**Universidade do Minho**
Escola de Psicologia

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# Mind wandering and musical creativity: Behavioral correlates in expert jazz improvisation

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# Mind wandering and musical creativity: Behavioral correlates in expert jazz improvisation

Dissertação de Mestrado
Mestrado Integrado em Psicologia

Trabalho efetuado sob a orientação do
**Professor Doutor Óscar Filipe Coelho Neves Gonçalves**
e do
**Professor Doutor Yann Coello**

setembro de 2020

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To Camille Poundall.

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## Declaração de integridade

Declaro ter atuado com integridade na elaboração do presente trabalho académico e confirmo que não recorri à prática de plágio nem a qualquer forma de utilização indevida ou falsificação de informações ou resultados em nenhuma das etapas conducente à sua elaboração.

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Mind Wandering e Criatividade Musical: Correlatos Comportamentais em Improvisação Jazz

## Resumo

*Mind wandering* é um fenómeno mental omnipresente no quotidiano, caracterizando-se por uma mudança no conteúdo do pensamento que o afasta de uma tarefa presente a favor de pensamentos auto-gerados. Embora estudos anteriores tenham sugerido uma relação positiva entre *mind wandering* e criatividade, esta linha de investigação ainda carece de mais estudos empíricos. A improvisação jazz fornece um contexto ecologicamente válido para o estudo desta relação. Com o objetivo de explorar se *mind wandering* aumenta a criatividade musical, formulamos a hipótese de que ocorrências de *mind wandering* durante uma tarefa de improvisação musical estariam associadas a níveis mais elevados de criatividade musical, em comparação com atenção focada na tarefa. Nove músicos experientes executaram tarefas de improvisação musical e reprodução musical com interrupções aleatórias por meio de *thought probes*, sendo simultaneamente registados movimentos de piscar de olhos. Os resultados mostraram que as improvisações com *mind wandering* não intencional alcançaram pontuações de criatividade musical significativamente mais altas do que as improvisações com atenção focada na tarefa. Ainda assim, ocorrências de *mind wandering* não afetaram significativamente a qualidade geral das improvisações. Os resultados mostraram também que as improvisações mais criativas registaram um número de piscar de olhos significativamente mais alto do que as improvisações menos criativas. Globalmente, estes dados sugerem que a relação positiva entre *mind wandering* e criatividade também se estende aos domínios da performance artística.

*Palavras-chave:* criatividade musical, *eye-blinking*, improvisação jazz, *mind wandering*

Mind Wandering and Musical Creativity: Behavioral Correlates in Expert jazz Improvisation

## Abstract

Mind wandering is a prevalent mental phenomenon characterized by a shift in the contents of thought away from an ongoing task towards self-generated thoughts. While previous studies have suggested a positive relationship between mind wandering and creativity, empirical evidence still lacks in replication, but also scope. Jazz improvisation provides an ecologically valid framework for the study of such relationship. Aiming to explore if mind wandering enhances musical creativity, we hypothesized that instances of self-reported mind wandering during a musical improvisation task would be associated with higher levels of musical creativity, compared to self-reported on-task attention. Nine experienced musicians performed musical improvisation and musical reproduction tasks with randomly occurring though probes and with concurrent eye-blink recording. Results showed that improvisations with unintentional mind wandering attained significantly higher musical creativity scores than improvisations where attention was reported to be mainly on-task. Still, instances of mind wandering didn't significantly impact the overall improvisational quality. Results also showed that highly creative improvisations registered significantly more eye-blinks than non-creative improvisations. Overall, these data suggest that the positive relationship between mind wandering and creativity also extends to artistic performance domains.

*Keywords:* eye-blinking, jazz improvisation, mind wandering, musical creativity

## Contents



## Index of Tables

## List of figures

## Mind wandering and musical creativity: Behavioral correlates in expert jazz improvisation

To think, therefore, of a fictional character: a man incapable of making decisions other than at the piano, playing . . . To make the most important decisions of existence in the very moment one thinks of something else.
When I hesitate, when I don't know what to do, I start to play. By the time I finish playing, I've already decided - says the musician.

- Gonçalo M. Tavares, *Breves Notas Sobre Música* [translated], 2015

Hold to the now, the here, through which all future plunges to the past.

- James Joyce, *Ulysses*, 1922

Despite Joyce's plead to seize and cherish the present moment, we often can't help but have our conscious experience stray from it. It is a common experience to find one's thoughts turn inwardly, wandering between memories, images, feelings and personal concerns. James Joyce, a precursor of the stream of consciousness narrative mode (whereby the character's thought processes are freely depicted with little to no punctuation), was aware of the mind's natural tendency to deviate attention from an ongoing task towards self-generated thoughts. Likewise, Tavares' fictional musician is also aware of this ubiquitous phenomenon, but this time with an important nuance: he is inspired by it. While playing, he accomplishes the feat of wandering through future and past without letting go of the present - the performative immediacy - reaping the benefits of split attention. In the following sections, building on the concept of mind wandering, I will attempt to show that this fictional musician is, indeed, a realistic analogy of our daily mental states.

The present section is structured as follows. In the first part, a guiding conceptual framework of mind wandering is presented. Second, relevant functional outcomes of mind wandering are discerned, revealing a complex balance of costs and benefits. In the third part, mind wandering is argued to facilitate creative cognition and that expert jazz improvisation provides an optimal research paradigm whereby this hypothesis can be empirically tested. Lastly, the significance of the present dissertation is justified, along with a presentation of the main goals and leading hypotheses and their correspondence in the methodology.

