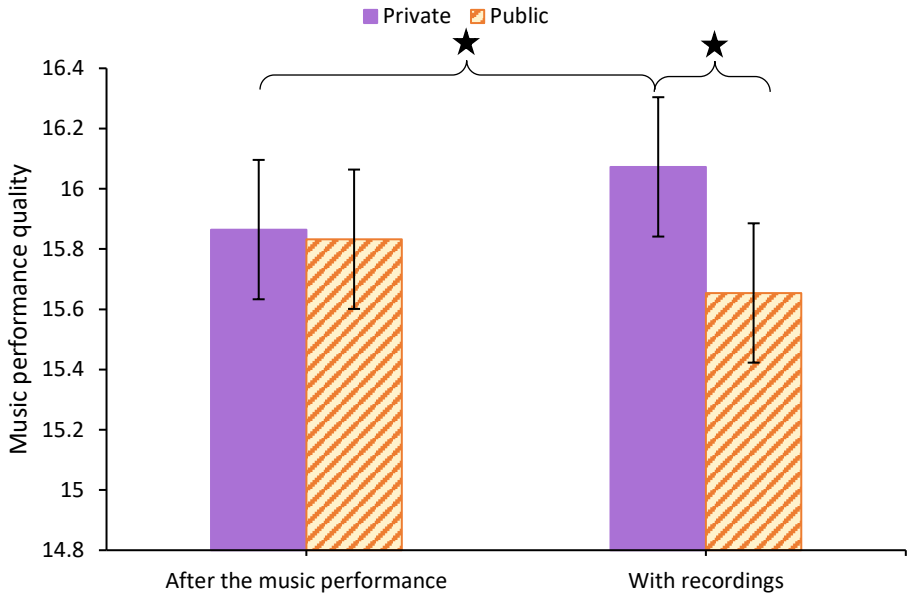

Figure 18. Model-predicted marginal means (SEs) for self-MPQ at the private and the public performance evaluated after the music performance and one week after the end of the experiment using recordings

Significant effects of session x order, gender x time, depressive symptoms x time, and time x time difference on self-rated MPQ were found in model 2. Concerning the effect of session x order (see figure 19), the post-hoc contrasts showed that in order 1, the self-rated MPQ was not significantly different between the private and the public music performance (coefficient= 0.36, SE= 0.32, *p*= 0.26). In order 2, the self-rated MPQ was significantly higher for the private than for the public performance (coefficient= -0.74, SE= 0.29, *p*= 0.011). The self-rated MPQ was not significantly different between order 1 and order 2 either for the private performance (coefficient= 0.53, SE= 0.49, *p*= 0.28) or the public performance (coefficient= -0.57, SE= 0.49, *p*= 0.25).

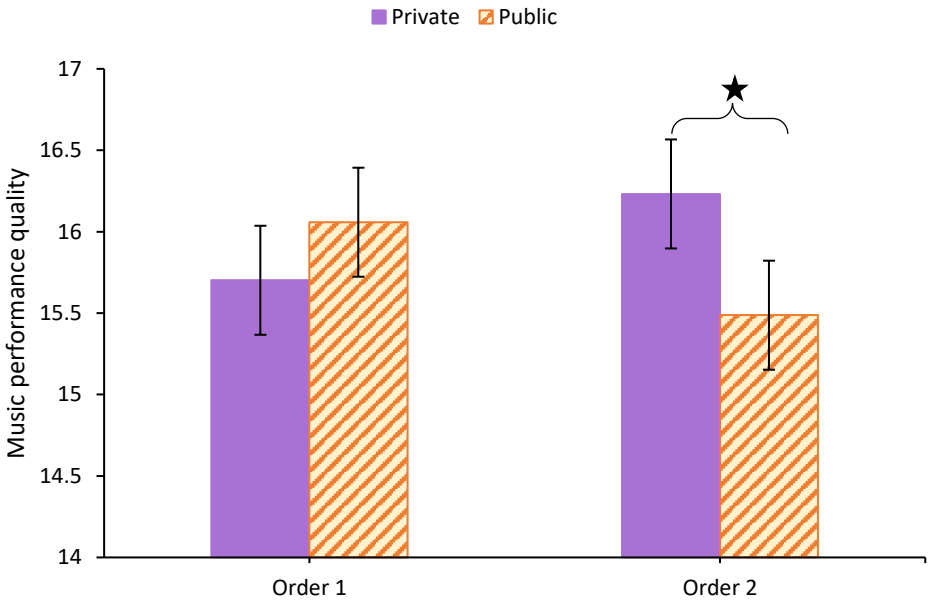

Figure 19. Model-predicted marginal means (SEs) for self-rated MPQ for private and public performance depending on the order

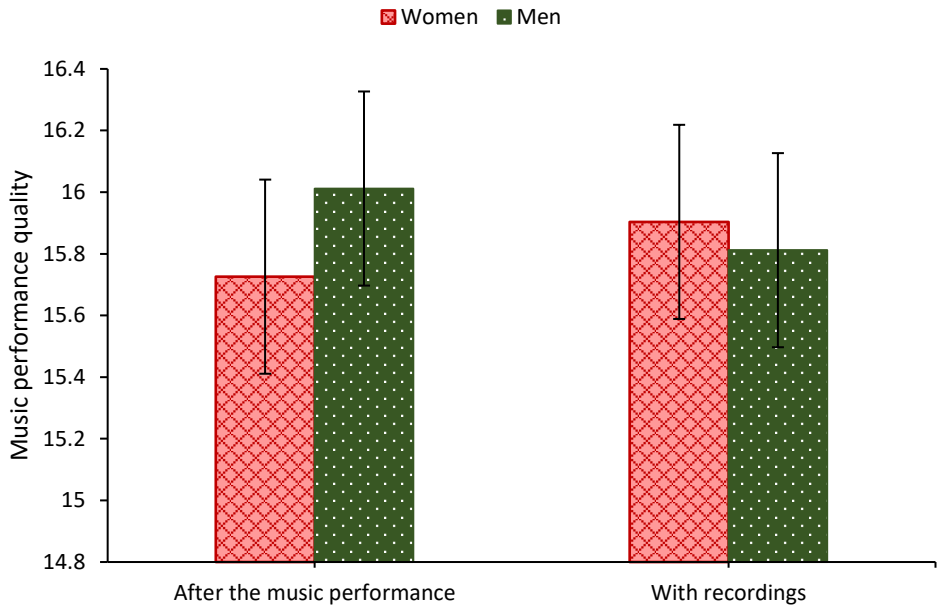

Figure 20. Model-predicted marginal means (SEs) for self-rated MPQ at the private and the public performance evaluated after the music performance and after the end of the experiment using performance

Concerning the significant interaction gender x time (see figure 20), the post-hoc contrast indicated that women and men did not significantly differ in their self-rated MPQ

either when the performance was evaluated after the music performance (coefficient= 0.29, SE= 0.46, *p*= 0.54) or one week after the end of the experiment with the recording (coefficient= -0.09, SE= 0.46, *p*= 0.84). There was no significant difference in self-rated MPQ between the evaluation made after the performance and the evaluation made one week after the end of the last performance with recordings either for women (coefficient= 0.17, SE= 0.10, *p*= 0.070) or for men (coefficient= -0.20, SE= 0.11, *p*= 0.079).

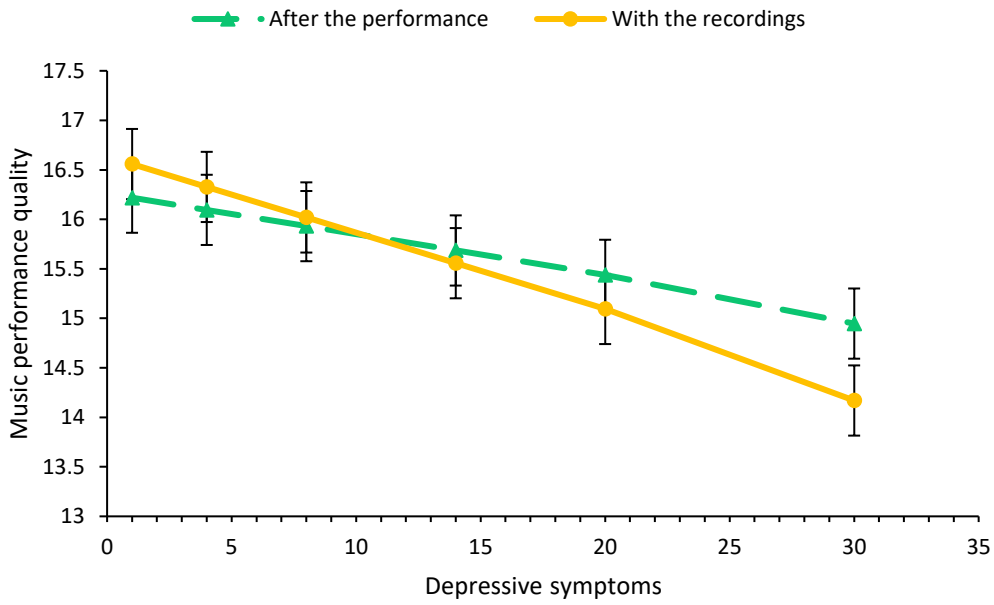

Figure 21. Model-predicted marginal means (SEs) for self-rated MPQ evaluated after the music performance and one week after the end of the experiment using recordings depending on the depressive symptoms' level

Concerning the significant effect of depressive symptoms x time, the post-hoc contrast showed that the self-rated MPQ was evaluated significantly higher one week after the performance with the recording when the depressive symptoms level was lower than 6 (see figure 21). The self-rated MPQ was evaluated significantly higher after the performance than one week after the last performance when the depressive symptoms level was 15. There was a significant depressive symptoms effect on self-rated MPQ when the performances were evaluated one week after the end of the last performance (coefficient= -0.08, SE= 0.03, *p*= 0.009), but not when the performances were evaluated after the performance end (coefficient= -0.04, SE= 0.03, *p*= 0.17).

For the significant interaction between time and time difference on self-rated MPQ, the post-hoc contrast showed that the self-rated MPQ was evaluated significantly more positively after the performance than one week after the end of the performance sessions with the recordings but only when the number of days between the habituation session and the first session performance was higher than 236 days. Further post-hoc analyses showed that there was no significant time difference effect on self-rated MPQ either when it was evaluated after the performance (coefficient= 0.03; SE= 0.04; *p*= 0.47) or when it was evaluated one week after the performance with recordings (coefficient= 0.00; SE= 0.04; *p*= 0.95). Finally, in model 3, no significant interaction was found.

4.5.4. Main analyses without outliers

In total for these analyses, we had 4 276 observations and we dropped 65 observations (1.5%) for model 1, 64 observations (1.5%) in model 2, and 69 (1.6%) for model 3. The results can be seen in the supplementary table S25. Dropping the outliers did not significantly change the main effects and interaction effects for model 1 and model 2. For model 3, the 3-way interaction session x time x depressive symptoms became significant.

4.5.5. Discussion

The research question in this chapter aimed to investigate how the general MPA level, audience presence, and time could influence MPQ. First, we hypothesized that music students with higher general MPA level would rate their MPQ more negatively than music students with lower general MPA level (**Hypothesis 3.1**). Our results supported the first hypothesis. In line with social anxiety literature (Clark & Wells, 1995; Hofmann, 2007) and previous research on music performance (Studer et al., 2014; Nielsen et al., 2018), the general MPA level of music students negatively influenced the music students self-rated MPQ whether it was in a private or public performance. Based on these results, we could assume that music students, like socially anxious people, would tend to minimize the quality of their performances.

In the second hypothesis, we considered that the general MPA level effect will be larger for the public performance session than for the private performance session (**Hypothesis 3.2**). Our results did not support this hypothesis. As the study by Studer et al. (2014), regardless of their general MPA level, music students gave similar ratings to the MPQ of their two performances. We could therefore consider that the self-rated MPQ was not influenced by audience presence for all music students regardless of their general MPA level.

However, one week after the end of the last performance, regardless of their general MPA level, music students evaluated the MPQ of their public performance more negatively than the MPQ of their private performance. Two possible explanations for this difference between the private self-rated MPQ and the public self-rated MPQ may be related to the temporal distance between the private and the public performance and the use of recordings. One week after the last performance session, music students were given two files containing respectively the recording of their private and the recording of their public music performances. Music students were instructed to listen to each recording and to evaluate them. Since music students could listen and rate their performances one after the other, they might be more likely to compare the MPQ of their performances with each other. This comparison was hardly possible when music students evaluate the MPQ after the performance since the two performance sessions were separated by 48h. Music students might have partially forgotten the grades they attributed to each dimension. In addition, we could not control the number of times the recordings were played, it might be possible that some students listened to the recordings more than once and were more likely to detect differences and mistakes.

Furthermore, our results showed music students rated the MPQ of their private performance more positively one week after the music performance based on the recording than just after the music performance. After the performance, music students did not have the opportunity to listen to the recording. Therefore, they had to base their judgments on their impressions and memories of the performance. However, in several studies, it has been shown that the psychological and physiological changes that occur before and during the

music performance can be sustained after the music performance is over (Gomez et al., 2018 ; Aufegger et al., 2018 ; Guyon et al., 2020a). We speculated that the self-rated MPQ evaluated after the performance may have been biased by the psychological and physiological state induced by the music performance, as we know that affective arousal may affect judgment and memory (Storbeck & Clore, 2008).

As performing a classical music piece is a complex activity, it is believed that long hours of practice may be necessary to reach a high achievement level (Sloboda et al., 1996; Lehmann & Ericsson, 1997; Sloboda et al., 2000). Our results seemed to support this idea as we found that the higher the amount of preparation time between the two performance sessions, the higher the self-rated MPQ.

In line with this idea, we also found that when the number of days between the habituation session and the first performance session exceeded 236 days, music students rated their MPQ more positively after the music performance than after one week on a recording basis. However, we caution against overinterpreting this finding because the number of music students who performed their first performance session 236 or more days after the habituation session is not sufficient to draw any conclusions.

Our results also showed that music students rated their public performance MPQ more negatively than their private performance MPQ when they performed the public performance before the private performance. As mentioned in chapter 4.4.4, this effect may be in line with the idea that the first performance session allowed the music students to habituate themselves to the performance situation (e.g., same experimental environment, instructions, music piece during both performance sessions; Groves & Thompson, 1970).

Music students with a level of depressive symptoms below 6 rated their performances MPQ more negatively just after the performance than one week after the end of the performance session with the recordings. In contrast, music students with a level of depressive symptoms above 15 rated their performance MPQ more negatively one week after the end of the last performance session on a recording basis.

4.6. Research question 4

4.6.1. Descriptive statistics

The descriptive statistics for the resources-demands differential, perceived resources and the perceived demands are reported in table 21. The correlation between the resources-demands differential, perceived resources, perceived demands, general MPA level, depressive symptoms, time difference, and preparation are provided in the supplementary tables S26 to S29.

4.6.2. Results

The estimated models for the resources-demands differential, perceived resources and perceived demands with all observations are reported in tables 22 to 24. The models without the outliers are given in the supplementary tables S30 to S32.

Table 21 - Descriptive statistics for the resources-demands differential, perceived resources, and perceived demands variables

	Private performance session								Public performance session							
	Before					During			Before				During			
Dimension	***M (SD)***	**Min-max**	***Skewness***	***Kurtosis***	***M (SD)***	**Min-max**	***Skewness***	***Kurtosis***	***M (SD)***	**Min-max**	**Skewness**	**Kurtosis**	***M (SD)***	**Min-max**	**Skewness**	**Kurtosis**
Resources – demands differential	1.28 (1.65)	-2 - 5	0.1	2.4	0.74 (2.01)	-5 - 5	-0.1	2.5	0.55 (1.58)	-3 - 5	0.3	2.6	0.11 (1.61)	-3 - 5	0.4	2.9
Perceived resources	4.83 (0.85)	3 - 6	-0.4	2.6	4.22 (1.15)	1 - 6	-0.4	2.7	4.55 (0.95)	2 - 6	-0.4	2.9	4.23 (1.09)	2 - 6	-0.1	2.3
Perceived demands	3.55 (1.30)	1 - 6	-0.1	2.3	3.49 (1.38)	1 - 6	0.1	2.1	4 (1.12)	1 - 6	-0.5	2.8	4.12 (1.08)	1 - 6	-0.5	3.3

4.6.2.1. Model 1

In model 1, we found a significant general MPA level main effect on the resource-demands differential and on the perceived resources. The higher the general MPA level, the lower the resources-demands differential, and the lower the perceived resources. We also observed a significant session main effect on the resources-demands differential, the perceived resources, and the perceived demands. During the private performance session, the resources-demands differential and the perceived resources were higher than during the public performance session. In contrast, the perceived demands were lower during the private performance than during the public performance session. We found a significant time main effect for the resources-demands differential and for the perceived resources. Before the music performance, the resources-demands differential and the perceived resources were higher than during the music performance. A significant preparation main effect on the perceived resources was found. The more participants reported to prepare the music piece between the first and the second performance session, the higher their perceived resources. Finally, we found a significant order main effect on the perceived demands. The perceived demands were higher for music students who started with the private performance than for music students who started with the public performance.

4.6.2.2. Model 2

In model 2, a significant interaction effect between session and time on the perceived resources was found. We used post-hoc analyses to test the time effect for each session as well as post-hoc contrast to see if the perceived resources level for each session was different at each time. The perceived resources were higher before the performance than during the performance for both the private performance session (Coefficient= -0.60, SE= 0.09, p <0.001) and the public performance session (Coefficient= -0.32, SE= 0.09, p <0.001). The perceived resources before the private performance were significantly higher than before the public performance (Coefficient= -0.27, SE= 0.07, p <0.001). The perceived resources during the private performance were not significantly different from the perceived resources during the public performance (Coefficient= 0.01, SE= 0.12, p= 0.94 – see figure 22).

Still in model 2, we found a significant interaction between gender and order on the resources-demands differential (see supplementary figure S6). With post-hoc contrasts, we tested the gender effect for order 1 (starting with the private performance session) and order 2 (starting with the public performance session), separately and the order effect for women and men, separately. We observed that the men's resources-demands differential was significantly higher than women's differential when music students followed order 1 (Coefficient= 0.87, SE= 0.38, p= 0.024) but not when music students followed order 2 (Coefficient= -0.35, SE= 0.37, p= 0.35). We also found that women had higher resources-demands differential when they followed order 2 than when they followed order 1 (Coefficient= 0.84, SE= 0.33, p= 0.012). There was no significant difference between men who followed order 1 and men who followed order 2 (Coefficient= -0.38, SE= 0.39, p= 0.33).

Table 22 - Estimated linear mixed models for resources-demands differential

	Model 1			*Model 2*			*Model 3*		
	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*
Main effects									
General MPA level	**-0.03**	**0.01**	**0.005**	-0.03	0.02	0.12	-0.02	0.02	0.37
Session	**-0.69**	**0.11**	**<0.001**	-0.75	0.24	0.002	-0.58	0.28	0.035
Time	**-0.50**	**0.10**	**<0.001**	-0.37	0.19	0.056	-0.16	0.25	0.53
Order	0.37	0.25	0.14	1.00	0.38	0.008	1.19	0.40	0.003
Preparation	-0.01	0.06	0.91	-0.01	0.09	0.88	-0.01	0.09	0.89
Gender	0.27	0.27	0.30	0.85	0.41	0.037	1.14	0.44	0.009
Depressive symptoms	0.00	0.02	0.90	0.01	0.02	0.71	0.02	0.03	0.50
Time difference	0.00	0.02	0.96	0.01	0.03	0.75	0.02	0.03	0.57
2-way interactions									
General MPA level x session				-0.01	0.01	0.36	-0.02	0.02	0.19
General MPA level x time				0.01	0.01	0.20	-0.03	0.02	0.15
General MPA level x order				-0.01	0.02	0.70	-0.02	0.03	0.59
Session x time				0.10	0.19	0.61	-0.06	0.33	0.86
Session x order				-0.03	0.34	0.94	-0.24	0.42	0.58
Time x order				-0.31	0.19	0.12	-0.56	0.33	0.084
Gender x session				0.08	0.24	0.75	-0.30	0.38	0.43
Gender x time				-0.04	0.21	0.86	-0.53	0.37	0.15
Gender x order				**-1.22**	**0.53**	**0.022**	-1.67	0.60	0.006
Depressive symptoms x session				-0.02	0.01	0.22	-0.03	0.02	0.23
Depressive symptoms x time				0.01	0.01	0.51	-0.01	0.02	0.68
Depressive symptoms x order				0.01	0.03	0.85	-0.00	0.04	0.92
Time difference x session				0.01	0.02	0.48	0.01	0.02	0.82
Time difference x time				-0.01	0.02	0.61	-0.03	0.02	0.23
Time difference x order				-0.05	0.04	0.29	-0.06	0.05	0.22
3-way interactions									
General MPA level x session x time							**0.05**	**0.02**	**0.013**
General MPA level x session x order							-0.00	0.02	0.85
General MPA level x time x order							0.02	0.02	0.23
Session x time x order							0.01	0.39	0.98
Gender x session x time							0.36	0.41	0.39
Gender x session x order							0.49	0.49	0.32
Gender x time x order							0.61	0.42	0.15
Depressive symptoms x session x time							0.01	0.03	0.64
Depressive symptoms x session x order							0.01	0.03	0.77
Depressive symptoms x time x order							0.02	0.03	0.54
Time difference x session x time							0.02	0.03	0.53
Time difference x session x order							0.01	0.04	0.90
Time difference x time x order							0.03	0.03	0.34

Note of table 22 - Model 1 tested the main effect of our factors. Model 2 tested the 2-way interactions of our factors. Model 3 tested the 3-way interactions of our factors. Significant main effects in Model 1 and significant interactions in Models 2 and 3 are written in bold. Reference categories for categorical predictors were as follows: session: private performance session; time: before the music performance; order: private performance session first – public performance session second; gender: women. For continuous predictors, coefficients express the change in the outcome measure per unit (unit for Preparation is hour and unit for Time difference is day).

Table 23 - Estimated linear mixed models for perceived resources

	Model 1			*Model 2*			*Model 3*		
	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*
Main effects									
General MPA level	**-0.02**	**0.01**	**0.001**	-0.01	0.01	0.38	-0.01	0.01	0.61
Session	**-0.20**	**0.07**	**0.002**	-0.04	0.14	0.78	-0.00	0.16	1.00
Time	**-0.46**	**0.07**	**<0.001**	-0.51	0.13	<0.001	-0.47	0.17	0.005
Order	-0.01	0.13	0.94	0.51	0.21	0.013	0.57	0.22	0.009
Preparation	**0.08**	**0.04**	**0.033**	-0.02	0.05	0.67	-0.02	0.05	0.65
Gender	0.25	0.14	0.070	0.50	0.22	0.021	0.54	0.23	0.022
Depressive symptoms	-0.01	0.01	0.30	-0.01	0.01	0.54	-0.00	0.01	0.80
Time difference	0.00	0.01	0.97	0.00	0.01	0.94	0.00	0.01	0.96
2-way interactions									
General MPA level x session				-0.01	0.01	0.20	-0.01	0.01	0.27
General MPA level x time				0.01	0.01	0.41	-0.01	0.01	0.22
General MPA level x order				-0.02	0.01	0.23	-0.02	0.02	0.31
Session x time				**0.28**	**0.13**	**0.029**	0.26	0.22	0.24
Session x order				**-0.49**	**0.20**	**0.013**	-0.59	0.24	0.015
Time x order				-0.18	0.13	0.15	-0.36	0.22	0.10
Gender x session				0.06	0.14	0.67	0.03	0.21	0.90
Gender x time				0.02	0.14	0.90	0.05	0.25	0.84
Gender x order				-0.53	0.28	0.061	-0.62	0.32	0.057
Depressive symptoms x session				0.00	0.01	0.89	-0.01	0.01	0.53
Depressive symptoms x time				**0.02**	**0.01**	**0.035**	0.02	0.01	0.16
Depressive symptoms x order				-0.01	0.02	0.59	-0.02	0.02	0.31
Time difference x session				0.00	0.01	0.77	0.01	0.01	0.53
Time difference x time				-0.00	0.01	0.87	-0.02	0.02	0.29
Time difference x order				-0.01	0.02	0.83	0.00	0.03	0.95
3-way interactions									
General MPA level x session x time							0.02	0.01	0.059
General MPA level x session x order							-0.01	0.01	0.56
General MPA level x time x order							0.01	0.01	0.26
Session x time x order							0.20	0.26	0.44
Gender x session x time							-0.20	0.28	0.47
Gender x session x order							0.09	0.28	0.75
Gender x time x order							0.18	0.28	0.52
Depressive symptoms x session x time							-0.00	0.02	0.81
Depressive symptoms x session x order							0.03	0.02	0.16
Depressive symptoms x time x order							-0.01	0.02	0.70
Time difference x session x time							0.01	0.02	0.62
Time difference x session x order							-0.03	0.02	0.21
Time difference x time x order							0.03	0.02	0.14

Note of table 23 – Model 1 tested the main effect of our factors. Model 2 tested the 2-way interactions of our factors. Model 3 tested the 3-way interactions of our factors. Significant main effects in Model 1 and significant interactions in Models 2 and 3 are written in bold. Reference categories for categorical predictors were as follows: session: private performance session; time: before the music performance; order: private performance session first – public performance session second; gender: women. For continuous predictors, coefficients express the change in the outcome measure per unit (unit for Preparation is hour and unit for Time difference is day).

Table 24 - Estimated linear mixed models for perceived demands

	Model 1			*Model 2*			*Model 3*		
	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*
Main effects									
General MPA level	0.01	0.01	0.16	0.02	0.01	0.14	0.01	0.02	0.38
Session	**0.54**	**0.08**	**<0.001**	0.69	0.18	<0.001	0.54	0.21	0.011
Time	0.03	0.06	0.60	-0.14	0.12	0.24	-0.31	0.16	0.051
Order	**-0.38**	**0.19**	**0.042**	-0.53	0.29	0.065	-0.67	0.31	0.031
Preparation	0.08	0.04	0.063	0.01	0.07	0.83	0.02	0.07	0.82
Gender	-0.01	0.20	0.95	-0.27	0.31	0.39	-0.61	0.34	0.071
Depressive symptoms	-0.01	0.01	0.52	-0.01	0.02	0.45	-0.02	0.02	0.34
Time difference	-0.00	0.02	1.00	-0.01	0.02	0.69	-0.02	0.02	0.45
2-way interactions									
General MPA level x session				0.00	0.01	0.92	0.01	0.01	0.47
General MPA level x time				-0.01	0.01	0.25	0.01	0.01	0.33
General MPA level x order				-0.01	0.02	0.75	-0.00	0.02	0.97
Session x time				0.18	0.12	0.14	0.32	0.21	0.13
Session x order				-0.35	0.25	0.16	-0.25	0.32	0.42
Time x order				0.12	0.13	0.33	0.21	0.21	0.32
Gender x session				-0.12	0.18	0.50	0.34	0.29	0.24
Gender x time				0.05	0.13	0.69	0.58	0.23	0.014
Gender x order				0.65	0.40	0.11	1.08	0.46	0.019
Depressive symptoms x session				0.02	0.01	0.13	0.02	0.02	0.38
Depressive symptoms x time				0.01	0.01	0.24	0.03	0.01	0.034
Depressive symptoms x order				-0.02	0.03	0.44	-0.02	0.03	0.46
Time difference x session				-0.01	0.01	0.46	0.01	0.02	0.78
Time difference x time				0.01	0.01	0.53	0.01	0.02	0.45
Time difference x order				0.05	0.03	0.17	0.07	0.04	0.073
3-way interactions									
General MPA level x session x time							-0.02	0.01	0.060
General MPA level x session x order							-0.00	0.02	0.93
General MPA level x time x order							-0.01	0.01	0.47
Session x time x order							0.19	0.25	0.44
Gender x session x time							**-0.56**	**0.27**	**0.035**
Gender x session x order							-0.46	0.36	0.19
Gender x time x order							-0.43	0.27	0.11
Depressive symptoms x session x time							-0.02	0.02	0.33
Depressive symptoms x session x order							0.03	0.02	0.26
Depressive symptoms x time x order							-0.02	0.03	0.17
Time difference x session x time							-0.01	0.02	0.65
Time difference x session x order							-0.05	0.03	0.11
Time difference x time x order							0.00	0.02	0.97

Note of table 24 - Model 1 tested the main effect of our factors. Model 2 tested the 2-way interactions of our factors. Model 3 tested the 3-way interactions of our factors. Significant main effects in Model 1 and significant interactions in Models 2 and 3 are written in bold. Reference categories for categorical predictors were as follows: session: private performance session; time: before the music performance; order: private performance session first – public performance session second; gender: women. For continuous predictors, coefficients express the change in the outcome measure per unit (unit for Preparation is hour and unit for Time difference is day).

Furthermore, for model 2, we observed a significant interaction between session and order for the perceived resources (see figure 23). We tested the session effect for order 1 (starting with the public performance session) and order 2 (starting with the private performance session), separately. We found that the perceived resources were significantly higher during the private performance session than during the public performance session for music students with order 2 (Coefficient= -0.36, SE= 0.12, *p*= 0.002) but not for music students with order 1 (Coefficient= 0.13, SE= 0.13, *p*= 0.32). We also investigated the order effect for the private and the public performance session, separately. There was no significant difference in the perceived resources between music students with order 1 and music students with order 2 for either the private performance session (Coefficient= 0.19, SE= 0.17, *p*= 0.26) or the public performance session (Coefficient= -0.30, SE= 0.17, *p*= 0.070).

A significant interaction between depressive symptoms and time was found for the perceived resources (see figure 24).

We used post-hoc analyses to test the depressive symptoms effect at each time as well as post-hoc contrast to see if the perceived resources for each time was different at different depression symptoms level. The perceived resources were significantly higher before the performance session than during the performance session when the depressive symptoms level was lower than 23. There was no significant effect of depressive symptoms on the perceived resources either before the music performance (Coefficient= -0.01, SE=0.01, *p*= 0.18) or during the music performance (Coefficient= 0.01, SE= 0.01, *p*= 0.61).

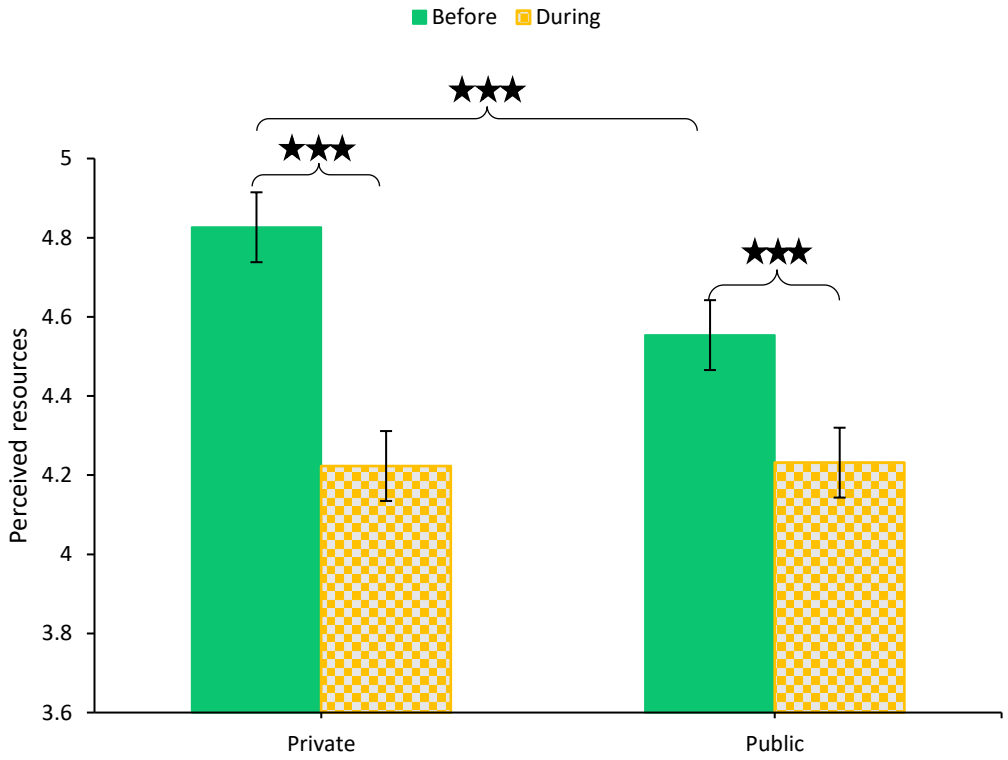

Figure 22. Model-predicted marginal means (SEs) for perceived resources before and during the private and public performance sessions

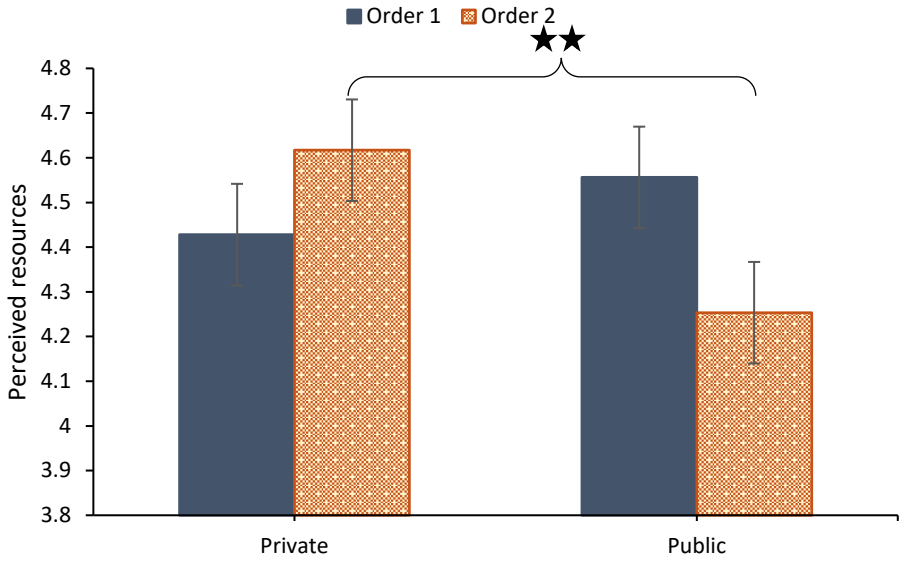

Figure 23. Model-predicted marginal means (SEs) for perceived resources during the private and public performance session for order 1 (starting with private performance session) and order 2 (starting with public performance session)

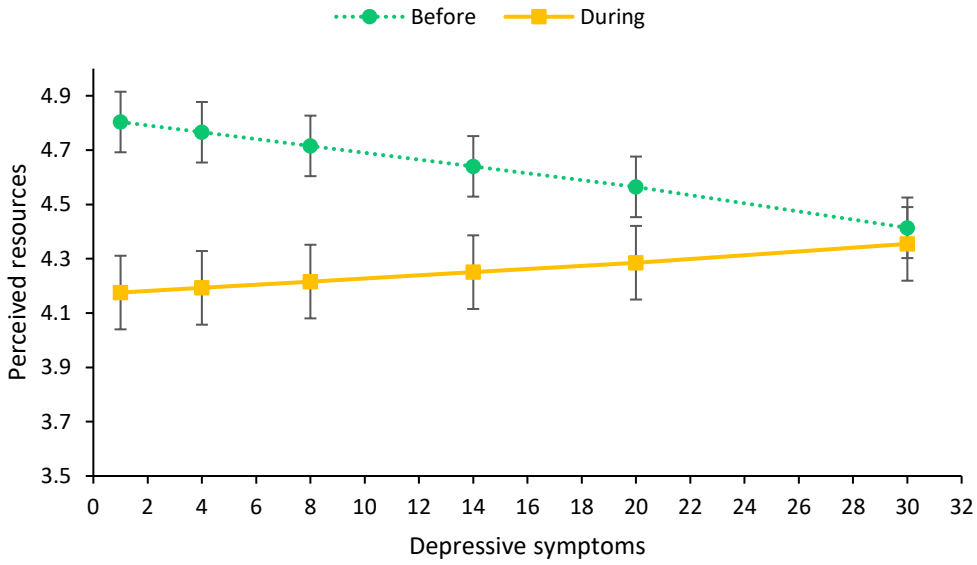

Figure 24. Model-predicted marginal means (SEs) for perceived resources before and during the music performance depending on the depressive symptoms level

4.6.2.3. Model 3

In model 3, we found a significant 3-way interaction between general MPA level, session, and time for the resources-demands differential (see figure 25). To understand this 3-way interaction, we performed the following post-hoc analyses.

First, we tested the general MPA level effect on the resources-demands differential for the different combinaisons of session and time. There was a significant main effect of the general MPA level during the private music performance (coefficient= -0.04, SE= 0.02, *p*=

0.015) and before the public music performance (coefficient= -0.05, SE= 0.01, p <0.001). Music students with higher general MPA level had reported lower resources-demands differential level than music students with lower general MPA level during the private music performance and before the public music performance. There was no significant difference before the private music performance (coefficient= -0.03, SE= 0.01, p= 0.060) and after the public music performance (coefficient= -0.02, SE= 0.02, p = 0.25).

Second, we tested the session effect before the music performance at different general MPA levels. Before the music performance, the resources-demands differential for private performance session was significantly higher than for the public performance session for music students having a general MPA level score higher than 35.

Third, we tested the session effect during the music performance at different general MPA levels. During the music performance, the resources-demands differential for the private performance session was significantly higher than for the public performance session for music students having a general MPA level score lower than 57.

Fourth, we tested the time effect during the private performance session at different general MPA levels. We observed that during the private music performance session, the resources-demands differential before the music performance was significantly higher than during the music performance for music students having a general MPA level score higher than 35.

Finally, we tested the time effect during the public performance session at different general MPA levels. During the public music performance session, the resources-demands differential before the music performance was significantly higher than during the music performance for music students having a general MPA level score lower than 53.

In addition, in model 3, we found a significant interaction between session, time, and gender for the perceived demands (see figure 26). To understand this 3-way interaction, we performed post-hoc analyses. First, there was no significant effect of gender on perceived demands either before the private performance (coefficient= -0.04, SE= 0.24, p= 0.88) or before the public performance (coefficient= 0.06, SE= 0.24, p= 0.82). There was also no significant effect of gender on perceived demands during the private performance (coefficient = 0.31, SE= 0.24, p= 0.19) or during the public performance (coefficient= -0.16, SE= 0.24, p= 0.51).