## What is mind wandering?

For decades, the act of disengaging from external attention has been object of study under a variety of different constructs, such as task unrelated thought, task unrelated images, stimuli independent thought, daydreaming, mind wandering or zone outs (Smallwood & Schooler, 2006). However, only recently did these mind states fall under scientific inquiry. Smallwood and Schooler (2015) suggest that the growing scientific interest on consciousness played an important role here, along with a confluence of several factors, namely: methodological refinements in the study of consciousness (e.g., triangulatory procedures, which involve a combination of self-report, behavioral and neurophysiologic measures); and the advent of the Default Network - a set of brain regions with increased activation in baseline conditions, compared with goal-directed conditions (Raichle, 2010). The construct of mind wandering gained additional attention following Smallwood and Schooler's review (2006), where previous construct disparities and conflicting findings were integrated into an unified theoretical framework under the common designation of mind wandering (MW). Since then, MW has become a widely used construct to refer to unconstrained mental processes, along with their behavioral, neuroimagiological, electrophysiological and even clinical correlates (Smallwood & Schooler, 2015).

Despite an ongoing debate over conceptual delimitations (Christoff, Irving, Fox, Spreng, & Andrews-Hanna, 2016), the majority of researchers endorse Smallwood and Schooler's definition of MW as a "shift in the contents of thought away from an ongoing task and/or from events in the external environment to self-generated thoughts and feelings" (Smallwood & Schooler, 2015, p. 488). Within a content-based taxonomy, this definition classifies as MW any thought that is both task-unrelated and stimuli-independent, excluding other "out of task" thoughts like external distraction and task related interference.

It could be argued, however, that this content-centric definition of MW fails to capture the dynamic and spontaneous nature that so seemingly characterizes this phenomenon (Christoff et al., 2016). Christoff and colleagues (2016) propose that MW is best characterized not by its contents, but instead by how these contents arise and the transition from one mental state to another. In this view, the authors sustain that spontaneity and unconstrainment constitute the defining characteristics of MW. However, despite its heuristic potentiality, this emerging perspective stills lacks theoretical and methodological consistency. In this sense, for the purposes of the present study, I will endorse the widely followed Smallwood and Schooler's definition of MW as stimuli independent and task unrelated thoughts (Smallwood & Schooler, 2006).

**Functional outcomes of mind wandering: costs and benefits**

Occupying up to half of our waking time (Killingsworth & Gilbert, 2010), MW involves perceptual decoupling from the immediate surroundings (Braboszcz & Delorme, 2011) and engagement in thought flow (Smallwood & Schooler, 2006). As a consequence, it is often associated with attentional costs, leading to task performance costs in a wide range of experimental studies (for a review, see Mooneyham & Schooler, 2013). Since MW is characterized by a parallel recruitment of executive and default network regions (DMN) (Mason et al., 2007; Christoff et al., 2009), the disruptive interference between MW and task-focused attention is thought to stem from an overlapping use of executive resources (Smallwood & Schooler, 2015). Likewise, MW has been recently associated with higher resting-state frontal theta/beta ratio (TBR) (Son et al., 2019), an electroencephalographic (EEG) marker negatively correlated with prefrontally-mediated executive control functions, namely attentional control (Angelidis et al., 2016). However, the functional outcomes of this overlap have also proved to be beneficial. For instance, MW has been found to enhance social problem solving (Ruby, Smallwood, Sackur, & Singer, 2013) and the development of more concrete personal goals (Medea et al., 2016). Moreover, due to the nature of its contents being highly self-referential, prone to mental time travel and biased towards a focus on affective states and personal interests, MW has been hypothesized to play an important role in autobiographical planning (Baird, Smallwood, & Schooler, 2011), as well as in the integration of experienced and anticipated events into meaningful life narratives (Smallwood & Schooler, 2015).

Still, the joint activation of executive and DMN regions in MW suggests that whichever executive cost MW might entail, the additional recruitment of the DMN could in fact facilitate attention processes like attention recycling, dis-habituation, and even mood regulation (Mooneyham & Schooler, 2013). Indeed, recent demonstrations that MW does not affect all types of attention tasks indicate that the relationship between attention and MW is a complex one (Gonçalves et al., 2017; Gonçalves et al., 2018). The context regulation hypothesis states that expertise in attentional control exerts influence over the allocation of attention to internal and external sources depending on task demands (Smallwood & Andrews-Hanna, 2013). Likewise, the relationship between MW and attention would be sensitive to task demands, whereby optimal cognition would decrease the occurrence of MW when executive resources are limited, while increasing the occurrence of MW when upon excess cognitive capacity (Baird et al., 2011). In the next part, I will address a functional outcome of MW where a complex balance of costs and benefits is achieved, that being the case of creative cognition.

**Mind wandering, creative cognition and expert jazz improvisation**

The parallel recruitment of the aforementioned networks is highly reminiscent of the neural correlates of both domain-general creativity in problem solving (e.g., insight problem solving, divergent thinking) and domain-specific creativity in artistic performance (e.g., musical improvisation, poetry composition, and visual art design) (Beaty, Benedek, Silvia, & Schacter, 2016). Likewise, functional connectivity between DM and executive control networks can reliably predict creative thinking ability (Beaty, Seli, & Schacter, 2019). At the electrophysiological level, MW and creative cognition share a dominance of low-frequency bands (e.g., theta; theta/alpha ratio) over high-frequency bands (e.g., beta) (Gruzelier, 2014). In addition, the up-training of theta (or theta/alpha ratio) and down-training of beta rhythms through real-time EEG (rtEEG) protocols has been found to enhance performance in divergent thinking tasks and musical creativity (e.g., improvisational quality, interpretative imagination) (Gruzelier, 2014).

Baird et al. (2012) observed that MW facilitated creative incubation of ideas in a divergent thinking task (unusual uses task), suggesting that, by increasing unconscious associative processing, MW facilitates the generation of novel or atypical solutions to problems. In a different study, despite harming performance in a sustained attention to response task, MW improved performance in concurrent creative problem solving (compound remote associates task) and daily routine planning tasks (Leszczynski et al., 2017).

Still, despite the theoretical robustness and growing scientific interest in the conception of MW as creative thinking (Fox & Beaty, 2018; Christoff et al., 2016), there is a substantial lack of empirical studies aiming to establish a concrete relationship between the two, namely in more domain-specific creative activities, such as artistic performance. Expert jazz improvisation has emerged as an optimal paradigm whereby both domain-specific and domain-general processes underlying creative cognition can be studied (Bengtsson, Csikszentmihalyi, & Ullén, 2007), providing fertile ground for the study of MW and its relationship with creativity. The present dissertation adopts the standard dual-criterion definition of creativity as the conjunction of original (also labelled novel, unusual, unique) and effective (or useful, contextually appropriate, practical) qualities (Runco & Jaeger, 2012). Stein (1953) originally defined a creative work as a "novel work that is accepted as tenable or useful or satisfying by a group in some point in time" (p. 311). By employing an external frame of reference, such as judges with domain-specific expertise, a reliable assessment of artistic creativity can be achieved following the guidelines of Amabile's Consensual Assessment Technique (1982) (jazz improvisation: e.g., Rosen et al., 2020)

Musical improvisation is an acquired skill of spontaneous creative expression (Pressing, 1988), consisting in the real-time production of novel, contextually appropriate and aesthetically and appealing passages of music (Bengtsson et al. 2007). Within the jazz genre, musical improvisation is regarded as an ecologically valid creative task (Bengtsson et al. 2007), where improvising proficiency is favoured by researchers, as it allows for a higher generation of creative improvisations, both in quantity and quality (Beaty, 2015).

Expert jazz improvisation has been consistently associated with perceptually decoupled, internally motivated, DMN-mediated states (Beaty, 2015; Belden et al., 2020; Mota et al., 2020), presenting a striking resemblance with MW states, either at the neuroimagiological and phenomenological level. In a recent EEG study, Rosen and colleagues (2020) observed that the quality of jazz improvisations was associated with hypofrontality in experts, but also independently of expertise, suggesting that improvisational quality benefits from decreased frontally-mediated executive control. Indeed, anodal transcranial direct current stimulation (tDCS) applied over the right dorsolateral prefrontal cortex (DLPFC) - whose deactivation characterizes expert improvisation (Pinho, de Manzano, Fransson, Eriksson, & Ullén, 2014), as well as defocused, free-floating attention (Limb & Braun, 2008) - was found to impair performance in expert jazz pianists (Rosen et al., 2016).

In sum, recent findings suggest that creative expression in musical performance is facilitated by MW-like states. Indeed, according to the context regulation hypothesis, it would be expected that expert improvisers, provided with a training-induced increase in executive resources for improvisation (Pinho et al., 2014), are able to mind wander without significant costs on their attention, and thus, more prone to engage in it. Suitably, jazz improvisation provides a context where the experience of MW can be analysed as to its impact on creativity. Whether engagement in MW during improvisation translates into more creative compositions, empirical testing remains non-existent.

## Aim of the present dissertation

The main goal of the present dissertation was to demonstrate that MW facilitates the expression of musical creativity. Therefore, using a within-subject design, we conducted real-time experience sampling of jazz pianists during musical improvisation and musical reproduction tasks, whose performance was evaluated by expert judges. The primary research hypothesis held that increased MW states would be associated with more creative compositions.

The secondary goal was to conduct an exploratory analysis of experience sampling data (degree of perceptual decoupling, mental navigation and mental improvisation), musical evaluations, but also

oculometric data (eye-blink frequency and pupillary dilation). The inclusion of the latter was motivated by the applicability of indirect, yet non-invasive, measures of cognitive processing to the study of MW. Spontaneous eye-blinking, besides its usage as a peripheral measure of dopaminergic function and cognitive control (Eckstein, Guerra-Carrillo, Singley, & Bunge, 2016), has been associated with attentional disengagement (Nakano, Kato, Morito, Itoi, & Kitazawa, 2013) and positively associated with MW (reading task: Smilek, Carriere, & Cheyne, 2010; breath counting task: Grandchamp, Braboszcz, & Delorme, 2014). Pupillary dilation, on the other hand, while often used as a measure of cognitive processing intensity, has produced contradicting results as a MW correlate (Smallwood et al., 2011; Grandchamp, Braboszcz, & Delorme, 2014), requiring further investigation. Therefore, in the present dissertation, we also sought to analyse oculometric differences between MW and on-task states, along with a possible association with musical evaluations.

## Method

### Participants

Nine experienced musicians (5 female) took part in this experiment. The sample included professional jazz musicians, jazz instructors and undergraduate students from Porto's School of Music and Performing Arts (ESMAE). Ages ranged between 20 and 31, with a mean age of 24.89 years (SD = 3.59). All participants were healthy and had normal or corrected to normal vision and hearing. Years of jazz improvisation experience ranged between 2 and 10 (M = 5.67, SD = 3.20), while years of overall musical training ranged between 10 and 19 (M = 15.33, SD = 3.08). All musicians but two had piano as dominant instrument. In addition, jazz was the primary performance genre in 7 out of 9 musicians, the remaining 2 performing mainly within the classical genre. Supplementary demographic data - including number of live jazz performances, age of onset of musical training, instrument practice routines and professional status - was also collected (see Table 1). Additionally, two jazz piano experts were recruited to judge the improvisations, having 10 and 9 years of professional performance experience, respectively.