Second, we tested the main effect of time. There was no significant effect of time on the perceived demands during the private performance session either for women (coefficient= -0.21, SE= 0.12, p= 0.08) or men (coefficient= 0.14, SE= 0.14, p= 0.30). There was also no significant effect of time on the perceived demands during the public performance session either for women (coefficient= 0.22, SE= 0.12, p= 0.069) or for men (coefficient= 0.00, SE= 0.14, p= 0.97).

Finally, we tested the main effect of session. There was a significant effect of session on the perceived demands for women before the music performance (coefficient= 0.42, SE= 0.14, p= 0.003) and during the music performance with recordings (coefficient= 0.84, SE= 0.14, p <0.001). Women music students perceived more demands before the public performance session than before the private performance session. In addition, women music students perceived more demands during the public performance than during the private performance.

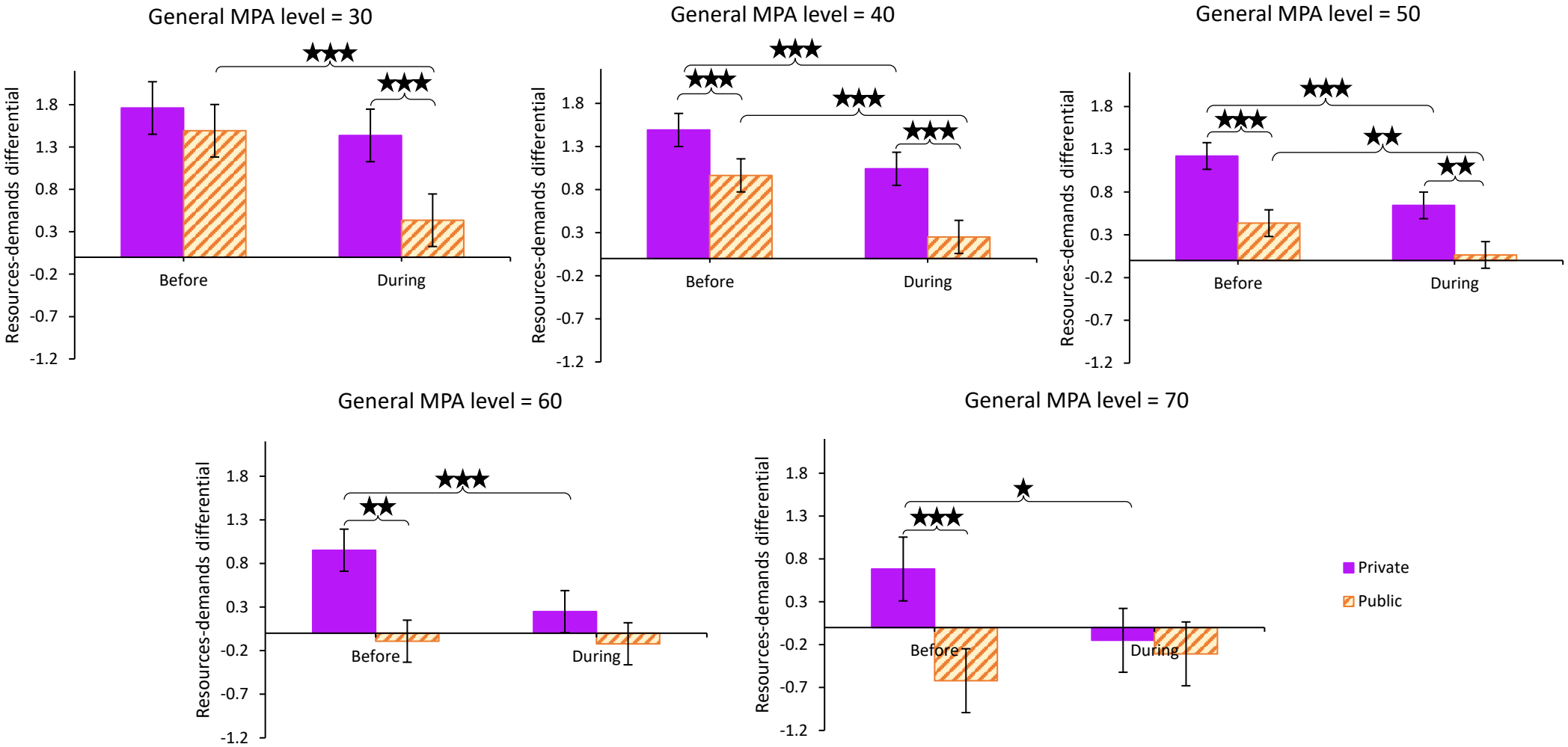

Figure 25. Model-predicted marginal means (SEs) for resources-demands differential before and during the music performance for the private and public performance session for five levels of general MPA

There was also a significant effect of session on perceived demands for men before the performance session (coefficient= 0.51, SE= 0.16, *p*= 0.002) and during the performance session (coefficient= 0.37, SE= 0.16, *p*= 0.024). Men music students reported more perceived demands before the public performance than before the private performance. They also reported more perceived demands during the public performance than during the private performance.

4.6.3. Discussion

In this thesis part, we aim to investigate how general MPA level, audience presence, and time influence the challenge-threat states operationalized as the resources-demands differential where a higher score represented a higher challenge state and lesser threat states.

Based on the BPSM of challenge and threat (Blascovich, 2008; Seery, 2011) and previous research investigating psychosocial stressors and social anxiety (Jamieson et al., 2013), we hypothesized that music students with higher general MPA level would have lower resources-demands differential and lower perceived resources level than music students with lower general MPA level (**Hypothesis 4.1**). Our results supported this hypothesis since we found that music students with higher general MPA level had lower resources-demands differential than music students with lower general MPA level. However, the 3-way interaction exploration showed that the main general MPA level effect on the resources-demands differential was only significant for the resources-demands differential evaluated during the private performance and before the public performance. Based on this result, we assumed that during the private performance and before the public performance, music students with higher general MPA level were more in a threat state than music students with lower general MPA level.

When investigating perceived resources and perceived demands separately, we found that music students with higher general MPA level perceived fewer resources than music students with low general MPA level. This result is in line with Jamieson et al. (2013) results which showed that socially anxious individuals tend to consider they have fewer resources to cope with a psychosocial stressor than non-socially anxious. However, they also found that socially anxious tend to perceive more demands than non-socially anxious, whereas, in our study, there was no significant difference in the perceived demands level between music students with higher or lower general MPA level. We speculated that the lack of difference between the demands perceived by music students with higher general MPA level and the demands perceived by music students with lower general MPA level may be explained by the type of task. In their study, Jamieson et al. (2013) used a TSST paradigm where participants had to deliver a speech either alone in a room or in front of people. Socially anxious already reported a higher perceived demands level than non-socially anxious when they had to deliver their speech in the absence of a listener in the room, whereas in our study, we did not find similar results. Instead, we observed that music students perceived lower perceived demands during the private performance session compared to the public performance session. We also found that music students had a higher resources-demands differential and perceived resources level during the private performance session than during the public performance session. These latter results supported our second hypothesis (**Hypothesis 4.2**). As expected, these results agreed with the theory of social self-preservation (Dickerson & Kemeny, 2004), which postulated that audience presence might create a certain “pressure” on music students. We speculated that the decrease in perceived resources during the public performance

compared to the private performance might be related to the increase in anxiety, distress, nervousness, bodily complaints, and negative cognitions observed in previous studies when the music performance was done in front of an audience (e.g., Craske & Craig, 1984; Fredrikson & Gunnarsson, 1992; Yoshie et al., 2009a; Studer et al., 2012; Larrouy-Maestri & Morsomme, 2014; Fancourt, Aufegger, & Williamon, 2015; Chanwimalueang et al., 2017; Aufegger & Wasley, 2018). If music students perceived more negative psychophysiological stress, they might doubt their ability to perform and consequently perceive fewer resources. Despite the presence of a significant 3-way interaction between session, time, and gender on the perceived demands, for all music students (women or men), the perceived demands were always higher for the public performance than for the private performance either when it was evaluated before the performance or during the performance. We could therefore consider that audience presence was perceived as an additional demand of the task that the music students needed to cope with to achieve the performance. Furthermore, the resources-demands differential level was also influenced by a 3-way interaction (general MPA level x session x time). The resources-differential level was higher before the private performance than before the public performance only for music students with a general MPA level higher than 35. In addition, the resources-demands differential was higher during the private performance than during the public performance only for music students with a general MPA level lower than 57. Based on these results, we might assume that only music students with a general MPA level between 35 and 57 were more in a threat state during the public performance session than during the private performance session. Outside of this range, we assumed that music students' motivational state might be similar for both types of performance. Music students with a general MPA level higher than 57 may be more in a threat state for both music performance sessions, whereas music students with a general MPA level lower than 35 may be more in a challenge state for both music performance sessions.

In a third hypothesis, we expected that during the public performance session, music students with higher general MPA level would have an even lower resources-demands differential level and a higher perceived demands level than the music students with lower general MPA level (**Hypothesis 4.3**). Our results partially supported this hypothesis. The 3-way interaction between general MPA level, session, and time on the resources-demands differential showed that music students with higher general MPA level had a lower resources-demands differential than music students with lower general MPA level only during the private music performance and before the public music performance. We can therefore consider that music students with higher general MPA level were more in a threat state than music students with lower general MPA level during the private performance and before the public performance. Concerning the perceived demands, our results showed that it was not influenced by the general MPA level. However, the 3-way interaction between session, time, and gender showed that all music students (women and men) did not perceive more demands before the music performance compared to after the performance.

Outside of our hypotheses, we observed that for both private and public performance sessions, music students reported more resources to cope with the music performance before than during the music performance. In addition, music students reported more perceived resources before the private music performance than before the public music performance, whereas there was no significant difference during both music performance types. These results supported Blascovich (2013b)’s assumption that the perceived resources and perceived demands evaluations are not fixed and can change over time as new information becomes available. It is therefore important to mention that this decreasing perception of

available resources was only significant for music students who had a level of depressive symptoms lower than 23. These findings were consistent with the fact that the feeling of worthlessness and self-criticism were two of the depressive symptoms assessed with the Beck Depression Inventory-II (Beck et al., 1996; American Psychiatric Association, 2013).

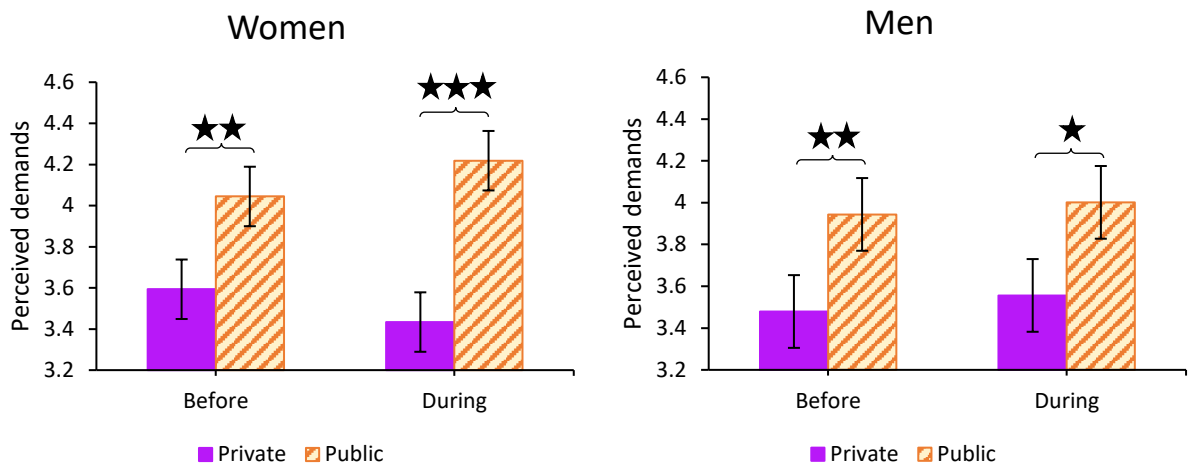

Figure 26. Model-predicted marginal means (SEs) for perceived demands before and during the music performance for the private and public performance sessions depending on the gender

Interestingly, our results showed that students perceived more demands when they started with the private performance session than when they started with the public performance session. We also observed that woman music students were more in a threat state (lower resources-demands differential) than man music students when they started with the private performance session. Additionally, women music students had a higher resources-demands differential level when they started with the private performance session than when they started with the public performance session. There was no significant difference for man music students. Finally, the results showed that the perceived resources level was higher during the private performance session than during the public performance session, but only when music students started with the public performance session. These effects might be linked to a habituation effect as previously observed in a previous chapter (see chapter 4.4), however, it is difficult to provide an explanation for these results since in everyday life, no student performs music in front of an audience without first rehearsing the entire performance alone.

In conclusion, although the motivational state (challenge vs. threat) changes over time, the audience presence seems to elicit more threat states in music students. Furthermore, the general MPA level influences the motivational state and especially the perceived resources, however, its influences also depend on audience presence and time.

4.7. Research question 5

4.7.1. Results

4.7.1.1. Descriptive statistics

The descriptive statistics for the resources-demands differential and the self-rated MPQ dimensions are provided in tables 18, 19, and 21.

4.7.1.2. Preliminary analyses

The correlation table is shown in the supplementary table S33.

4.7.1.3. Main analyses

The estimated models for the self-rated MPQ evaluated after the music performance and one week after the performance are reported in table 25 and 26. The models without the outliers are given in the supplementary materials (see supplementary tables S34 and S35).

In the first model, we saw a significant main resources-demands differential between effect on the self-rated MPQ evaluated after the performance. The higher the resources-demands differential between component, the higher self-rated MPQ. We also found a significant main effect of preparation. The higher the amount of preparation time between the two performance sessions, the higher self-rated MPQ.

In the second model, we also found a significant main resources-demands differential between effect on the self-rated MPQ evaluated with recordings one week after the last performance session. The higher the resources-demands differential between component, the high self-rated MPQ. We also found a significant main effect of preparation. The higher the amount of preparation time between the two performance sessions, the higher self-rated MPQ. In addition, we found a significant main effect of depressive symptoms. Music students with higher level of depressive symptoms rated more negatively their MPQ than music students with lower level of depressive symptoms.

Table 25 - Estimated linear mixed models for self-rated MPQ rated after the music performance

	Self-rated MPQ		
	Coeff.	*SE*	*p*
Main effects			
Between R-D	**0.81**	**0.13**	**<0.001**
Within R-D	0.12	0.13	0.34
Order	-0.54	0.37	0.15
Preparation	**0.33**	**0.11**	**0.004**
Gender	0.13	0.38	0.73
Depressive symptoms	-0.04	0.02	0.080
Time difference	0.02	0.03	0.52

Note of table 25 – Between R-D: between component of the resources-demands differential; Wihtin R-D: within component of the resources-demands differential. Model 1 tested the main effect of our factors. Significant main effects in Model 1 are written in bold. Reference categories for categorical predictors were as follows: order: private performance session first – public performance session second; gender: women. For continuous predictors, coefficients express the change in the outcome measure per unit (unit for Preparation is hour and unit for Time difference is day).

Table 26 - Estimated linear mixed models for self-rated MPQ rated one week after the last performance session with recordings

	Self-rated MPQ		
	Coeff.	*SE*	*p*
Main effects			
Between R-D	**0.78**	**0.16**	**<0.001**
Within R-D	0.10	0.13	0.41
Order	-0.29	0.45	0.51
Preparation	**0.37**	**0.11**	**0.001**
Gender	-0.20	0.46	0.66
Depressive symptoms	**-0.08**	**0.03**	**0.006**
Time difference	-0.00	0.04	0.92

Note of table 26 – Between R-D: between component of the resources-demands differential; Wihtin R-D: within component of the resources-demands differential. Model 1 tested the main effect of our factors. Significant main effects in Model 1 are written in bold. Reference categories for categorical predictors were as follows: order: private performance session first – public performance session second; gender: women. For continuous predictors, coefficients express the change in the outcome measure per unit (unit for Preparation is hour and unit for Time difference is day).

4.7.1.4. Main analyses without outliers

For each model, we had a total of 2138 observations. We dropped 18 observations (0.84%) for model 1 and 35 observations (1.64%) for model 2. As can be seen in the supplementary tables S34 and S35, in the estimated linear mixed model for self-rated MPQ evaluated after the music performance, a main effect of depressive symptoms became significant, whereas in the estimated linear mixed model for self-rated MPQ evaluated one week after the last performance session, the results after dropping the outliers did not change from the analyses with all observations.

4.7.2. Discussion

With this last research question, we investigated how the challenge-threat states evaluated before the music performance could influence the self-rated MPQ whether it was evaluated after the performance or one week after the performance using recordings.

As many studies seem to support the idea that individuals in a higher challenge state would be more likely to perform better (Behnke & Kaczmareck, 2018; Hase et al., 2019), we hypothesized music students who tend to have higher resources-demands differential level (more challenge across music performances) before the music performance would rate their MPQ more positively than music students who tend to have lower resources-demands differential level (**Hypothesis 5.1**). Our results supported this hypothesis as music students with a higher between component of the resources-demands differential rated their performance MPQ more positively than music students with a lower between components. This significant difference was visible for the MPQ assessed after the music performance but also when the MPQ was assessed one week after the last music performance with the recordings. We could therefore assume that this difference between the self-rated MPQ would not be related to an evaluation bias related to the psychophysiological state caused by the performance as mentioned in chapter 4.5.5 (e.g., if they felt more anxiety during the music

performance then they might tend to evaluate their performance more negatively - Storbeck & Clore, 2008) but rather to an increase in MPQ that would also be perceived once the psychophysiological changes of the performance were over.

To date, only one study has examined challenge and threat states in the music context (Osborne & McPherson, 2019). In contrast to our findings, this study did not find significant differences in MPQ between music students with challenge appraisals and music students with threat appraisals. These differences can be explained at different levels. Beyond the fact that this study has a small number of participants, the measurement tool used to measure challenge and threat appraisals was different from the one we used in our study. The questionnaire used by Osborne & McPherson measures primary and secondary appraisals as defined by Lazarus (2006). Primary appraisals refer to the relevance of the goal of the task performed and its importance, while secondary appraisals refer to coping skills. Based on the answers to this questionnaire, the authors observed two clusters and deduced that one group had more challenge appraisals while the other group had more threatening appraisals. One could therefore infer that the challenge appraisals used in that study and the challenge state we measured in our study are not conceptually identical. Furthermore, in the Osborne & McPherson study, the MPQ was assessed by judges, whereas in our study, the students assessed their own MPQ. Although it seems that there might be a correlation between self-rated MPQ and judge rated MPQ (Kenny, Fortune, & Ackermann, 2013), these two types of judgments may lead to different results.

We had also formulated the hypothesis that the within-person changes in resources-demands differential from the first to the second music performance session would be significantly related to the within-person changes in self-rated MPQ from the first to the second music performance session (**Hypothesis 5.2**). This hypothesis was not supported by our results, and we could therefore deduce that being in a state of challenge before a musical performance does not necessarily imply an improvement in performance. However, it is important to take these results with caution since we only have two observations by individuals (one for the private and one for the public performance.)

Finally, in line with the results obtained and discussed in chapter 4.5, we observed a main effect of preparation on both self-rated MPQ and a main effect of depressive symptoms on the self-rated MPQ evaluated one week after the last performance session with recordings.