Inclusion criteria for participation in the experimental task were: (i) being able to improvise to novel chord progressions, depicted in jazz notation; (ii) being able to reproduce a novel musical piece, depicted in classical notation; (iii) having at least two years of experience in jazz piano improvisation.

Table 1

*Musical demographic profiles*

| Subject | Improvisation experience (years) | Live jazz performances (number) | Live piano jazz performances (number) | Primary performance genre | Musical training (years) | Dominant instrument | Professional status |
|---|---|---|---|---|---|---|---|
| 1 | 9 | ≥ 100 | ≥ 100 | Jazz | 17 | Piano | Professional pianist, jazz instructor |
| 2 | 8 | ≥ 100 | ≥ 100 | Jazz | 12 | Piano | Professional pianist |
| 3 | 7 | ≥ 100 | ≥ 100 | Jazz | 18 | Piano | Professional pianist, jazz instructor |
| 4 | 7 | ≥ 100 | ≥ 100 | Jazz | 13 | Piano | Professional pianist, jazz graduate student |
| 5 | 4 | ≥ 30 | ≥ 10 | Jazz | 16 | Voice, piano | Professional singer, jazz graduate student |
| 6 | 10 | ≥ 100 | 5 | Jazz | 15 | Drums | Professional drummer |
| 7 | 2 | 0 | 0 | Jazz | 10 | Piano | Undergraduate jazz student |
| 8 | 2 | 0 | 0 | Classical | 18 | Piano | Graduate classical student |
| 9 | 2 | 0 | 0 | Classical | 19 | Piano | Graduate classical student |
| 10[a] | 6 | ≥ 90 | ≥ 70 | Jazz, electronic | 18 | Piano, electronics | Professional pianist |

[a] This participant was removed from analysis due to audio distortions in the musical recording.

The sampling was driven by a convenience method, always relying on voluntary participation. Monetary compensation was provided to musical judges, but not to experimental task participants. The latter provided signed informed consent, and the study was carried out under the ethical standards defined by the Institutional Ethics Committee and the Code of Ethics of the World Medical Association (Declaration of Helsinki). In addition, the procedure followed Direção Geral de Saúde (DGS) and University of Minho's recommendations for the reduction of COVID-19 transmission risk.

## Experimental task

We used a within-subject design in which participants individually performed two alternating conditions: musical improvisation and musical reproduction. Each condition was performed 12 times in trials lasting up to 120 seconds, totaling in 24 trials per participant. The 24 trials were presented in a randomized order and preceded by a preparatory period of 10 seconds. In each trial, performance was randomly interrupted between the 80th and 120th second by a thought probe. After responding to the probe, the trial ended and a new trial was immediately initiated.

**Musical improvisation condition.** In this condition, participants were instructed to improvise for 2 minutes to a given chord progression (see Figure 1 for an example). Each trial featured a single chord progression, which was presented on a monitor and accompanied by a backing track. There were 3 different progressions, each being presented 4 times, amounting to 12 musical improvisation trials. Chord progressions were composed by the researcher David Rosen (Rosen et al., 2020), aiming at creating unique, 16-bar sequences of equal difficulty, tempo and duration, while also encompassing familiar jazz patterns. The author was contacted, and permission was obtained for their use in the present dissertation, along with the respective backing tracks. By asking participants to improvise to novel chord progressions, the present experiment aimed to capture more authentic improvisations than previous studies, which commonly use chord progressions from jazz standards.

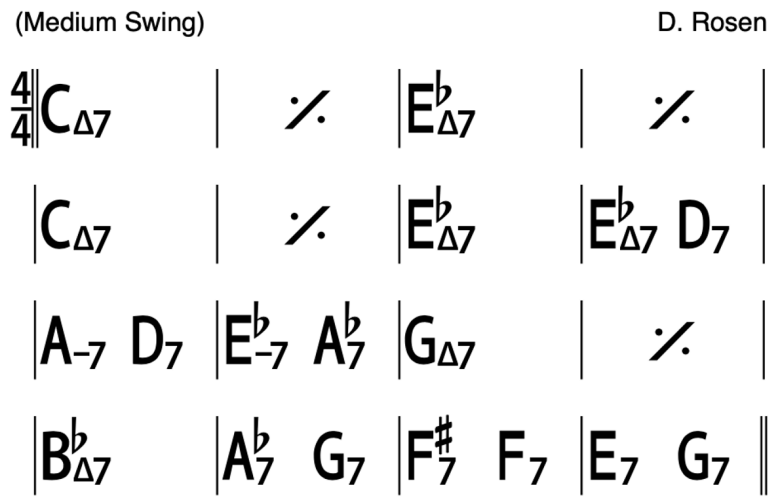


*Figure 1*. Example of a chord progression presented in the Improvise condition.
Source: Rosen et al. (2020)

**Musical reproduction condition.** In this condition, participants were instructed to reproduce a given musical piece over the course of 2 minutes. In each trial, a single music sheet with no backing track was presented, all trials being different. There was a total of 12 trials, and thus, 12 different musical pieces. These consisted of slightly modified versions of Béla Bártok's *Mikrokosmos* piano pieces (see Figure 2 for example) (Bártok, 1987). This ensured that the participants were completely unfamiliar with the compositions and that no learning effect occurred from trial to trial.