5. General discussion and implications

This thesis was the first study to investigate how the general MPA level and the audience presence influence classical music students' HPA axis and SAM system activity, flow experience, challenge and threat states, and MPQ across a music performance. Its findings complement those of earlier studies providing a better understanding of the processes that underpin individual reactions to social-evaluative stressors over time, especially in music performance situations.

First, in line with previous studies highlighting the debilitating effect of general MPA level (e.g. Studer et al., 2014; Guyon et al., 2020a), our results showed that music students with high general MPA levels tended to be less focused on the task at hand, perceive themselves to be less in control, experience less autotelic experience, feel more in a threat state before public music performances and during private music performances, and perceive that they have fewer resources to cope with performance than music students with lower general MPA levels.

Second, our findings significantly contribute to the literature on the negative psychological effects of social-evaluative stressors (Dickerson & Kemeny, 2004) by showing which psychophysiological variables are affected by the audience's presence. Our results also allowed us to observe that the audience during a music performance compared to a music performance carried out in private caused in the music students an increase in HPA axis activation, in particular, an increase in sC and sDHEA secretion and a decrease in the anabolic balance, a decrease in the feeling of control, an alteration of the perception of time, and an increase in the perceived demands of the situation.

Third, as observed in previous studies (e.g., Craske & Craig, 1984, Fredrikson & Gunnarsson, 1992; Nielsen et al., 2018; Guyon et al., 2020a), we also found that the general MPA level and audience presence could jointly influence music students' psychological responses to a music performance. Music students with a general MPA level above 47 perceived more ambiguous feedback when performing in front of an audience, music students with an MPA level above 32 had a lower level of self-consciousness during the public performance, and music students with an MPA level between 35 and 57 were in a more threat state during the public performance session than during the private performance session. In addition, music students with higher general MPA level had a higher threat state than music students with lower general MPA level but only before the public music performance and during the private music performance.

Fourth, we found that time played an important role, particularly in the music students' physiological responses to psychosocial stressors. Both in agreement and disagreement with previous studies (Aufegger & Wasley, 2018; Tùran et al., 2022), our results supported that the audience presence causes an increased HPA axis activation before the beginning of the music performance but also after the end of the music performance. Similarly, the SAM activation increased after the music performance but was not influenced by the audience's presence. At the psychological level, we observed that music students rated the MPQ of their public music performance more negatively than the MPQ of their private music performance only one week after the last performance session.

Fifth, this thesis provides additional support to the recommendation, in line with the original multidimensional perspective on flow, that whenever possible the flow experience should be analyzed at the level of its nine dimensions rather than as a global score since the effects of audience presence and general MPA level vary greatly across the nine flow dimensions. (Jackson & Eklund, 2002).

Finally, this thesis highlights the validity and utility of the BPSM of challenge and threat as a framework by which performance variability can be examined, understood, and predicted in the field of music performance. The BPSM of challenge and threat postulates that an individual's performance depends mainly on his or her evaluation of the situation (Blascovich, 2008). It would then be based on these evaluations that physiological changes would take place and influence performance. Overall, our results suggest that the general level of MPA may not influence the HPA axis or the activity of the SAM system, nevertheless, it may influence most of the psychological variables we studied and particularly the challenge and threat states.

Although influenced by the general MPA level and audience presence, the level of challenge and threat state seems to evolve over time and in general, music students who were more in a challenge state tended to evaluate their performance quality more positively than individuals who were more in a threat state. These findings seem to be promising information for the development and implementation of interventions in the context of music

performances. To date, many studies have investigated arousal reappraisal in motivated performance situations (e.g., Jamieson et al., 2010; Jamieson et al., 2013; Beltzer et al., 2014; Moore et al., 2015; Jamieson et al., 2016; Yeager, Lee, & Jamieson, 2016). Similar to cognitive behavioral therapy programs, stress reappraisal consists of modifying the cognitive appraisals of an individual in order to promote a favorable behavior towards the performance situation while maintaining the increase in arousal that is necessary to achieve the performance (Jamieson et al., 2013). More concretely, individuals are told that the physiological arousal linked to the stress felt during a performance is not debilitating but must be perceived as a resource that can help them to achieve a better performance (Beltzer et al., 2014). At the psychological level, people who used stress reappraisal when exposed to a psychosocial stressor reported a decrease in feelings of shame, feelings of anxiety, as well as an increase in perceived coping resources, and more challenge state than people who did not use stress reappraisal (Beltzer et al., 2014; Jamieson et al., 2016; Jacquart et al., 2020).

At the physiological level, some researchers observed an increase in sAA activity in individuals using stress reappraisal compared to a control group, but no difference was observed in heart rate, cardiac output, and total peripheral resistance between individuals in a reapparaisal condition and individuals in a control condition (Jamieson et al., 2010; Moore et al., 2015). However, another study showed a cardiac output increase and a vascular resistance decrease in individuals who were instructed to do arousal reappraisal compared to individuals who did not receive any instruction (Jamieson et al., 2013). At the behavioral level, a decrease in non-verbal signals was found in people who used stress reappraisal compared to people who did not use it (Beltzer et al., 2014). Finally, these studies have shown an improvement in performance during a speech, a math exam or a golf putting experience (Jamieson et al., 2010; Beltzer et al., 2014; Moore et al., 2015). This improvement in performance is visible within the same individual since with stress reappraisal, individuals perform better than without stress reappraisal, but also between individuals since those who used reappraisal seem to perform better than those who did not use reappraisal (Jamieson et al., 2010; Moore et al., 2015; Jamieson et al., 2016). A previous study investigated stress reappraisal in socially anxious individuals in a social evaluation context and observed that stress reappraisal significantly increased the level of perceived coping resources in socially anxious individuals compared to socially anxious who received no instructions (Jamieson et al., 2013). In addition, this study found that socially anxious had better performance with the stress reappraisal instruction than with no instructions. Another important area of research would be the possible benefits that music students could obtain from stress reappraisal in the context of a music performance whether it is for their well-being, health, and performance outcomes.

5.1. Limitations[7]

The inclusion of a habituation session in the study procedure is a strength of the present thesis. Yet, due to several factors (i.e., Covid-19 pandemic, personal issues, rescheduling of the appointments), the time between the habituation session and the first performance session was longer than originally planned (around 30days) for numerous participants (mean of 68 days). In addition, participants were allowed to play/sing freely (e.g., any pieces with or without scores) during the habituation session. This was not the case during

[7] The chapter 5.1 is based on a published article (Guyon et al., 2020b).

the performance sessions. These factors may have contributed to a weaker habituation effect than initially anticipated and indirectly, at least partly, to the above-mentioned significant differences between first and second performance sessions obtained for four flow dimensions. Future studies should organize a habituation session closer in time to the performance sessions and reproduce more closely the conditions of the performance sessions.

As it can be seen in the supplementary table S3, Cronbach's alphas were good to excellent for seven of the nine flow dimensions. Yet, for unambiguous feedback and action-awareness merging they were lower than 0.70 (for all subjects and the French version). The validation of the French version of the FSS-2 by Fournier et al. (2007) was conducted with a sample of athletes. The flow experience of athletes and musicians may be different (Habe, Biasutti, & Kajtna, 2019). It might therefore be important to conduct a validation study with French-speaking musicians as well to determine if the reliability of the subscales assessing these two dimensions can be improved.

One of the other limitations that can be raised in this study is the use of audio recordings to assess MPQ performance. As mentioned in the discussion of this research question, we could not control the number of times the recordings were listened to, and the temporal proximity of the ratings may have increased the chances of different MPQ levels between the two musical performances. To avoid this problem, a future study could ask music students to assess the MPQ of their performances at two different points in time using audio recordings each time.

For our last research question, we disaggregate the resources-demands variable into its between and within-component, however, for each music students we only had two repeated measures. More observations would be needed to be able to generalize these results.

Finally, this thesis only looked at music students' psychophysiological responses in two contexts of short music performances in the laboratory. To generalize these results, it would be necessary to investigate if the effects found in this thesis are observed in other more naturalistic contexts (e.g., actual audition or concert) during longer performances as well as in different musician populations (e.g., musicians who finished their studies or jazz musicians).

5.2. Further research

We introduced this thesis with a question: "Is the music performance anxiety in classical music students a matter of challenge and threat?" Although our results provide some insight into this initial question, it does not provide a complete answer. In the literature, challenge and threat states are generally associated with different psychological (e.g., motivational tendencies), physiological (e.g., cardiovascular patterns) and behavioral (e.g., performance) responses.

At the psychological level, among the nine flow dimensions, the challenge-skills balance seem to be the closest conceptually to the resources-demands evaluations. As described by the flow experience theory (Nakamura & Csikszentmihalyi, 2009), the dimension challenge-skill balance intends to measure the perceived balance between the perceived situation challenge induced by the activity and the perceived personal skills to overcome it. As observed in our findings for the challenge state, the flow experience may improve MPQ (Kirchner, Bloom, & Skutnick-Henley, 2008; Clark, Lisboa, & Williamon, 2014; Iusca, 2015). Although these two variables seem to have similarities at the conceptual level and seem to be able to

improve MPQ, our results show that the challenge-skills balance dimension was not influenced by either the general level of MPA or the presence of the audience, whereas the challenge and threat state was. Based on flow research and our results, a natural progression of this work would be to investigate to what extent the challenge-skills balance and the challenge and threat state are conceptually different and to what extent they interact to influence the MPQ. Furthermore, we only considered the general MPA level, but the MPA state was also measured during this experiment. It might have been important to investigate how MPA state was also influencing our variables of interest.

Considering the physiological variables, as indicated in the methodology section, the number of physiological variables measured was much larger than the number of physiological variables analyzed in this thesis. Among these additional variables, we measured heart rate, ventricular contractility, cardiac output, and total peripheral resistance. According to the BPSM of challenge and threat, these measures would make it possible to determine if people are engaged in the task being performed but also to know if they are more in a challenge state than a threat state and vice versa. Indeed, the more engaged a person would be in a task relevant to their goal, the more their heart rate and ventricular contractility would increase. In addition, people in the challenge state would have higher cardiac output and lower total peripheric resistance than people in a threat state. These cardiovascular patterns have been widely studied in the literature and are of particular interest because perceived resources and demands evaluations obtained via questionnaire do not measure the unconscious component of these evalutions (Tomaka et al., 1993; Tomaka et al., 1997; Blascovich, 2008; Moore et al., 2012; Turner et al., 2012; Moore et al., 2013; Turner et al., 2014). The next logical step in this thesis would therefore be to determine if music students were engaged in the music performance and had distinct cardiovascular patterns that could be associated with a more challenging or more threatening state. We could then determine if the general MPA level and the audience presence influence these response patterns. Finally, we could also investigate whether these cardiovascular patterns predict MPQ. The existence of a weak to moderate correlation between cardiovascular patterns and levels of resources and perceived demands (Hase et al., 2019) still suggests that we should observe similar results to those obtained with the resources-demands differential. It is important to note that most studies investigating the cardiovascular responses of music students according to their general MPA level have not found significant differences in heart rate and heart rate variability. However, differences were observed at the respiratory level (e.g., Guyon et al., 2020a). Respiratory measurements were performed in this study. First, one can ask whether challenge and threat states are associated with respiratory patterns, and second, one can ask whether these respiratory patterns can also predict MPQ.

Through this thesis, we have chosen to investigate the influence of the same predictor variables (general MPA level, presence of the audience, and for some research questions time) on different outcome variables. Nevertheless, the use of a model grouping together all these variables seems justified. For example, our results show that the general MPA level influences the challenge-threat state but also the MPQ. However, the MPQ is also influenced by the challenge-threat state. Therefore, it is possible that the challenge-threat state plays a mediating role in the relationship between the general MPA level and MPQ. The next step in this thesis would therefore be to use a more complex model taking into account the potentially mediating role of certain variables.

In conclusion, we can estimate that the challenge-threat state is influenced by the general MPA level and does have an influence on a classical music student's MPQ. However, there are

still many questions that need to be addressed before we can state that music performance anxiety is a matter of challenge and threat.

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7. Supplementary materials

7.1. General method

Supplementary table S1 - List of pieces performed by the participants ordered by instrument with the number of participants performing each piece

N	Music pieces performed
	Accordion
1	Haydn – Sonata in D major Hob XVI 37 – 1st movement Allegro con brio – without repetitions
	Bassoon
6	Mozart – Concerto for bassoon in B-flat major K.191 – 1st movement Allegro – Bars 35-152
	Cello
6	Haydn – Cello concerto n°1 in C major Hob.VIIb.1 – 1st movement Allegro – Bars 22-89
5	Haydn – Cello concerto n°2 in D major Hob.VIIb.2 – 1st movement Allegro moderato – Bars 29-106
	Clarinet
7	Mozart – Clarinet concerto in A major K.622 – 1st movement Allegro – Bars 57 - 192
	Double Bass
3	Dittersdorf – Concerto for double bass n°2 Kr.172 – 1st movement Allegro moderato with cadenza by Gruber
1	Vanhal – Concerto for double bass in D major – 1st movement Allegro moderato
	Flute
2	Mozart – Flute concerto n°1 in G major K.313 – 1st movement Allegro maestoso – Bars 31-149
5	Mozart – Flute concerto n°2 in D major K.314 – 1st movement Allegro aperto – Bars 32-151
	Guitar
1	Craeyvanger – Introduction and variations on a theme from the Opera "Der Freischütz" from Von Weber
1	Giuliani – Concerto for guitar n°1 in A major, Op. 30 – 1st movement Allegro maestoso – Bars 106-206
1	Matiegka – Guitar sonata, Op.23
1	Coste – La source du Lyson, Op.47 – Rondeau villageois Allegretto
1	Sor – Fantaisie N°6 ('Les Adieux') for Guitar, Op. 21. – Bars 1-68
	Horn
3	Mozart – Horn concerto n°2 in E flat major KV.417 – 1st movement Allegro maestoso
1	Mozart – Horn concerto n°4 in E flat K.495 – 1st movement Allegro moderato – Bars 36-189
	Oboe
12	Mozart – Oboe Concerto in C major K.314/271k – 1st movement Allegro aperto
	Piano
1	Haydn – Sonata n°60 in C major Hob.XVI.50 – 1st movement Allegro – Bars 1-53 & 102-150 - without repetitions
1	Mozart - Rondo in D major k485
1	Mozart – Sonata n°6 in D major K.284/205b – 1st movement Allegro –without repetitions
2	Mozart – Sonata n°7 in C major K.309/284b – 1st movement Allegro con spirito – without repetitions
1	Mozart – Sonata n°8 in A minor K.310/300d – 1st movement Allegro maestoso – without repetitions

4	Mozart – Sonata n°10 in C major K.330/300h – 1st movement Allegro moderato – without repetitions
1	Mozart – Sonata n°12 in F major K.332 – 1st movement Allegro – Bars 1-176 – without repetitions
3	Mozart – Sonata n°14 in C minor K.457 – 1st movement Molto allegro – without repetitions
	Saxophone
1	Telemann – Fantasia n°2 in A minor Grave - Vivace - Adagio – Allegro
1	Telemann – Fantasia n°10 in F-sharp minor A Tempo giusto – Presto – Moderato
	Trombone
2	David – Concertino for trombone in E-flat major – 1st movement Allegro maestoso
2	Handel – Concerto in F minor – 2nd and 4th movements Allegro
	Trumpet
3	Haydn – Concerto for trumpet in E-flat major Hob.VIIe:1 – 1st movement Allegro
2	Hummel – Trumpet concerto in E-flat major S.49 – 1st movement Allegro con spirito – Bars 66-224
	Viola
3	Hoffmeister – Viola concerto in D major – 1st movement Allegro
	Violin
1	Bach – Partita no°2 in D minor – Allemande
2	Mozart – Violin concerto n°3 in G major K.216 – 1st movement Allegro – Bars 38-192
4	Mozart – Violin concerto n°4 in D major K.218 – 1st movement Allegro – Bars 42-177
6	Mozart – Violin concerto n°5 in A major K.219 – 1st movement Allegro aperto – Bars 40-139
	Voice
	Baritone
2	Mozart – Die Zauberflöte – Ein Mädchen oder Weibchen
	Countertenor
1	Mozart – La Clemenza di Tito – Deh per questo istante –Adagio only
	Mezzo-Soprano
1	Mozart – Ascanio in Alba - Ah di sì nobil alma
	Soprano
3	Mozart – Così fan tutte - Una donna a quindici anni
1	Mozart - Così fan tutte – Ah, scostati! ... Smanie implacabili
2	Mozart – Dans un bois solitaire
3	Mozart – Die Zauberflöte - Ach ich fühl's, es ist verschwunden!
1	Mozart – Don Giovanni - Batti, batti oh bel Masetto
1	Mozart - Le nozze di Figaro - Dove sono i bei momenti - without recitativo
5	Mozart - Le nozze di Figaro - Giunse alfin il momento...Deh vieni, non tardar
2	Mozart - Le nozze di Figaro - Venite inginocchiatevi
	Tenor
1	Mozart - Le nozze di Figaro – Un' aura amorosa

Supplementary table S2 - MPQ scale

Tempo

Tempo refers to the execution speed of a piece of music (e.g., largo, adagio, andante, allegro) and to the time management of bars and/or tone groups. This may also include tempo variations (ex. Accelerando, Ritardando, unequal notes).

Please use the scale below (1 = worst mark, 6 = best mark) to evaluate the interpretation of the tempo of the performance in terms of stability, accuracy and consistency with the printed tempo markings and with the composer´s style.

1	1.25	1.5	1.75	2	2.25	2.5	2.75	3	3.25	3.5	3.75	4	4.25	4.5	4.75	5	5.25	5.5	5.75	6

Rhythm

Rhythm refers to the musical event organization in time forming a temporal structure.

Please use the scale below (1 = worst mark, 6 = best mark) to evaluate the interpretation of the rhythmic patterns and characteristics of the performance in terms of accuracy, clarity, character and consistency with the composer´s style.

1	1.25	1.5	1.75	2	2.25	2.5	2.75	3	3.25	3.5	3.75	4	4.25	4.5	4.75	5	5.25	5.5	5.75	6

Intonation

Intonation refers to the accuracy of pitches in relation to each other and/or to a fixed standard.

Please use the scale below (1 = worst mark, 6 = best mark) to evaluate the intonation quality of the performance in terms of accuracy and consistency across ranges and registers.

1	1.25	1.5	1.75	2	2.25	2.5	2.75	3	3.25	3.5	3.75	4	4.25	4.5	4.75	5	5.25	5.5	5.75	6

Tone

Tone refers to the sound produced by the instrument.

Please use the scale below (1 = worst mark, 6 = best mark) to evaluate the overall tone quality of the performance by referring to the projection, the color, the character, the variability and the control of the sound across ranges and registers as well as the richness of the overtone spectrum.

1	1.25	1.5	1.75	2	2.25	2.5	2.75	3	3.25	3.5	3.75	4	4.25	4.5	4.75	5	5.25	5.5	5.75	6

Dynamics

The dynamics of a piece refers to the variations in loudness between notes or phrases (e.g., piano, forte, crescendo, decrescendo, dynamic contrasts).

Please use the scale below (1 = worst mark, 6 = best mark) to evaluate the interpretation of the dynamics of the performance in terms of accuracy, expressivity, variability and consistency with the printed dynamics marking.

1	1.25	1.5	1.75	2	2.25	2.5	2.75	3	3.25	3.5	3.75	4	4.25	4.5	4.75	5	5.25	5.5	5.75	6

Articulation

Articulation refers to the way in which the transition from one sound to another occurs (e.g., legato, staccato, accents, ornamentation).

Please use the scale below (1 = worst mark, 6 = best mark) to evaluate the interpretation of the articulation of the performance in terms of accuracy, clarity and consistency with the printed articulation marking and with the composer´s style.

1	1.25	1.5	1.75	2	2.25	2.5	2.75	3	3.25	3.5	3.75	4	4.25	4.5	4.75	5	5.25	5.5	5.75	6

Musical understanding, interpretation and expressive involvement

Musical understanding, interpretation and expressive involvement refer to the performer's understanding and respect of the intention, the aesthetic and the musical idea given by the composer to the piece. It also includes the expressive involvement of the performer in the music.

Please use the scale below (1 = worst mark, 6 = best mark) to evaluate the musical understanding and the interpretation of the performance.

1	1.25	1.5	1.75	2	2.25	2.5	2.75	3	3.25	3.5	3.75	4	4.25	4.5	4.75	5	5.25	5.5	5.75	6

Missing notes, wrong notes and unwritten breaks

Missing notes are notes which are written in the scores but which are omitted during music production.
Wrong notes are produced notes, which are different from the notes in the original score.
Unwritten breaks refer to pauses or stops not written in the original score.

Please use the scale below (1 = A lot of missing, wrong notes and/or unwritten breaks, 6 = No missing, wrong notes and/or unwritten breaks) to evaluate globally the missing, wrong notes and/or unwritten breaks frequency in the performance.

1	1.25	1.5	1.75	2	2.25	2.5	2.75	3	3.25	3.5	3.75	4	4.25	4.5	4.75	5	5.25	5.5	5.75	6

Global appreciation

Global appreciation refers to the overall quality of the performance.

Please use the scale below (1 = worst mark, 6 = best mark) to evaluate the overall quality of the performance.

1	1.25	1.5	1.75	2	2.25	2.5	2.75	3	3.25	3.5	3.75	4	4.25	4.5	4.75	5	5.25	5.5	5.75	6

Supplementary table S3 - Cronbach's alphas for all nine flow dimensions

	Private performance session						Public performance session					
	All subjects		English version		French version		All subjects		English version		French version	
	All observations	w.o. outliers	All observations	w.o. outliers	All observations	w.o. outliers	All observations	w.o. outliers	All observations	w.o. outliers	All observations	w.o. outliers
CS	0.81	0.89	0.91		0.80	0.89	0.84	0.89	0.87		0.84	0.89
UF	0.66	0.69	0.70	0.86	0.67		0.72	0.74	0.88		0.68	0.70
CG	0.83	0.86	0.93		0.83	0.85	0.84		0.93		0.82	
AM	0.68	0.72	0.85		0.63	0.68	0.69	0.72	0.86		0.66	0.70
CT	0.94	0.95	0.90	0.94	0.95	0.95	0.91	0.93	0.90	0.93	0.92	0.93
SC	0.87		0.92		0.86		0.90		0.95		0.89	
LS	0.87	0.89	0.84	0.87	0.88	0.89	0.88	0.90	0.83	0.83	0.87	0.90
TT	0.86	0.91	0.81		0.88	0.92	0.88	0.91	0.66		0.89	0.92
AE	0.90	0.90	0.93		0.89	0.90	0.90	0.90	0.94		0.90	0.90

Note of Supplementary table S3 – w.o. outliers: Cronbach's alpha calculated excluding outliers; CS: Challenge-skill balance; UF: Unambiguous feedback; CG: Clear goals; AM: action-awareness merging; CT: Concentration on task at hand; SC: Sense of control; LS: Loss of self-consciousness; TT: Transformation of time; AE: Autotelic experience

7.2. Research question 1

Supplementary table S4 - Estimated linear mixed models for sC without outliers

	sC					
	Model 1			*Model 2*		
	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*
Main effects						
General MPA level	-0.00	0.00	0.64	-0.00	0.01	0.92
Session	**0.65**	**0.05**	**<0.001**	0.16	0.12	0.19
Time			**<0.001**			<0.001
Order	**-0.23**	**0.09**	**0.010**	-0.26	0.15	0.088
Hour	**-0.25**	**0.09**	**0.006**	-0.48	0.14	0.001
Preparation	-0.03	0.03	0.25	-0.03	0.04	0.43
Gender	**0.21**	**0.10**	**0.027**	-0.07	0.18	0.72
Depressive symptoms	-0.00	0.01	0.76	0.01	0.01	0.24
Time difference	0.01	0.01	0.26	0.02	0.01	0.15
Interactions						
General MPA level x session				0.00	0.00	0.81
General MPA level x time						0.58
General MPA level x hour				0.01	0.01	0.48
General MPA level x order				-0.00	0.01	0.94
Session x time						**<0.001**
Session x hour				0.14	0.09	0.15
Session x order				-0.01	0.14	0.96
Time x hour						0.89
Time x order						0.69
Gender x session				0.11	0.10	0.27
Gender x time						**0.012**
Gender x hour				0.30	0.20	0.13
Gender x order				0.15	0.20	0.44
Depressive symptoms x session				-0.00	0.01	0.58
Depressive symptoms x time						0.94
Depressive symptoms x hour				-0.01	0.01	0.57
Depressive symptoms x order				-0.02	0.01	0.17
Time difference x session				0.01	0.01	0.34
Time difference x time						0.56
Time difference x hour				-0.02	0.02	0.32
Time difference x order				-0.02	0.02	0.25

Note of suuplementary table S4 - Model 1 tested the main effect of our factors and Model 2 tested the interactions of our factors. Significant main effects in Model 1 and significant interaction effect in Model 2 are written in bold. Reference categories for categorical predictors were as follows: session: private performance session; time: S1; hour: early afternoon; order: private performance session first – public performance session second; gender: women. For continuous predictors, coefficients express the change in the outcome measure per unit (unit for Preparation is hour and unit for Time difference is day).

Supplementary table S5 - Estimated linear mixed models for sDHEA without outliers

	sDHEA					
	Model 1			*Model 2*		
	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*
Main effects						
General MPA level	-0.00	0.00	0.68	0.00	0.01	0.90
Session	**0.25**	**0.03**	**<0.001**	0.09	0.07	0.19
Time			**<0.001**			<0.001
Order	-0.02	0.09	0.77	-0.04	0.13	0.73
Hour	-0.05	0.09	0.55	-0.05	0.13	0.68
Preparation	-0.03	0.01	0.071	-0.02	0.02	0.43
Gender	0.00	0.09	0.96	0.02	0.16	0.91
Depressive symptoms	-0.00	0.01	0.68	0.00	0.01	0.72
Time difference	0.00	0.01	0.89	0.02	0.01	0.14
Interactions						
General MPA level x session				-0.00	0.00	0.14
General MPA level x time						0.94
General MPA level x hour				0.00	0.01	0.72
General MPA level x order				-0.00	0.01	0.68
Session x time						**<0.001**
Session x hour				0.02	0.05	0.74
Session x order				0.03	0.08	0.69
Time x hour						0.44
Time x order						0.44
Gender x session				-0.02	0.06	0.80
Gender x time						0.24
Gender x hour				0.03	0.19	0.89
Gender x order				-0.01	0.19	0.98
Depressive symptoms x session				-0.00	0.00	0.51
Depressive symptoms x time						0.75
Depressive symptoms x hour				0.00	0.01	0.96
Depressive symptoms x order				-0.01	0.01	0.34
Time difference x session				-0.00	0.00	0.78
Time difference x time						0.78
Time difference x hour				-0.01	0.01	0.45
Time difference x order				-0.03	0.02	0.058

Note of Supplementary table S5 - Model 1 tested the main effect of our factors and Model 2 tested the interactions of our factors. Significant main effects in Model 1 and significant interaction effect in Model 2 are written in bold. Reference categories for categorical predictors were as follows: session: private performance session; time: S1; hour: early afternoon; order: private performance session first – public performance session second; gender: women. For continuous predictors, coefficients express the change in the outcome measure per unit (unit for Preparation is hour and unit for Time difference is day).

Supplementary table S6 - Estimated linear mixed models for anabolic balance without outliers

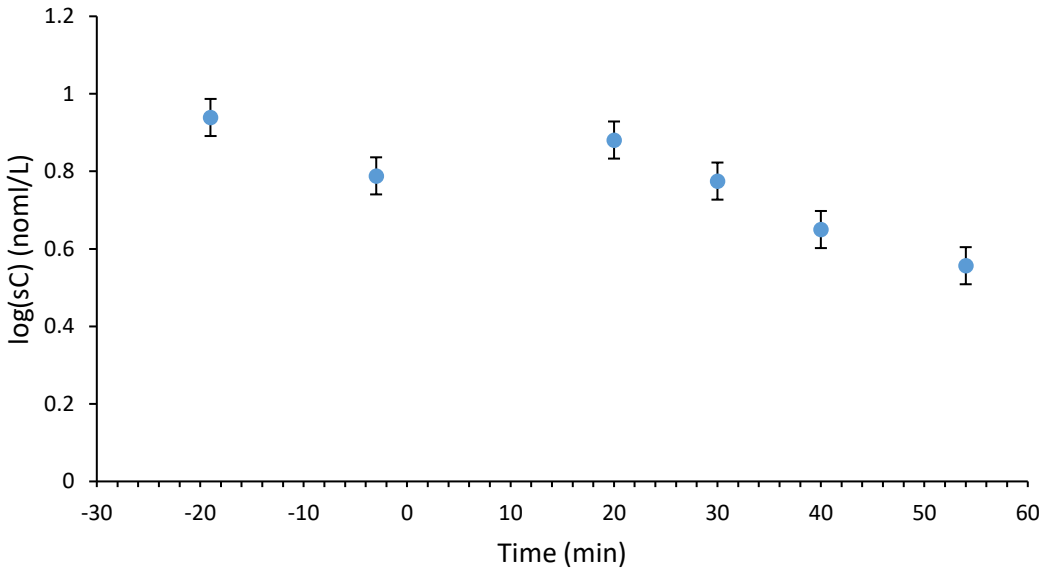
	Anabolic balance					
	Model 1			*Model 2*		
	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*
Main effects						
General MPA level	0.00	0.01	0.94	0.00	0.01	0.77
Session	**-0.36**	**0.04**	**<0.001**	-0.07	0.09	0.48
Time			**<0.001**			<0.001
Order	**0.22**	**0.11**	**0.045**	0.28	0.17	0.11
Hour	0.19	0.11	0.087	0.38	0.17	0.025
Preparation	-0.00	0.02	0.97	0.02	0.03	0.58
Gender	-0.17	0.12	0.14	0.10	0.21	0.63
Depressive symptoms	0.00	0.01	0.93	-0.01	0.01	0.58
Time difference	-0.01	0.01	0.54	-0.00	0.02	0.87
Interactions						
General MPA level x session				-0.00	0.00	0.24
General MPA level x time						0.73
General MPA level x hour				-0.00	0.01	0.83
General MPA level x order				-0.00	0.01	0.79
Session x time						**<0.001**
Session x hour				-0.10	0.07	0.19
Session x order				0.07	0.11	0.52
Time x hour						0.56
Time x order						0.84
Gender x session				-0.12	0.08	0.12
Gender x time						**0.012**
Gender x hour				-0.23	0.25	0.35
Gender x order				-0.22	0.25	0.38
Depressive symptoms x session				0.00	0.00	0.69
Depressive symptoms x time						0.89
Depressive symptoms x hour				0.01	0.02	0.60
Depressive symptoms x order				0.00	0.02	0.77
Time difference x session				-0.01	0.01	0.17
Time difference x time						0.62
Time difference x hour				0.00	0.02	0.80
Time difference x order				-0.01	0.02	0.62

Note of Supplementary table S6 - Model 1 tested the main effect of our factors and Model 2 tested the interactions of our factors. Significant main effects in Model 1 and significant interactions in Model 2 are written in bold. Reference categories for categorical predictors were as follows: session: private performance session; time: S1; hour: early afternoon; order: private performance session first – public performance session second; gender: women. For continuous predictors, coefficients express the change in the outcome measure per unit (unit for Preparation is hour and unit for Time difference is day).

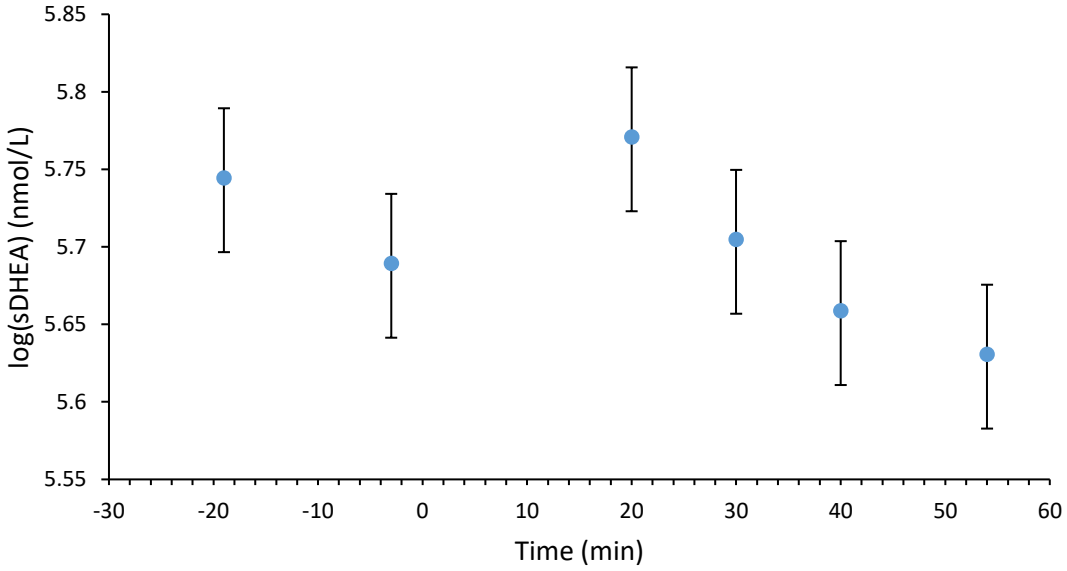
Supplementary table S7 - Estimated linear mixed models for sAA without outliers

	sAA					
	Model 1			*Model 2*		
	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*
Main effects						
General MPA level	0.00	0.01	0.91	-0.01	0.01	0.63
Session	0.02	0.03	0.42	-0.11	0.08	0.16
Time						<0.001
Order	-0.06	0.14	0.68	-0.19	0.20	0.35
Hour	-0.01	0.14	0.94	-0.05	0.20	0.79
Preparation	-0.02	0.02	0.17	-0.01	0.02	0.58
Gender	0.20	0.15	0.19	0.05	0.26	0.86
Depressive symptoms	0.01	0.01	0.55	0.02	0.02	0.30
Time difference	-0.02	0.01	0.093	0.00	0.02	0.83
Interactions						
General MPA level x session				0.00	0.00	0.90
General MPA level x time						0.42
General MPA level x hour				-0.00	0.01	0.99
General MPA level x order				0.02	0.01	0.26
Session x time						0.08
Session x hour				0.09	0.06	0.14
Session x order				0.04	0.09	0.66
Time x hour						**0.02**
Time x order						0.57
Gender x session				-0.02	0.06	0.73
Gender x time						**<0.001**
Gender x hour				0.06	0.31	0.86
Gender x order				0.37	0.30	0.23
Depressive symptoms x session				0.00	0.00	0.44
Depressive symptoms x time						0.10
Depressive symptoms x hour				0.01	0.02	0.62
Depressive symptoms x order				-0.03	0.02	0.11
Time difference x session				0.00	0.00	0.31
Time difference x time						0.30
Time difference x hour				-0.01	0.02	0.55
Time difference x order				-0.05	0.03	0.071

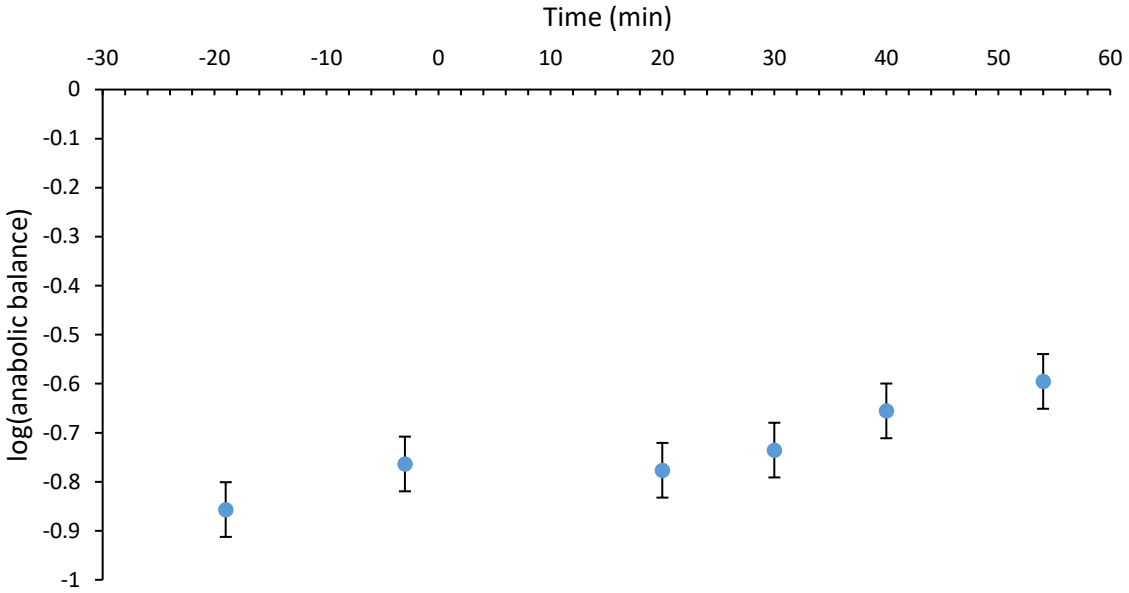
Note of Supplementary table S7 - Model 1 tested the main effect of our factors and Model 2 tested the interactions of our factors. Significant main effects in Model 1 and significant interactions in Model 2 are written in bold. Reference categories for categorical predictors were as follows: session: private performance session; time: S1; hour: early afternoon; order: private performance session first – public performance session second; gender: women. For continuous predictors, coefficients express the change in the outcome measure per unit (unit for Preparation is hour and unit for Time difference is day).