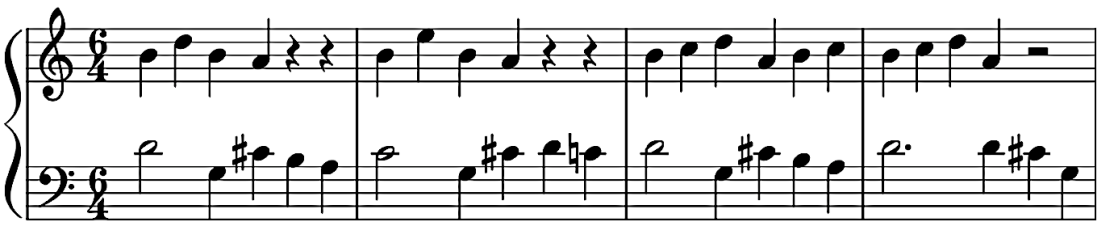

Figure 2. Excerpt of a musical piece from the Reproduce condition

**Thought probes.** In both conditions, between the 80th and 120th second, performance was randomly interrupted by the ceasing of the backing track, along with the replacement of the musical sheet by a set of questions, to be answered with a wired mouse. These aimed to provide a self-report assessment of ongoing conscious experience immediately before interruption, as well as to timestamp the data excerpts destined to analysis. Prompting a "yes or no" response, the participants were first asked to indicate whether their mind was focused on the task immediately before the interruption. This provided

a dichotomic measure of task attention, where a positive answer was scored as on-task, and a positive one as mind wandering. If participants were on-task, the experiment would proceed to the next trial. On the other hand, if the answer was "no", participants would be asked a set of questions which intended to characterize the MW state. First, they were asked whether their attention was deviated from the task intentionally ("yes or no" response). This item classified mind wandering as either intentional or unintentional. Then, on a scale of 1 to 10 (1 = completely disagree; 10 = completely agree), the following items were rated: "My mind was turned off from my surroundings"; "I was imagining being somewhere else" and "The content of my thoughts was very varied". These items were intended to assess the degree of perceptual decoupling, mental navigation and mental improvisation, respectively (Gonçalves et al., 2020).

**Experimental setup.** The task was programmed and presented in E-Prime 2.0 (Psychology Software Tools, Sharpsburg, PA) through a laptop computer. All music and auditory stimuli were recorded and delivered using Reaper 6.0 digital audio workstation (Cockos Inc., New York, NY) via the Focusrite Scarlett Solo USB Interface and Beyerdynamic's DT-770 studio headphones. Additionally, participants played with both hands on a standard 88-key touch-sensitive Yamaha P-105 digital piano (with pedal unit) in front of a digital video camera and a smartphone, which video recorded the participant's performance (see Figure 3).

*Figure 3.* Picture of the experimental setup from the participant's point of view

## Procedure

The present experiment took place at Ermo do Caos - an independent cultural and artistic space situated in Porto - and was submitted to the Ethics Committee of the University of Minho. After providing signed informed consent, the participants went through the following steps: (1) description of the overall procedure; (2) familiarization with the digital piano and audio mix adjustments; (3) a practice block with the chord progressions of the musical improvisation condition; (4) experimental task, performed without interruptions; (4) musical demographic questionnaire. The total duration of this procedure was of approximately 1 hour and 30 minutes.

## Assessment of musical performance

Two expert musicians independently rated audio recordings of the participants' improvisational performance. Having performed 12 improvisation trials, each experimental subject produced 12 improvisations for analysis, amounting to 108 observations in all subjects. Only the 60 seconds that preceded the probe interruption were selected for analysis, and every improvisation was individually rated by both judges in a randomized order.

Prior to the assessment, the author of the present dissertation and the musical judges agreed upon a common set of criteria for the evaluation of musical creativity and the overall quality of improvisational performance. Likewise, for each improvisation, 3 parameters were rated on a 7-point Likert scale: originality, effectiveness and overall improvisational quality. Originality refers to the consistency of novel, unusual or unique musical output throughout each excerpt. Effectiveness, on the other hand, refers to the aesthetic coherence and contextual appropriateness of original musical output. Finally, overall improvisational quality reflected a more holistic appreciation of each composition. While originality and effectiveness measured different aspects of musical creativity, overall improvisational quality aimed to measure a global assessment of compositional quality, different from the average of the latter two.

Inter-rater reliability was good to excellent for all rating scales (see Table 2), as estimated by the intraclass correlation coefficient (ICC) for originality (ICC=0.90, N=2), effectiveness (ICC=0.84, N=2) and overall improvisational quality (ICC=0.85, N=2). ICC estimates and their 95% confident intervals were calculated using SPSS version 26 (SPSS Inc., Chicago, IL) based on a mean-rating (N=2), consistency, two-way mixed-effects model.

For each scale, the two ratings were averaged so that each improvisation produced three composite scores for originality, effectiveness and overall improvisational quality.

Table 2

*Results of ICC calculation for musical rating scales*

| | | 95% CI | | | |
|---|---|---|---|---|---|
| | *ICC* | *LL* | *UL* | *F* (107, 107) | *p* |
| Originality | .90 | .86 | .93 | 10.22 | <.001 |
| Effectiveness | .84 | .76 | .89 | 6.19 | <.001 |
| OIQ | .85 | .78 | .90 | 6.50 | <.001 |

*Note.* OIQ = overall improvisational quality; ICC= intraclass correlation coefficient; CI = confidence interval; LL = lower limit; UL = upper limit; df = degrees of freedom.

**Oculometric data acquisition and analysis**

The participant's upper torso and face were recorded using two video sources: a high definition video camera, placed head-level in a frontal position, and a smartphone, placed slightly above the keyboard level in a frontal position. Each participant produced 24 excerpts for analysis (12 improvisation trials and 12 reproduction trials), amounting to 216 observations in all participants. Similar to the musical performance analysis, only the 60 seconds that preceded the probe interruption were selected for analysis.