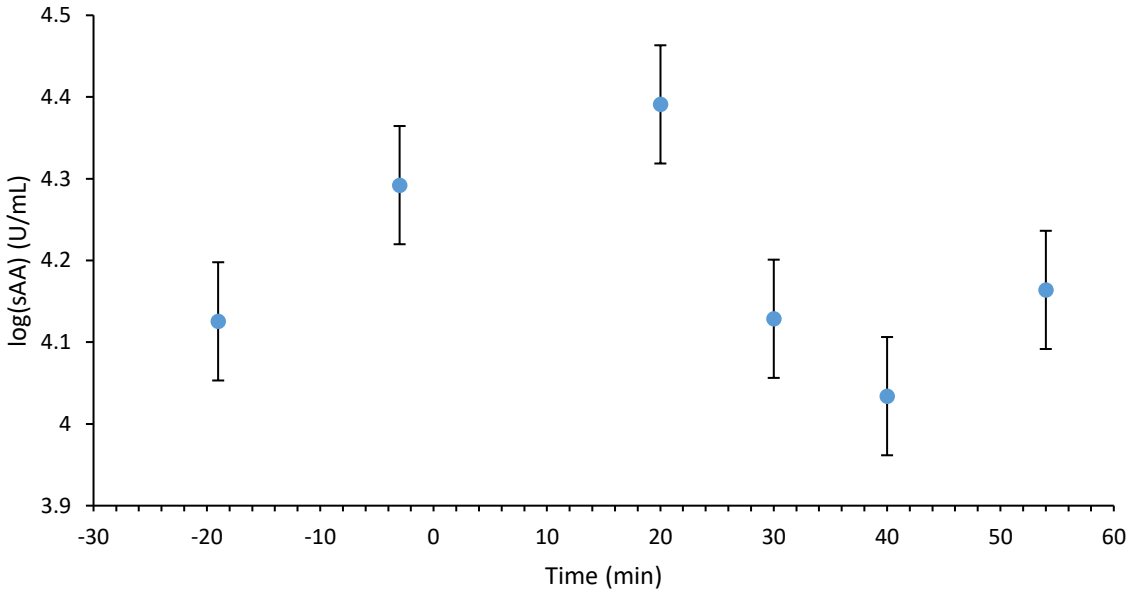
Supplementary figure S1. Model-predicted marginal means (SEs) for sC across time



Supplementary figure S2. Model-predicted marginal means (SEs) for log(sDHEA) across time



Supplementary figure S3. Model-predicted marginal means (SEs) for log(anabolic balance) across time



Supplementary figure S4. Model-predicted marginal means (SEs) for log(sAA) across time

Supplementary table S8 - Time x session interaction contrasts for log(sC)

Time point	Session		Time point	Session	Contrast	Std. Err.	z	P>|z|	Corrected P>|z|
S1	Public	vs	S1	Private	0.27	0.07	3.86	<0.001	<0.001
S3	Private	vs	S1	Private	-0.28	0.04	-6.77	<0.001	<0.001
S6	Private	vs	S1	Private	-0.53	0.04	-12.45	<0.001	<0.001
S3	Public	vs	S1	Public	0.17	0.04	4	<0.001	<0.001
S6	Public	vs	S1	Public	-0.24	0.04	-5.55	<0.001	<0.001
S2	Public	vs	S2	Private	0.28	0.06	4.48	<0.001	<0.001
S3	Public	vs	S2	Public	0.31	0.04	8.5	<0.001	<0.001
S3	Public	vs	S3	Private	0.72	0.05	13.57	<0.001	<0.001
S4	Private	vs	S3	Private	-0.11	0.02	-4.46	<0.001	<0.001
S6	Private	vs	S3	Private	-0.24	0.03	-8.75	<0.001	<0.001
S4	Public	vs	S3	Public	-0.10	0.02	-4.19	<0.001	<0.001
S6	Public	vs	S3	Public	-0.40	0.03	-14.49	<0.001	<0.001
S4	Public	vs	S4	Private	0.73	0.05	14.44	<0.001	<0.001
S5	Private	vs	S4	Private	-0.10	0.02	-4.58	<0.001	<0.001
S5	Public	vs	S4	Public	-0.15	0.02	-6.93	<0.001	<0.001
S5	Public	vs	S5	Private	0.68	0.05	13.37	<0.001	<0.001
S6	Public	vs	S5	Public	-0.15	0.03	-5.92	<0.001	<0.001
S6	Public	vs	S6	Private	0.56	0.05	10.46	<0.001	<0.001
S2	Private	vs	S1	Private	-0.16	0.05	-3.25	0.001	0.004
S3	Private	vs	S2	Private	-0.13	0.04	-3.44	0.001	0.003
S2	Public	vs	S1	Public	-0.14	0.05	-2.95	0.003	0.006
S6	Private	vs	S5	Private	-0.04	0.03	-1.38	0.17	0.17

Supplementary table S9 - Time x session interaction contrasts for log(sDHEA)

Time point	Session		Time point	Session	Contrast	Std. Err.	z	P>|z|	Corrected P>|z|
S6	Private	vs	S1	Private	-0.13	0.03	-4.27	>0.001	>0.001
S3	Public	vs	S1	Pubic	0.13	0.03	4.25	>0.001	>0.001
S2	Public	vs	S2	Private	0.16	0.03	4.7	>0.001	>0.001
S3	Public	vs	S2	Public	0.17	0.02	6.98	>0.001	>0.001
S3	Public	vs	S3	Private	0.33	0.04	9.45	>0.001	>0.001
S6	Public	vs	S3	Public	-0.22	0.03	-8.13	>0.001	>0.001
S4	Public	vs	S4	Private	0.30	0.04	8.13	>0.001	>0.001
S5	Public	vs	S5	Private	0.30	0.03	8.67	>0.001	>0.001
S6	Public	vs	S6	Private	0.17	0.04	4.59	>0.001	>0.001
S1	Public	vs	S1	Private	0.14	0.04	3.27	0.001	0.013
S4	Public	vs	S3	Public	-0.09	0.03	-3.3	0.001	0.012
S6	Public	vs	S5	Public	-0.09	0.03	-3.43	0.001	0.011
S6	Public	vs	S1	Public	-0.09	0.03	-3.04	0.002	0.020
S3	Private	vs	S1	Private	-0.07	0.03	-2.47	0.014	0.126
S2	Private	vs	S1	Private	-0.07	0.023	-2.33	0.020	0.16
S6	Private	vs	S3	Private	-0.06	0.03	-2.2	0.028	0.20
S5	Private	vs	S4	Private	-0.05	0.03	-1.91	0.056	0.34
S4	Private	vs	S3	Private	-0.05	0.03	-1.79	0.073	0.37
S5	Public	vs	S4	Public	-0.04	0.03	-1.66	0.096	0.38
S2	Public	vs	S1	Public	-0.04	0.03	-1.52	0.13	0.39
S6	Private	vs	S5	Private	0.04	0.03	1.35	0.18	0.36
S3	Private	vs	S2	Private	-0.01	0.02	-0.26	0.80	0.80

Supplementary table S10 - Time x session interaction contrasts for log(anabolic balance)

Time point	Session		Time point	Session	Contrast	Std. Err.	z	P>|z|	Corrected P>|z|
S3	Private	vs	S1	Private	0.20	0.03	5.86	<0.001	<0.001
S6	Private	vs	S1	Private	0.38	0.04	10.4	<0.001	<0.001
S6	Public	vs	S1	Public	0.14	0.04	3.82	<0.001	<0.001
S3	Private	vs	S2	Private	0.11	0.03	3.55	<0.001	<0.001
S3	Public	vs	S2	Public	-0.14	0.03	-4.36	<0.001	<0.001
S3	Public	vs	S3	Private	-0.39	0.04	-8.83	<0.001	<0.001
S6	Private	vs	S3	Private	0.18	0.03	6.03	<0.001	<0.001
S6	Public	vs	S3	Public	0.18	0.03	6.26	<0.001	<0.001
S4	Public	vs	S4	Private	-0.43	0.04	-10.04	<0.001	<0.001
S5	Public	vs	S4	Public	0.11	0.03	3.9	<0.001	<0.001
S5	Public	vs	S5	Private	-0.38	0.04	-8.66	<0.001	<0.001
S6	Public	vs	S6	Public	-0.38	0.05	-8.15	<0.001	<0.001
S2	Public	vs	S2	Private	-0.14	0.05	-2.73	0.006	0.060
S1	Public	vs	S1	Private	-0.14	0.05	-2.58	0.010	0.090
S2	Public	vs	S1	Public	0.09	0.04	2.45	0.014	0.11
S4	Private	vs	S3	Private	0.06	0.03	2.4	0.016	0.11
S2	Private	vs	S1	Private	0.09	0.04	2.37	0.018	0.11
S6	Public	vs	S5	Public	0.06	0.03	2.06	0.039	0.20
S5	Private	vs	S4	Private	0.06	0.03	2.05	0.040	0.16
S6	Private	vs	S5	Private	0.06	0.03	1.96	0.050	0.15
S3	Public	vs	S1	Public	-0.04	0.03	-1.27	0.21	0.42
S4	Public	vs	S3	Public	0.02	0.03	0.66	0.51	0.51

Supplementary table S11 - Time x gender interaction contrasts for log(sC)

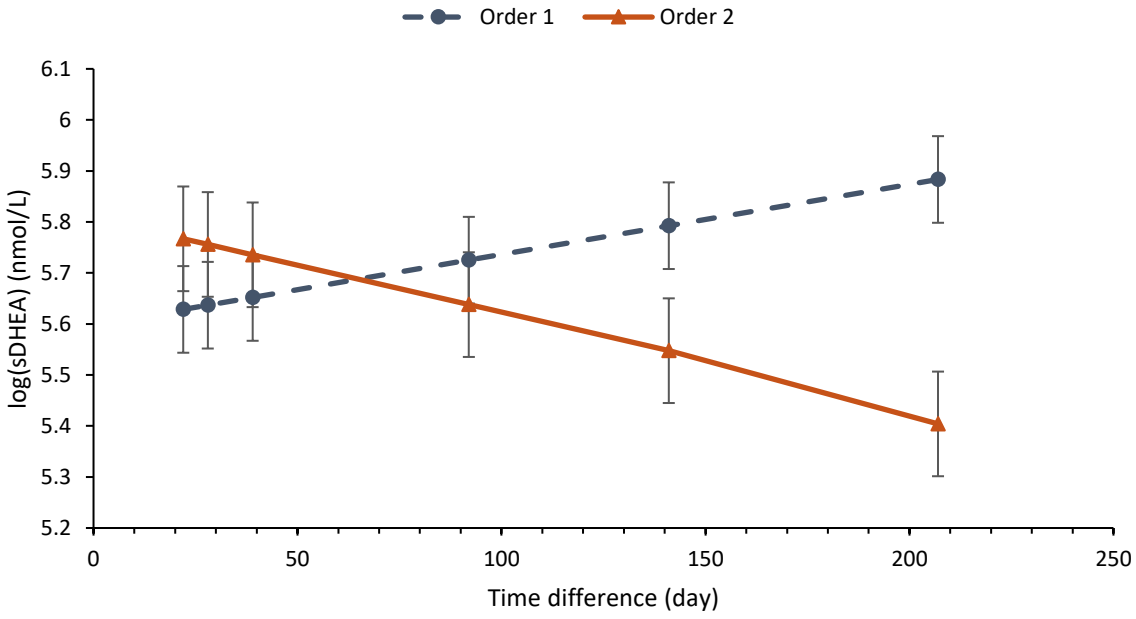
Time point	Gender		Time point	Gender	Contrast	Std. Err.	z	P>|z|	Corrected P>|z|
S6	Woman	vs	S1	Woman	-0.36	0.04	-8.77	<0.001	<0.001
S6	Man	vs	S1	Man	-0.41	0.05	-8.66	<0.001	<0.001
S3	Man	vs	S2	Man	0.17	0.04	4.13	<0.001	<0.001
S4	Woman	vs	S3	Woman	-0.10	0.02	-4.14	<0.001	<0.001
S6	Woman	vs	S3	Woman	-0.27	0.03	-10.07	<0.001	<0.001
S4	Man	vs	S3	Man	-0.12	0.03	-4.25	<0.001	<0.001
S6	Man	vs	S3	Man	-0.39	0.03	-12.61	<0.001	<0.001
S5	Woman	vs	S4	Woman	-0.10	0.02	-4.71	<0.001	<0.001
S5	Man	vs	S4	Man	-0.16	0.02	-6.56	<0.001	<0.001
S6	Man	vs	S5	Man	-0.12	0.03	-4.09	<0.001	<0.001
S2	Man	vs	S1	Man	-0.19	0.05	-3.44	0.001	0.012
S6	Woman	vs	S5	Woman	-0.08	0.02	-3.04	0.002	0.022
S3	Man	vs	S3	Woman	0.29	0.10	2.83	0.005	0.050
S4	Man	vs	S4	Woman	0.27	0.10	2.69	0.007	0.063
S2	Woman	vs	S1	Woman	-0.12	0.05	-2.62	0.009	0.072
S3	Woman	vs	S1	Woman	-0.09	0.04	-2.16	0.031	0.22
S5	Man	vs	S5	Woman	0.21	0.10	2.08	0.038	0.23
S1	Man	vs	S1	Woman	0.22	0.11	1.94	0.052	0.26
S6	Woman	vs	S6	Woman	0.17	0.10	1.64	0.10	0.40
S2	Man	vs	S2	Woman	0.16	0.11	1.43	0.15	0.45
S3	Woman	vs	S2	Woman	0.04	0.04	1.00	0.32	0.64
S3	Man	vs	S1	Man	-0.02	0.05	-0.39	0.70	0.70

Supplementary table S12 - Time x gender interaction contrasts for log anabolic balance

Time point	Gender		Time point	Gender	Contrast	Std. Err.	z	P>|z|	Corrected P>|z|
S3	Woman	vs	S1	Woman	0.12	0.03	3.59	<0.001	<0.001
S6	Woman	vs	S1	Woman	0.23	0.04	6.43	<0.001	<0.001
S6	Man	vs	S1	Man	0.30	0.04	7.39	<0.001	<0.001
S6	Woman	vs	S3	Woman	0.11	0.03	3.77	<0.001	<0.001
S6	Man	vs	S3	Man	0.28	0.03	8.43	<0.001	<0.001
S5	Man	vs	S4	Man	0.10	0.03	3.25	0.001	0.017
S6	Man	vs	S5	Man	0.10	0.03	3.11	0.002	0.032
S2	Woman	vs	S1	Woman	0.10	0.04	2.58	0.010	0.15
S4	Man	vs	S3	Man	0.08	0.03	2.55	0.011	0.15
S5	Woman	vs	S4	Woman	0.07	0.03	2.55	0.011	0.14
S3	Man	vs	S3	Woman	-0.28	0.13	-2.25	0.024	0.30
S2	Man	vs	S1	Man	0.09	0.04	2.05	0.040	0.44
S3	Man	vs	S2	Man	-0.06	0.04	-1.78	0.076	0.76
S4	Man	vs	S4	Woman	-0.22	0.12	-1.76	0.078	0.70
S2	Man	vs	S2	Woman	-0.19	0.13	-1.52	0.13	1.04
S5	Man	vs	S5	Woman	-0.19	0.13	-1.50	0.13	0.91
S1	Man	vs	S1	Woman	-0.19	0.13	-1.43	0.15	0.90
S6	Woman	vs	S5	Woman	0.03	0.03	0.93	0.36	1.8
S6	Man	vs	S6	Woman	-0.11	0.13	-0.89	0.38	1.52
S3	Woman	vs	S2	Woman	0.02	0.03	0.81	0.42	1.26
S3	Man	vs	S1	Man	0.03	0.04	0.65	0.51	1.02
S4	Woman	vs	S3	Woman	0.01	0.03	0.54	0.59	0.59

Supplementary table S13 - Time x gender interaction contrasts for log(sAA)

Time point	Gender		Time point	Gender	Contrast	Std. Err.	z	P>|z|	Corrected P>|z|
S2	Woman	vs	S1	Woman	0.23	0.04	5.03	<0.001	<0.001
S3	Woman	vs	S1	Woman	0.38	0.04	9.16	<0.001	<0.001
S3	Woman	vs	S2	Woman	0.16	0.04	4.09	<0.001	<0.001
S4	Woman	vs	S3	Woman	-0.33	0.04	-9.00	<0.001	<0.001
S6	Woman	vs	S3	Woman	-0.31	0.04	-8.74	<0.001	<0.001
S4	Man	vs	S3	Man	-0.17	0.04	-4.08	<0.001	<0.001
S5	Woman	vs	S4	Woman	-0.14	0.04	-3.65	<0.001	<0.001
S6	Woman	vs	S5	Woman	0.15	0.04	4.15	<0.001	<0.001
S6	Man	vs	S3	Man	-0.11	0.04	-2.70	0.007	0.098
S6	Man	vs	S5	Man	0.10	0.04	2.37	0.018	0.23
S3	Man	vs	S1	Man	0.11	0.05	2.19	0.028	0.34
S2	Man	vs	S1	Man	0.09	0.05	1.71	0.088	0.97
S6	Woman	vs	S1	Woman	0.07	0.04	1.70	0.090	0.9
S1	Man	vs	S1	Woman	0.27	0.16	1.65	0.098	0.88
S5	Man	vs	S5	Woman	0.24	0.16	1.53	0.13	1.04
S6	Man	vs	S6	Woman	0.19	0.16	1.21	0.23	1.61
S4	Man	vs	S4	Woman	0.15	0.16	0.92	0.36	2.16
S5	Man	vs	S4	Man	-0.04	0.04	-0.92	0.36	1.80
S2	Man	vs	S2	Woman	0.13	0.16	0.82	0.41	1.64
S3	Man	vs	S2	Man	0.02	0.05	0.40	0.69	2.07
S6	Man	vs	S1	Man	-0.01	0.05	-0.11	0.91	1.82
S3	Man	vs	S3	Woman	-0.01	0.16	-0.06	0.95	0.95



Supplementary figure S5. Model-predicted marginal means (SEs) for log(sDHEA) along the time difference for order 1 (private then public performance session) and order 2 (public then private performance session)

7.3. Research question 2

Supplementary table S14 - Preliminary analyses – Pearson correlations between the flow dimensions and individual factors included in the model for the private performance session (N = 121)

	CS	UF	CG	MA	CT	SC	LS	TT	AE	General MPA level	Depressive symptoms
UF	**0.35**										
CG	**0.36**	**0.55**									
MA	**0.35**	**0.38**	**0.24**								
CT	**0.49**	**0.48**	**0.42**	**0.23**							
SC	**0.45**	**0.44**	**0.46**	**0.45**	**0.60**						
LS	**0.27**	**0.20**	0.03	**0.25**	**0.27**	**0.40**					
TT	-0.08	-0.07	-0.05	0.03	-0.08	-0.17	**-0.31**				
AE	0.49	**0.43**	**0.51**	**0.48**	**0.53**	**0.66**	**0.30**	0.00			
General MPA level	**-0.23**	-0.18	-0.17	-0.16	**-0.25**	**-0.24**	-0.08	0.07	**-0.20**		
Depressive symptoms	**-0.24**	-0.15	-0.07	-0.10	**-0.28**	**-0.12**	-0.08	0.02	**-0.19**	**0.27**	
Time difference	0.09	-0.01	-0.11	-0.04	0.16	0.07	0.17	0.02	-0.02	-0.11	0.08

Note of Supplementary table S14 - CS: Challenge-skill balance; UF: Unambiguous feedback; CG: Clear goals; AM: Action-awareness merging; CT: Concentration on task at hand; SC: Sense of control; LS: Loss of self-consciousness; TT: Transformation of time; AE: Autotelic experience. Time difference = number of days between the habituation session and the first performance session. Significant correlations ($p < 0.05$) are written in bold.

Supplementary table S15 - Preliminary analyses – Pearson correlations between the flow dimensions and individual factors included in the model for the public performance session (N = 121)

	CS	UF	CG	MA	CT	SC	LS	TT	AE	General MPA level	Depressive symptoms
UF	**0.62**										
CG	**0.59**	**0.56**									
MA	**0.39**	**0.26**	**0.25**								
CT	**0.50**	**0.57**	**0.38**	**0.26**							
SC	**0.63**	**0.59**	**0.52**	**0.47**	**0.64**						
LS	**0.39**	**0.42**	**0.24**	**0.39**	**0.41**	**0.48**					
TT	**-0.25**	**-0.29**	**-0.22**	0.05	**-0.27**	**-0.31**	-0.17				
AE	**0.60**	**0.47**	**0.51**	**0.40**	**0.46**	**0.60**	**0.36**	-0.12			
General MPA level	**-0.22**	**-0.35**	-0.16	**-0.21**	**-0.28**	**-0.40**	**-0.41**	0.13	**-0.30**		
Depressive symptoms	**-0.19**	-0.13	-0.10	-0.09	-0.13	**-0.22**	**-0.33**	0.01	-0.16	**0.27**	
Time difference	0.05	0.14	0.02	0.01	0.15	0.08	-0.02	0.07	0.07	-0.11	0.08

Note of Supplementary table S15 - CS: Challenge-skill balance; UF: Unambiguous feedback; CG: Clear goals; AM: Action-awareness merging; CT: Concentration on task at hand; SC: Sense of control; LS: Loss of self-consciousness; TT: Transformation of time; AE: Autotelic experience. Time difference = number of days between the habituation session and the first performance session. Significant correlations (p < 0.05) are written in bold.

Supplementary table S16 - Estimated linear mixed models for the dimensions challenge-skill balance, unambiguous feedback, and clear goals excluding outliers

	Challenge-skill balance						**Unambiguous feedback**						**Clear goals**					
	Model 1			*Model 2*			*Model 1*			*Model 2*			*Model 1*			*Model 2*		
	Coeff.	*SE*	*p*	Coeff.	SE	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*
Main effects																		
General MPA level	-0.01	0.01	0.15	-0.00	0.01	0.74	**-0.01**	**0.00**	**0.007**	-0.01	0.01	0.47	-0.01	0.01	0.15	-0.01	0.01	0.28
Session	-0.03	0.06	0.59	0.01	0.13	0.93	**-0.12**	**0.06**	**0.039**	-0.04	0.11	0.73	-0.04	0.07	0.55	0.23	0.15	0.12
Order	-0.07	0.13	0.58	0.05	0.20	0.81	-0.11	0.10	0.26	0.10	0.16	0.53	-0.17	0.12	0.18	0.41	0.20	0.040
Preparation	**0.09**	**0.03**	**0.007**	0.10	0.05	0.059	0.05	0.03	0.088	0.01	0.04	0.82	**0.09**	**0.04**	**0.021**	-0.04	0.06	0.54
Gender	0.21	0.13	0.12	0.43	0.21	0.039	0.02	0.10	0.85	0.12	0.16	0.45	**0.30**	**0.13**	**0.024**	0.57	0.21	0.006
Depressive symptoms	-0.02	0.01	0.061	-0.01	0.01	0.26	-0.01	0.01	0.18	-0.01	0.01	0.23	-0.00	0.01	0.71	0.01	0.01	0.57
Time difference	0.01	0.01	0.47	0.01	0.01	0.53	0.01	0.01	0.55	-0.00	0.01	0.73	-0.00	0.01	0.62	-0.01	0.01	0.56
Interactions																		
General MPA level x order				-0.01	0.01	0.60				-0.00	0.01	0.82				-0.00	0.01	0.85
General MPA level x session				-0.00	0.01	0.63				**-0.01**	**0.01**	**0.020**				0.01	0.01	0.39
Order x session				0.01	0.19	0.94				-0.21	0.17	0.21				**-0.60**	**0.22**	**0.005**
Gender x order				-0.28	0.27	0.30				-0.25	0.21	0.25				**-0.65**	**0.26**	**0.015**
Gender x session				-0.12	0.13	0.37				0.07	0.12	0.55				0.11	0.16	0.49
Depressive symptoms x order				-0.01	0.02	0.69				0.00	0.01	1.00				-0.01	0.02	0.51
Depressive symptoms x session				0.00	0.01	0.63				0.01	0.01	0.48				-0.01	0.01	0.53
Time difference x order				0.01	0.02	0.74				0.01	0.02	0.64				-0.02	0.02	0.30
Time difference x session				-0.01	0.01	0.51				0.01	0.01	0.23				0.02	0.01	0.15

Note of Supplementary table S16 – Model 1 tested the main effect of our factors and Model 2 tested the interactions of our factors. Significant main effects in Model 1 and significant interactions in Model 2 are written in bold. Reference categories for categorical predictors were as follows: session: private performance session; order: private performance session first – public performance session second; gender: women. For continuous predictors, coefficients express the change in the outcome measure per unit (unit for Preparation is hour and unit for Time difference is day).

Supplementary table S17 - Estimated linear mixed models for the dimensions "action-awareness merging", "concentration on task at hand", and "sense of control" excluding outliers

	Action-awareness merging						**Concentration on task at hand**						**Sense of control**					
	Model 1			*Model 2*			*Model 1*			*Model 2*			*Model 1*			*Model 2*		
	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*
Main effects																		
General MPA level	-0.01	0.01	0.095	-0.01	0.01	0.14	**-0.02**	**0.01**	**0.008**	-0.02	0.01	0.21	**-0.02**	**0.01**	**0.001**	-0.02	0.01	0.019
Session	-0.06	0.07	0.37	-0.10	0.14	0.50	0.18	0.11	0.097	0.17	0.22	0.44	**-0.20**	**0.09**	**0.032**	-0.12	0.19	0.53
Order	0.09	0.11	0.42	0.17	0.18	0.34	-0.09	0.15	0.55	-0.00	0.27	0.99	0.21	0.12	0.078	0.51	0.21	0.014
Preparation	-0.00	0.04	1.00	-0.01	0.06	0.79	**0.14**	**0.06**	**0.017**	0.16	0.09	0.077	**0.16**	**0.05**	**0.001**	0.13	0.07	0.090
Gender	0.09	0.12	0.44	0.05	0.19	0.80	0.10	0.16	0.55	0.29	0.27	0.28	**0.27**	**0.13**	**0.032**	0.50	0.20	0.015
Depressive symptoms	-0.00	0.01	0.51	-0.01	0.01	0.43	**-0.02**	**0.01**	**0.043**	-0.03	0.02	0.048	-0.01	0.01	0.21	-0.01	0.01	0.65
Time difference	-0.00	0.01	0.91	0.01	0.01	0.66	**0.03**	**0.01**	**0.025**	0.03	0.02	0.105	0.01	0.01	0.19	0.00	0.01	0.75
Interactions																		
General MPA level x order				0.01	0.01	0.41				0.00	0.02	0.88				0.02	0.01	0.12
General MPA level x session				-0.00	0.01	0.53				-0.01	0.01	0.32				-0.01	0.01	0.15
Order x session				-0.06	0.21	0.77				0.07	0.33	0.84				-0.20	0.28	0.47
Gender x order				-0.14	0.24	0.55				-0.28	0.33	0.41				-0.47	0.25	0.059
Gender x session				0.15	0.15	0.30				-0.07	0.23	0.78				0.06	0.20	0.74
Depressive symptoms x order				0.01	0.02	0.63				-0.00	0.02	0.87				-0.01	0.02	0.68
Depressive symptoms x session				0.00	0.01	0.78				0.02	0.01	0.097				-0.01	0.01	0.60
Time difference x order				-0.04	0.02	0.073				0.01	0.03	0.65				0.02	0.02	0.26
Time difference x session				0.01	0.01	0.63				-0.01	0.02	0.55				-0.00	0.01	0.84

Note of Supplementary table S17 - Model 1 tested the main effect of our factors and Model 2 tested the interactions of our factors. Significant main effects in Model 1 and significant interactions in Model 2 are written in bold. Reference categories for categorical predictors were as follows: session: private performance session; order: private performance session first – public performance session second; gender: women. For continuous predictors, coefficients express the change in the outcome measure per unit (unit for Preparation is hour and unit for Time difference is day).

Supplementary table S18 - Estimated linear mixed models for the dimensions "loss of self-consciousness", "transformation of time", and "autotelic experience" excluding outliers

	Loss of self-consciousness						**Transformation of time**						**Autotelic experience**					
	Model 1			*Model 2*			*Model 1*			*Model 2*			*Model 1*			*Model 2*		
	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*
Main effects																		
General MPA level	**-0.02**	**0.01**	**0.030**	0.00	0.01	0.78	0.01	0.01	0.15	-0.01	0.01	0.70	**-0.02**	**0.01**	**0.026**	-0.01	0.01	0.39
Session	**-0.94**	**0.12**	**<0.001**	-0.68	0.23	0.003	**0.46**	**0.11**	**<0.001**	-0.32	0.21	0.13	-0.03	0.09	0.77	0.34	0.19	0.073
Order	**0.47**	**0.17**	**0.006**	0.98	0.29	0.001	-0.05	0.17	0.76	1.07	0.29	0.000	0.01	0.14	0.93	0.37	0.24	0.12
Preparation	0.06	0.07	0.33	-0.06	0.09	0.53	**-0.18**	**0.06**	**0.002**	0.11	0.08	0.17	0.07	0.05	0.18	-0.05	0.07	0.52
Gender	0.29	0.18	0.11	0.42	0.29	0.15	0.21	0.19	0.27	-0.12	0.30	0.69	0.22	0.15	0.15	0.38	0.25	0.12
Depressive symptoms	**-0.03**	**0.01**	**0.024**	-0.02	0.02	0.25	-0.01	0.01	0.60	-0.02	0.02	0.27	-0.01	0.01	0.13	-0.01	0.01	0.60
Time difference	0.02	0.01	0.21	0.02	0.02	0.21	0.02	0.01	0.27	-0.00	0.02	0.90	0.01	0.01	0.54	0.00	0.02	0.94
Interactions																		
General MPA level x order				-0.01	0.02	0.64				0.03	0.02	0.15				0.00	0.01	0.86
General MPA level x session				**-0.04**	**0.01**	**0.002**				0.01	0.01	0.61				-0.01	0.01	0.23
Order x session				**-0.68**	**0.34**	**0.049**				**1.50**	**0.31**	**<0.001**				**-0.59**	**0.28**	**0.036**
Gender x order				-0.40	0.37	0.28				0.64	0.38	0.092				-0.16	0.31	0.62
Gender x session				0.23	0.24	0.35				-0.04	0.22	0.86				-0.12	0.20	0.53
Depressive symptoms x order				0.01	0.02	0.80				0.02	0.02	0.41				-0.02	0.02	0.29
Depressive symptoms x session				-0.02	0.02	0.24				0.00	0.01	0.99				0.00	0.01	0.71
Time difference x order				0.04	0.03	0.22				0.02	0.03	0.50				0.01	0.03	0.64
Time difference x session				**-0.04**	**0.02**	**0.037**				0.02	0.02	0.18				0.01	0.01	0.70

Note of Supplementary table S18 - Model 1 tested the main effect of our factors and Model 2 tested the interactions of our factors. Significant main effects in Model 1 and significant interactions in Model 2 are written in bold. Reference categories for categorical predictors were as follows: session: private performance session; order: private performance session first – public performance session second; gender: women. For continuous predictors, coefficients express the change in the outcome measure per unit (unit for Preparation is hour and unit for Time difference is day).

7.4. Research question 3

Supplementary table S19 - Preliminary analyses – Pearson correlations between the self-rated MPQ dimensions evaluated after the private music performance and individual factors included in the model (N = 121 except for intonation N = 101)

	Tempo	Rhythm	Intonation	Tone	Dynamics	Articulation	Musical understanding	Missing notes	Global appreciation	General MPA level	Depressive symptoms	Time difference
Rhythm	**0.75**											
Intonation	**0.46**	**0.50**										
Tone	**0.42**	**0.49**	**0.58**									
Dynamics	**0.58**	**0.58**	**0.51**	**0.61**								
Articulation	**0.52**	**0.54**	**0.44**	**0.57**	**0.72**							
Musical understanding	**0.56**	**0.55**	**0.48**	**0.50**	**0.74**	**0.67**						
Missing notes	**0.31**	**0.45**	**0.47**	**0.49**	**0.37**	**0.42**	**0.31**					
Global appreciation	**0.58**	**0.67**	**0.61**	**0.71**	**0.76**	**0.65**	**0.67**	**0.68**				
General MPA level	**-0.21**	-0.14	**-0.20**	**-0.26**	**-0.20**	**-0.24**	**-0.28**	-0.13	**-0.24**			
Depressive symptoms	-0.11	-0.04	**-0.34**	**-0.29**	-0.17	-0.14	**-0.25**	-0.10	-0.14	**0.27**		
Time difference	0.05	0.06	0.10	0.05	0.02	0.07	0.05	0.03	0.05	-0.11	0.07	
Preparation	0.04	-0.01	0.14	0.18	0.14	0.12	0.03	**0.18**	**0.22**	-0.03	-0.01	-0.06

Note of Supplementary table S19 - Time difference = number of days between the habituation session and the first performance session. Significant correlations ($p < 0.05$) are written in bold.

Supplementary table S20 - Preliminary analyses – Pearson correlations between the self-rated MPQ dimensions evaluated after listening the private music performance and individual factors included in the model (N = 121 except for intonation N = 101)

	Tempo	Rhythm	Intonation	Tone	Dynamics	Articulation	Musical understanding	Missing notes	Global appreciation	General MPA level	Depressive symptoms	Time difference
Rhythm	**0.80**											
Intonation	**0.68**	**0.73**										
Tone	**0.59**	**0.69**	**0.76**									
Dynamics	**0.64**	**0.72**	**0.68**	**0.69**								
Articulation	**0.70**	**0.78**	**0.69**	**0.70**	**0.80**							
Musical understanding	**0.58**	**0.67**	**0.62**	**0.63**	**0.76**	**0.68**						
Missing notes	**0.57**	**0.70**	**0.57**	**0.59**	**0.64**	**0.62**	**0.57**					
Global appreciation	**0.71**	**0.79**	**0.81**	**0.75**	**0.80**	**0.82**	**0.75**	**0.73**				
General MPA level	-0.16	-0.16	**-0.20**	**-0.21**	**-0.31**	**-0.19**	**-0.25**	**-0.22**	**-0.23**			
Depressive symptoms	-0.05	**-0.21**	**-0.21**	**-0.23**	**-0.28**	**-0.23**	**-0.31**	-0.10	**-0.18**	**0.27**		
Time difference	-0.03	0.01	0.04	0.01	-0.12	-0.03	-0.05	0.03	0.00	-0.11	0.07	
Preparation	0.13	0.12	0.12	0.18	0.19	0.09	0.02	0.14	0.17	-0.03	-0.01	-0.06

Note of Supplementary table S20 - Time difference = number of days between the habituation session and the first performance session. Significant correlations ($p < 0.05$) are written in bold.

Supplementary table S21 - Preliminary analyses – Pearson correlations between the self-rated MPQ dimensions evaluated after the public music performance and individual factors included in the model (N = 121 except for intonation N = 101)

	Tempo	Rhythm	Intonation	Tone	Dynamics	Articulation	Musical understanding	Missing notes	Global appreciation	General MPA level	Depressive symptoms	Time difference
Rhythm	**0.65**											
Intonation	**0.46**	**0.62**										
Tone	**0.36**	**0.43**	**0.58**									
Dynamics	**0.57**	**0.54**	**0.56**	**0.57**								
Articulation	**0.48**	**0.56**	**0.56**	**0.63**	**0.68**							
Musical understanding	**0.54**	**0.49**	**0.55**	**0.50**	**0.69**	**0.59**						
Missing notes	**0.39**	**0.40**	**0.37**	**0.37**	**0.39**	**0.41**	**0.39**					
Global appreciation	**0.58**	**0.58**	**0.64**	**0.59**	**0.77**	**0.68**	**0.63**	**0.64**				
General MPA level	**-0.30**	**-0.31**	-0.13	**-0.18**	-0.18	**-0.24**	**-0.22**	**-0.18**	**-0.20**			
Depressive symptoms	-0.12	-0.14	-0.15	-0.15	-0.11	-0.10	-0.12	0.10	-0.08	**0.27**		
Time difference	0.04	0.06	0.05	-0.02	0.04	-0.10	0.11	0.03	0.06	-0.11	0.07	
Preparation	-0.01	-0.01	0.09	-0.01	0.12	0.05	0.10	0.11	0.09	0.03	0.01	0.06

Note of Supplementary table S21- Time difference = number of days between the habituation session and the first performance session. Significant correlations ($p < 0.05$) are written in bold.

Supplementary table S22 - Preliminary analyses – Pearson correlations between the self-rated MPQ dimensions evaluated after listening the public music performance and individual factors included in the model (N = 121 except for intonation N = 101)

	Tempo	Rhythm	Intonation	Tone	Dynamics	Articulation	Musical understanding	Missing notes	Global appreciation	General MPA level	Depressive symptoms	Time difference
Rhythm	**0.83**											
Intonation	**0.59**	**0.66**										
Tone	**0.50**	**0.48**	**0.60**									
Dynamics	**0.63**	**0.59**	**0.47**	**0.62**								
Articulation	**0.62**	**0.64**	**0.54**	**0.63**	**0.74**							
Musical understanding	**0.52**	**0.54**	**0.46**	**0.59**	**0.73**	**0.73**						
Missing notes	**0.52**	**0.54**	**0.57**	**0.47**	**0.53**	**0.53**	**0.53**					
Global appreciation	**0.75**	**0.71**	**0.75**	**0.64**	**0.74**	**0.72**	**0.70**	**0.72**				
General MPA level	**-0.26**	**-0.19**	**-0.25**	-0.17	**-0.31**	**-0.20**	**-0.20**	**-0.28**	**-0.28**			
Depressive symptoms	-0.15	**-0.20**	**-0.29**	**-0.27**	**-0.25**	**-0.23**	**-0.24**	-0.07	**-0.19**	**0.27**		
Time difference	0.06	0.00	-0.02	-0.01	-0.00	-0.02	-0.08	0.06	0.09	-0.11	0.07	
Preparation	0.07	0.06	-0.00	-0.01	0.11	0.09	0.12	0.04	0.07	0.03	0.01	0.06

Note of Supplementary table S22 - Time difference = number of days between the habituation session and the first performance session. Significant correlations ($p < 0.05$) are written in bold.