In a first moment, data was processed in OpenFace 2.2 (Baltrušaitis, Zadeh, Lim, & Morency, 2018) a facial behavior analysis toolkit that allows for offline video processing. However, the analysis of features such as eye-blinks per minute, pupil dilation and gaze patterns were discarded due to high number of artifacts. These were caused by excessive head movements, as well as gaze fixation on the keyboard, which rendered eye visibility unreliable. Hence, this software proved unusable for the purposes of the present experiment. In a second moment, data was processed in Eye-blink-detection (Soukupová & Čech, 2016), a Python script that counts the frequency of eye-blinks from a given video source. Unfortunately, the same issues remained, as an excessive number of false positives was observed. The final attempt to extract relevant data from the video recordings entailed a manual count of eyeblinks by two naive subjects, which conducted this task independently.

Inter-rater reliability was excellent (ICC=0.964, N = 2), with a 95% confidence interval ranging from 0.949 to 0.974. ICC estimates were calculated using SPSS version 26 (SPSS Inc., Chicago, IL) based on a mean-rating (N=2), consistency, two-way mixed-effects model.

### Statistical analysis

Given that each participant produced 24 independent observations of the variables task attention, perceptual decoupling, mental navigation, mental improvisation, originality, effectiveness, overall improvisational quality and eye-blink frequency, data from all participants was stacked and treated as 216 independent observations.

For each of the musical rating scale, a high-score and low-score group was created. Rather than using a median split, an omission of the middle quintile allowed for a comparison with higher inter-group discriminability between the top 40% and bottom 40% of scored improvisations on each rating scale.

An exploratory analysis of data encompassed parametric testing, including independent samples *t*-tests and point-biserial correlations when parametric assumptions were met, as well as non-parametric statistics, including Mann–Whitney U tests, Spearman correlations, mean and standard deviation.

## Results

### Thought probe data

Across both conditions, participants reported being predominantly on-task (89.8%, n = 194), compared with MW (10.2%, n = 22). Surprisingly, percentages remained equal on each condition, with on-task attention occurring in 97 trials and MW occurring in 11 trials. MW was generally reported as unintentional (90.9%, n = 20), compared to intentional (9.1%, n = 2), displaying equal percentages for each condition. In addition, scores for perceptual decoupling, mental navigation and mental improvisation didn't differ significantly between improvisation and reproduction conditions (see Table 3 and Figure 4).

Table 3

*Descriptive statistics for perceptual decoupling, mental navigation and mental improvisation scores by condition, reporting mean and standard deviation (between parenthesis)*

| Condition | *n* | Perceptual Decoupling | Mental navigation | Mental improvisation |
|---|---|---|---|---|
| Improvisation | 11 | 5.82 (2.23) | 1.64 (1.03) | 5.91 (1.64) |
| Reproduction | 11 | 5.82 (2.48) | 2.55 (2.54) | 6.18 (2.04) |
| All | 22 | 5.82 (2.30) | 2.09 (1.95) | 6.05 (1.81) |

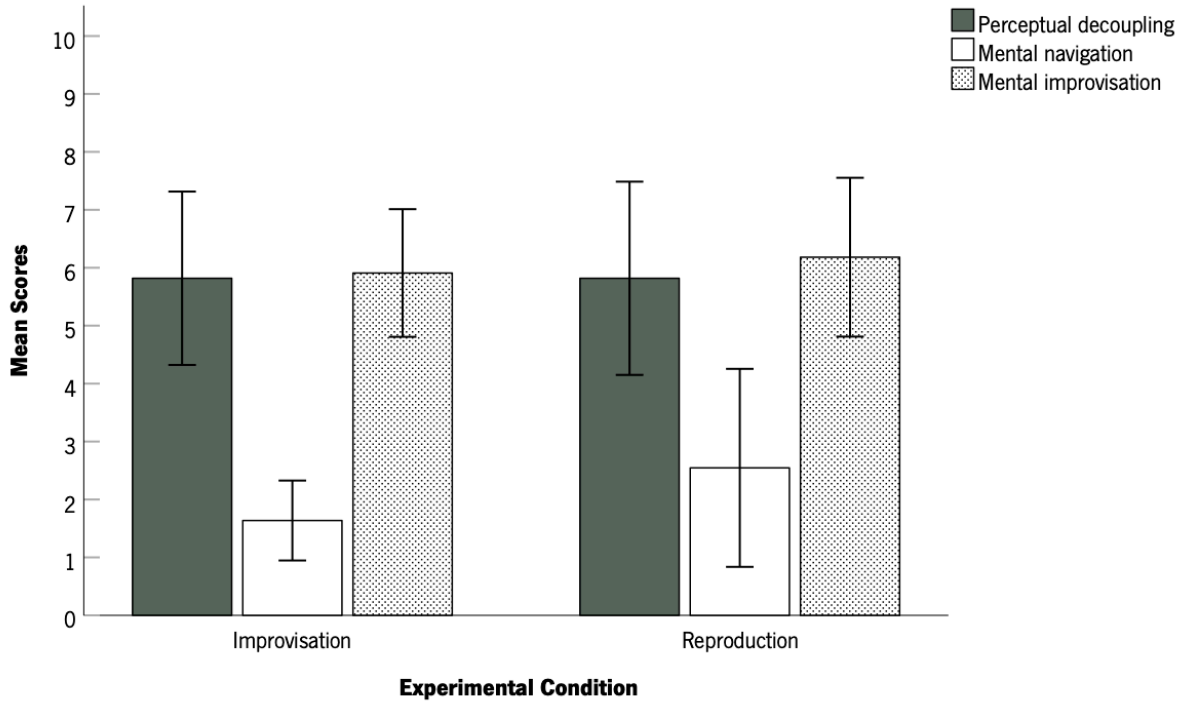


*Figure 4*. Mean scores and 95% confidence intervals for perceptual decoupling, mental navigation and mental improvisation by condition