Supplementary table S23 - Eigenvalues, percentages of variance, and cumulative percentages for factors for the 9 items (including intonation/excluding accordion, guitar, piano players) from the MPQ scale

Factor	Eigenvalue	% of variance	Cumulative %
1	5.76	83.3%	83.3%
2	0.46	6.71%	90.0%
3	0.33	4.83%	94.8%
4	0.17	2.48%	97.3%
5	0.10	1.37%	98.6%
6	0.06	0.86%	99.5%
7	0.03	0.37%	99.9%
8	0.01	0.14%	100%

Supplementary table S24 - Eigenvalues, percentages of variance, and cumulative percentages for factors for the 8 items (excluding intonation) from the MPQ scale

Factor	Eigenvalue	% of variance	Cumulative %
1	5.03	85.07%	85.07%
2	0.42	7.13%	92.20%
3	0.30	5.15%	97.35%
4	0.10	1.75%	99.10%
5	0.04	0.71%	99.81%
6	0.01	0.15%	99.96%
7	0.00	0.05%	100%

Supplementary table S25 - Estimated linear mixed models for self-rated MPQ without outliers

	Model 1			*Model 2*			*Model 3*		
	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*
Main effects									
General MPA level	**-0.05**	**0.02**	**0.009**	-0.06	0.03	0.048	-0.07	0.03	0.050
Session	-0.21	0.16	0.20	0.35	0.33	0.29	0.17	0.35	0.63
Time	0.10	0.06	0.14	0.23	0.13	0.077	0.04	0.16	0.82
Order	-0.01	0.41	0.97	0.29	0.61	0.64	0.15	0.62	0.81
Preparation	**0.30**	**0.08**	**<0.001**	0.17	0.13	0.20	0.17	0.13	0.18
Gender	0.13	0.43	0.76	0.46	0.67	0.49	0.43	0.67	0.52
Depressive symptoms	-0.05	0.03	0.064	-0.06	0.04	0.13	-0.07	0.04	0.071
Time difference	0.00	0.03	0.95	0.00	0.04	0.99	0.01	0.04	0.90
2-way interactions									
General MPA level x session				-0.01	0.02	0.57	-0.00	0.02	0.85
General MPA level x time				-0.00	0.01	0.53	-0.00	0.01	0.88
General MPA level x order				0.03	0.04	0.47	0.04	0.04	0.38
Session x time				**-0.36**	**0.13**	**0.005**	-0.03	0.22	0.91
Session x order				-0.70	0.48	0.15	-0.46	0.50	0.36
Time x order				**0.34**	**0.13**	**0.008**	0.59	0.18	0.001
Gender x session				0.01	0.35	0.99	0.09	0.37	0.80
Gender x time				**-0.32**	**0.14**	**0.022**	-0.18	0.20	0.36
Gender x order				-0.28	0.90	0.75	-0.28	0.89	0.75
Depressive symptoms x session				0.03	0.02	0.25	0.04	0.02	0.063
Depressive symptoms x time				**-0.02**	**0.01**	**0.027**	0.00	0.01	0.69
Depressive symptoms x order				0.00	0.06	0.99	0.00	0.06	0.92
Time difference x session				-0.01	0.03	0.65	-0.02	0.03	0.50
Time difference x time				**-0.03**	**0.01**	**0.012**	-0.04	0.01	0.017
Time difference x order				0.05	0.07	0.46	0.05	0.07	0.47
3-way interactions									
General MPA level x session x time							0.00	0.01	0.83
General MPA level x session x order							-0.01	0.03	0.66
General MPA level x time x order							-0.01	0.01	0.42
Session x time x order							-0.43	0.26	0.092
Session x time x gender							-0.25	0.28	0.36
Session x time x depressive symptoms							**-0.04**	**0.02**	**0.027**
Session x time x time difference							0.02	0.02	0.44

Note of Supplementary table S25 - Model 1 tested the main effect of our factors. Model 2 tested the 2-way interactions of our factors. Model 3 tested the 3-way interactions of our factors. Significant main effects in Model 1 and significant interactions in Models 2 and 3 are written in bold. Reference categories for categorical predictors were as follows: session: private performance session; time: evaluation after the music performance; order: private performance session first – public performance session second; gender: women. For continuous predictors, coefficients express the change in the outcome measure per unit (unit for Preparation is hour and unit for Time difference is day

7.5. Research question 4

Supplementary table S26 - Preliminary analyses – Pearson correlations between the outcome variables and individual factors included in the model for the private performance session before the music performance (*N* = 121)

	Resources	Demands	R-D differential	General MPA level	Depressive symptoms	Time difference
Demands	-0.14					
R-D differential	**0.63**	**-0.86**				
General MPA level	**-0.27**	0.06	**-0.18**			
Depressive symptoms	**-0.21**	-0.12	-0.01	**0.27**		
Time difference	-0.01	-0.01	0.00	-0.11	0.07	
Preparation	0.11	-0.01	0.07	-0.03	-0.01	-0.06

Note of Supplementary table S26 - Time difference = number of days between the habituation session and the first performance session. Significant correlations (p < 0.05) are written in bold.

Supplementary table S27 - Preliminary analyses – Pearson correlations between the outcome variables and individual factors included in the model for the private performance session during the music performance (N = 121)

	Resources	Demands	R-D differential	General MPA level	Depressive symptoms	Time difference
Demands	**-0.26**					
R-D differential	**0.75**	**-0.83**				
General MPA level	**-0.24**	0.08	**-0.19**			
Depressive symptoms	-0.05	-0.02	-0.01	**0.27**		
Time difference	-0.03	0.03	-0.03	-0.11	0.07	
Preparation	0.04	0.00	0.02	-0.03	-0.01	-0.06

Note of Supplementary table S27 - Time difference = number of days between the habituation session and the first performance session. Significant correlations (p < 0.05) are written in bold.

Supplementary table S28 - Preliminary analyses – Pearson correlations between the outcome variables and individual factors included in the model for the public performance session before the music performance (N = 121)

	Resources	Demands	R-D differential	General MPA level	Depressive symptoms	Time difference
Demands	-0.16					
R-D differential	**0.71**	**-0.80**				
General MPA level	**-0.42**	**0.21**	**-0.40**			
Depressive symptoms	**-0.22**	0.05	-0.17	**0.27**		
Time difference	0.02	-0.04	0.04	-0.11	0.07	
Preparation	0.05	0.16	-0.08	0.03	0.01	0.06

Note of Supplementary table S28 - Time difference = number of days between the habituation session and the first performance session. Significant correlations (p < 0.05) are written in bold.

Supplementary table S29 - Preliminary analyses – Pearson correlations between the outcome variables and individual factors included in the model for the public performance session during the music performance (N = 121)

	Resources	Demands	R-D differential	General MPA level	Depressive symptoms	Time difference
Demands	-0.10					
R-D differential	**0.75**	**-0.74**				
General MPA level	-0.15	0.06	-0.15			
Depressive symptoms	-0.03	-0.02	-0.04	**0.27**		
Time difference	0.04	0.00	0.02	-0.11	0.07	
Preparation	0.09	0.14	-0.03	0.03	0.01	0.06

Note of Supplementary table S29 - Time difference = number of days between the habituation session and the first performance session. Significant correlations (p < 0.05) are written in bold.

Supplementary table S30 - Estimated linear mixed models for differential perceived resources-demands without outliers

	Model 1		
	Coeff.	*SE*	*p*
Main effects			
General MPA level	**-0.04**	**0.01**	**0.004**
Session	**-0.68**	**0.11**	**<0.001**
Time	**-0.48**	**0.09**	**<0.001**
Order	0.38	0.25	0.13
Preparation	-0.01	0.06	0.91
Gender	0.25	0.27	0.35
Depressive symptoms	0.00	0.01	0.94
Time difference	-0.00	0.02	0.98

Note of Supplementary table S30 - Model 1 tested the main effect of our factors. Significant main effects in Model 1 are written in bold. Reference categories for categorical predictors were as follows: session: private performance session; time: before the music performance; order: private performance session first – public performance session second; gender: women. For continuous predictors, coefficients express the change in the outcome measure per unit (unit for Preparation is hour and unit for Time difference is day).

Supplementary table S31 - Estimated linear mixed models for perceived resources without outliers

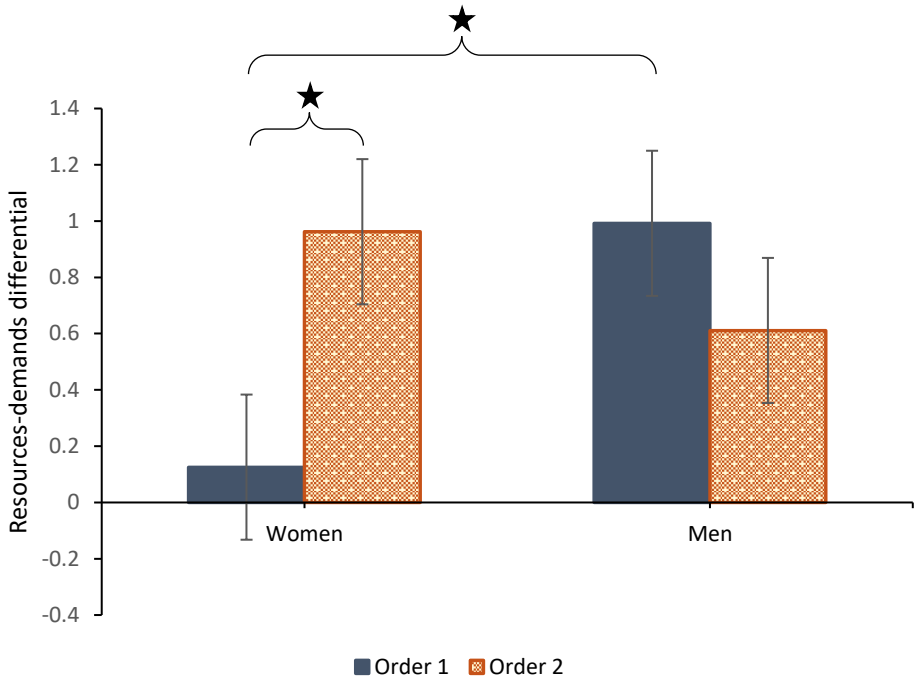
	Model 1			*Model 2*			*Model 3*		
	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*
Main effects									
General MPA level	**-0.02**	**0.01**	**0.002**	-0.01	0.01	0.44	-0.00	0.01	0.68
Session	**-0.21**	**0.07**	**0.001**	-0.05	0.14	0.74	-0.00	0.16	1.00
Time	**-0.43**	**0.06**	**<0.001**	-0.46	0.12	<0.001	-0.47	0.16	0.004
Order	-0.02	0.13	0.90	0.51	0.20	0.013	0.57	0.22	0.009
Preparation	**0.08**	**0.04**	**0.030**	-0.02	0.05	0.76	-0.02	0.05	0.75
Gender	0.26	0.14	0.065	0.53	0.22	0.015	0.55	0.24	0.019
Depressive symptoms	-0.01	0.01	0.29	-0.01	0.01	0.52	-0.00	0.01	0.81
Time difference	-0.00	0.01	1.00	0.00	0.01	0.97	0.00	0.01	0.95
2-way interactions									
General MPA level x session				-0.01	0.01	0.14	-0.01	0.01	0.19
General MPA level x time				0.01	0.01	0.17	-0.01	0.01	0.62
General MPA level x order				-0.02	0.01	0.20	-0.02	0.02	0.26
Session x time				0.22	0.12	0.069	0.24	0.22	0.28
Session x order				**-0.46**	**0.20**	**0.010**	-0.59	0.24	0.014
Time x order				-0.20	0.12	0.12	-0.38	0.21	0.074
Gender x session				0.04	0.14	0.77	-0.00	0.21	1.00
Gender x time				0.04	0.13	0.76	0.20	0.24	0.40
Gender x order				**-0.57**	**0.28**	**0.046**	-0.64	0.32	0.048
Depressive symptoms x session				0.00	0.01	0.81	-0.01	0.01	0.52
Depressive symptoms x time				0.02	0.01	0.050	0.02	0.01	0.22
Depressive symptoms x order				-0.01	0.02	0.59	-0.02	0.02	0.31
Time difference x session				0.00	0.01	0.71	0.01	0.01	0.54
Time difference x time				-0.00	0.01	0.76	-0.02	0.02	0.25
Time difference x order				-0.00	0.02	0.83	0.00	0.03	0.95
3-way interactions									
General MPA level x session x time							0.02	0.01	0.14
General MPA level x session x order							-0.00	0.01	0.75
General MPA level x time x order							0.01	0.01	0.50
Session x time x order							0.27	0.25	0.28
Gender x session x time							-0.30	0.27	0.27
Gender x session x order							0.13	0.28	0.63
Gender x time x order							0.08	0.28	0.79
Depressive symptoms x session x time							-0.00	0.02	0.94
Depressive symptoms x session x order							0.03	0.02	0.16
Depressive symptoms x time x order							-0.01	0.02	0.77
Time difference x session x time							0.01	0.02	0.58
Time difference x session x order							-0.03	0.02	0.21
Time difference x time x order							0.03	0.02	0.13

Note of Supplementary S31 - Model 1 tested the main effect of our factors. Model 2 tested the 2-way interactions of our factors. Model 3 tested the 3-way interactions of our factors. Significant main effects in Model 1 and significant interactions in Model 2 and 3 are written in bold. Reference categories for categorical predictors were as follows: session: private performance session; time: before the music performance; order: private performance session first – public performance session second; gender: women. For continuous predictors, coefficients express the change in the outcome measure per unit (unit for Preparation is hour and unit for Time difference is day).

Supplementary table S32 - Estimated linear mixed models for perceived demands without outliers

	Model 1			*Model 2*			*Model 3*		
	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*
Main effects									
General MPA level	0.01	0.01	0.11	0.03	0.02	0.056	0.02	0.02	0.21
Session	**0.56**	**0.08**	**<0.001**	0.77	0.17	<0.001	0.56	0.20	0.006
Time	0.06	0.06	0.31	-0.05	0.12	0.65	-0.29	0.16	0.065
Order	-0.36	0.19	0.060	-0.45	0.29	0.12	-0.65	0.31	0.035
Preparation	**0.10**	**0.04**	**0.021**	0.02	0.06	0.73	0.02	0.06	0.80
Gender	-0.01	0.20	0.968	-0.26	0.31	0.41	-0.70	0.33	0.037
Depressive symptoms	-0.01	0.01	0.517	-0.01	0.02	0.48	-0.02	0.02	0.36
Time difference	-0.00	0.02	0.993	-0.01	0.02	0.73	-0.02	0.02	0.37
2-way interactions									
General MPA level x session				-0.00	0.01	0.85	0.01	0.01	0.70
General MPA level x time				-0.01	0.01	0.083	0.01	0.01	0.57
General MPA level x order				-0.01	0.02	0.61	-0.01	0.02	0.77
Session x time				0.13	0.12	0.28	0.29	0.21	0.17
Session x order				-0.40	0.24	0.095	-0.28	0.30	0.35
Time x order				0.06	0.12	0.59	0.18	0.20	0.39
Gender x session				-0.11	0.17	0.52	0.42	0.28	0.13
Gender x time				0.04	0.13	0.76	0.65	0.23	0.004
Gender x order				0.65	0.41	0.11	1.16	0.46	0.012
Depressive symptoms x session				0.02	0.01	0.12	0.01	0.02	0.37
Depressive symptoms x time				0.01	0.01	0.25	0.03	0.02	0.036
Depressive symptoms x order				-0.02	0.03	0.43	-0.02	0.03	0.45
Time difference x session				-0.01	0.01	0.44	0.01	0.02	0.66
Time difference x time				0.01	0.01	0.53	0.02	0.02	0.32
Time difference x order				0.04	0.03	0.19	0.07	0.04	0.067
3-way interactions									
General MPA level x session x time							-0.02	0.01	0.087
General MPA level x session x order							0.00	0.02	0.88
General MPA level x time x order							-0.01	0.01	0.65
Session x time x order							0.25	0.24	0.31
Gender x session x time							-0.62	0.26	0.018
Gender x session x order							-0.51	0.35	0.14
Gender x time x order							-0.48	0.26	0.069
Depressive symptoms x session x time							-0.02	0.02	0.33
Depressive symptoms x session x order							0.02	0.02	0.26
Depressive symptoms x time x order							-0.02	0.02	0.18
Time difference x session x time							-0.01	0.02	0.52
Time difference x session x order							-0.04	0.03	0.11
Time difference x time x order							-0.00	0.02	0.97

Note of Supplementary table S32 - Model 1 tested the main effect of our factors. Model 2 tested the 2-way interactions of our factors. Model 3 tested the 3-way interactions of our factors. Significant main effects in Model 1 and significant interactions in Model 2 and 3 are written in bold. Reference categories for categorical predictors were as follows: session: private performance session; time: before the music performance; order: private performance session first – public performance session second; gender: women. For continuous predictors, coefficients express the change in the outcome measure per unit (unit for Preparation is hour and unit for Time difference is day).



Supplementary figure S6. Model-predicted marginal means (SEs) for resources-demands differential for women and for men for order 1 (starting with private performance session) and order 2 (starting with public performance session)

7.6. Research question 5

Supplementary table S33 - Preliminary analyses – Pearson correlations between the self-rated MPQ dimensions evaluated after the private music performance and the resources-demands differential (N = 121 except for intonation N = 101)

	Tempo	Rhythm	Intonation	Tone	Dynamics	Articulation	Musical understanding and interpretation	Missing notes, wrong notes, and unwritten breaks	Global appreciation
Rhythm	**0.75**								
Intonation	**0.46**	**0.50**							
Tone	**0.42**	**0.49**	**0.58**						
Dynamics	**0.58**	**0.58**	**0.51**	**0.61**					
Articulation	**0.52**	**0.54**	**0.44**	**0.57**	**0.72**				
Musical understanding and interpretation	**0.56**	**0.55**	**0.48**	**0.50**	**0.74**	**0.67**			
Missing notes, wrong notes, and unwritten breaks	**0.31**	**0.45**	**0.47**	**0.49**	**0.37**	**0.42**	**0.31**		
Global appreciation	**0.58**	**0.67**	**0.61**	**0.71**	**0.76**	**0.65**	**0.67**	**0.68**	
Resource-demands differential	**0.32**	**0.31**	**0.22**	**0.28**	**0.42**	**0.42**	**0.38**	**0.23**	**0.35**

Note of Supplementary table S33 –Significant correlations ($p < 0.05$) are written in bold.

Supplementary table S34 - Estimated linear mixed models for self-rated MPQ evaluated after the music performance without outliers

	Self-rated MPQ		
	Coeff.	*SE*	*p*
Main effects			
Between R-D	**0.81**	**0.13**	**<0.001**
Within R-D	0.12	0.13	0.35
Order	-0.56	0.37	0.13
Preparation	**0.31**	**0.11**	**0.006**
Gender	0.18	0.38	0.64
Depressive symptoms	**-0.05**	**0.02**	**0.047**
Time difference	0.01	0.03	0.63

Note of Supplementary table S34 – Between R-D: between component of the resources-demands differential; Wihtin R-D: within component of the resources-demands differential. Model 1 tested the main effect of our factors. Significant main effects in Model 1 are written in bold. Reference categories for categorical predictors were as follows: order: private performance session first – public performance session second; gender: women. For continuous predictors, coefficients express the change in the outcome measure per unit (unit for Preparation is hour and unit for Time difference is day).

Supplementary table S35 - Estimated linear mixed models for self-rated MPQ rated one week after the last performance session with recordings without outliers

	Self-rated MPQ		
	Coeff.	*SE*	*p*
Main effects			
Between R-D	**0.81**	**0.16**	**<0.001**
Within R-D	0.07	0.12	0.57
Order	-0.25	0.44	0.57
Preparation	**0.35**	**0.11**	**0.001**
Gender	-0.19	0.46	0.68
Depressive symptoms	**-0.08**	**0.03**	**0.008**
Time difference	-0.00	0.03	0.89

Note of Supplementary table S35 – Between R-D: between component of the resources-demands differential; Wihtin R-D: within component of the resources-demands differential. Model 1 tested the main effect of our factors. Significant main effects in Model 1 are written in bold. Reference categories for categorical predictors were as follows: order: private performance session first – public performance session second; gender: women. For continuous predictors, coefficients express the change in the outcome measure per unit (unit for Preparation is hour and unit for Time difference is day).