## Relationship between thought probe data and improvisational performance

**Task attention.** Descriptive statistics, along with *t*-test results for differences in musical scores between task attention reports are presented on Table 4, revealing that improvisations attained higher mean ratings on all scales when unintentional MW was reported (originality: M = 4.63; effectiveness: M = 4.48; overall improvisational quality = 4.18), compared with on-task attention (originality: M = 3.53; effectiveness: M = 3.41; OIQ = 3.37). However, statistically significant differences were found only for originality, $t$ (105) = -2.43, $p$ = .017 and effectiveness, $t$ (105) = -2.30, $p$ = .024, but not overall improvisational quality scores, $t$ (105) = -1.80, $p$ = 0.075 (Figure 5). Likewise, there was a significant positive correlation between unintentional MW and originality scores, $r_{pb}$ = .23, $p$ = .017, effectiveness scores, $r_{pb}$ = .22, $p$ = .024, but not overall improvisational quality scores $r_{pb}$ = .17, $p$ = .075.

Curiously, the single improvisation where intentional MW was reported attained below average scores on all scales (originality = 3.50; effectiveness = 3.50; overall improvisational quality = 3.50), when compared with improvisations where unintentional MW occurred, while still exceeding the average scores of on-task improvisation for effectiveness and overall improvisational quality.

Table 4

*t-test results for differences in musical scores between improvisations with self-reported on-task attention and improvisations with self-reported unintentional mind wandering*

| Musical rating | On-task | MW-U | | | 95% CI | | |
|---|---|---|---|---|---|---|---|
| scale | *M (SD)* | *M (SD)* | *t* (105) | *p* | *LL* | *UL* | *d* |
| Originality | 3.53 (1.40) | 4.63 (0.92) | -2.43* | .017 | -2.00 | -0.20 | 0.93 |
| Effectiveness | 3.41 (1.43) | 4.48 (0.94) | -2.30* | .024 | -1.99 | 0.14 | 0.88 |
| OIQ | 3.37 (1.37) | 4.18 (0.92) | -1.80 | .075 | -1.68 | 0.08 | 0.69 |

*Note*. MW-U = unintentional mind wandering; OIQ = overall improvisational quality; df = degrees of freedom; LL = lower limit; UL = upper limit.

* $p < .05$

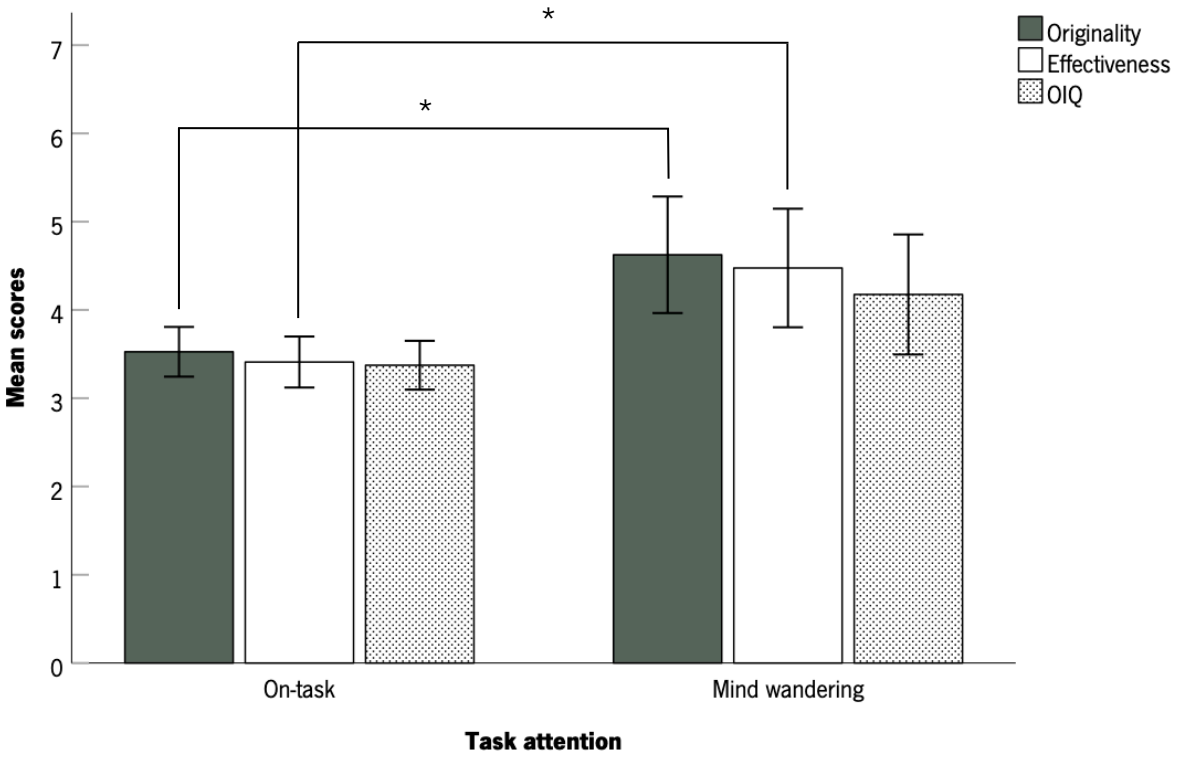


Figure 5. Mean scores and 95% confidence intervals for originality, effectiveness and overall improvisational quality (OIQ) by task attention

* $p < .05$

**Perceptual decoupling, mental navigation and mental improvisation.** Spearman correlation analyses shown in Table 5 revealed that mental navigation impaired musical performance on

all evaluated domains, displaying a significant negative correlation with overall improvisational quality, $r_s$ = -.66, $p$ = .037 and originality, $r_s$ = -.63, $p$ < .051 and with marginal significance for effectiveness, $r_s$ = -.63, $p$ < .051. Indeed, there was a significant difference in mental navigation scores between high and low-OIQ improvisations, $U$ = 1.00, $p$ = .037, but not between high and low-originality, $U$ = 1.00, $p$ = 0.153, or high and low-effectiveness improvisations $U$ = 1.50, $p$ = 0.076. No significant correlation was found between perceptual decoupling or mental improvisation and any of the musical performance scores.

Table 5

*Spearman correlation analyses between perceptual decoupling, mental navigation, mental improvisation and musical scores (originality, effectiveness and OIQ)*

| | Originality | Effectiveness | OIQ |
|---|---|---|---|
| Perceptual decoupling | .20 | 0.12 | .21 |
| | $p$ = .587 | $p$ = .74 | $p$ = .552 |
| Mental navigation | -.63 | -.63 | -.66* |
| | $p$ = .051 | $p$ = .051 | $p$ = .037 |
| Mental improvisation | .31 | .06 | .22 |
| | $p$ = .376 | p = .875 | $p$ = .550 |

*Note.* Analyses were run on a total of 10 observations (intentional mind wandering trial removed from analysis).

* $p$ < .05

## Eye-blink frequency

There were no significant differences in eye-blink frequency between trials where participants mind wandered (M = 7.52, SD = 6.29) and trials where on-task attention was reported (M = 7.28, SD = 4.54). Similarly, eye-blink frequencies didn't differ significantly between improvisation (M = 7.02, SD = 4.11) and reproduction trials (M = 7.60, SD = 5.33).

However, there were significant differences in eye-blink frequencies between high (M = 8.29, SD = 4.74) and low-originality improvisations (M = 6.20, SD = 2.58), $t$(52.40) = -2.36, $p$ = 0.022 (see Table 6). Similarly, differences in eye-blink frequency were significant between high (M = 8.59, SD = 4.99) and low-effectiveness improvisations (M = 6.62, SD = 3.19), $t$(56.13) = -2.01, $p$ = .050, while only being

marginally significant between high (M = 7.89, SD = 3.93) and low-OIQ improvisations (M = 6.38, SD = 2.68), $t$ (54.98) = -1.87, $p$ = .067.

Table 6

*t-test results for differences in eye-blink frequency between low and high-originality, effectiveness and overall improvisational quality*

| Contrast | Low | High | | | | 95% CI | | |
|---|---|---|---|---|---|---|---|---|
| group | *M (SD)* | *M (SD)* | *t* | *df* | *p* | *LL* | *UL* | *d* |
| ORI | 6.20 (2.58) | 8.29 (4.74) | -2.36* | 52.40 | .022 | -3.88 | -0.32 | 0.55 |
| EFF | 6.62 (3.19) | 8.59 (4.99) | -2.01 | 56.13 | .050 | -3.93 | 0.00 | 0.47 |
| OIQ | 6.38 (2.68) | 7.89 (3.93) | -1.87 | 54.98 | .067 | -3.13 | 0.11 | 0.45 |

*Note.* ORI = originality; EFF = effectiveness; OIQ = overall improvisational quality; df = degrees of freedom; CI = confidence interval; LL = lower limit; UL = upper limit.

* $p < 0.05$

## Musical demographic data

Spearman correlation analyses shown in Table 7 revealed significant positive correlations between number of jazz piano live performances and originality, $r_s = .74$, $p = .024$, effectiveness, $r_s = .85$, $p = .004$, and overall improvisational quality, $r_s = .75$, $p = .019$. Surprisingly, there was no significant correlation between years of experience in piano improvisation and any of the musical scores. In addition, no correlation was found between demographic data and the frequency of MW reports.

Table 7

*Spearman correlation analyses between musical demographic data (years of piano improvisation experience, jazz piano live performances), though probe data and musical scores*

| | ORI | EFF | OIQ | MW[a] |
|---|---|---|---|---|
| Years of experience | .48 | .48 | .39 | -.03 |
| | $p = .194$ | $p = .194$ | $p = .297$ | $p = .949$ |
| Live performances | .74* | .85** | .75* | .07 |
| | $p = .024$ | p = .004 | $p = .019$ | $p = .850$ |

*Note.* Correlation coefficients and respective p-values were calculated based on an inter-subject analysis (n = 9). MW = mind wandering; ORI = originality; EFF = effectiveness; OIQ = overall improvisational quality.

* $p < .05$

** $p < .005$

[a] Sum of MW reports throughout the experimental task

## Discussion

The central aim of this dissertation was to explore if mind wandering enhances musical creativity in the context of jazz piano improvisation. Using a sample of experienced musicians, the present experiment departs from previous studies of mind wandering in its relation to domain-general creativity in laboratory settings (unusual uses task: Baird et al., 2012; remote associates task: Leszczynski et al., 2017) towards a more naturalistic assessment of mind wandering and domain-specific creativity. In addition, by separately evaluating creative output for its novelty and effectiveness, we aimed to provide a more balanced account of musical creativity than previous studies, which have evaluated musical creativity either by rating it in a unitary rating scale (e.g. Rosen et al., 2016), focusing on a specific component of creative thinking (divergent thinking: Palmiero, Guariglia, Crivello, & Piccardi, 2020), or even by quantifying creative performative elements (Villarreal et al., 2013). With this, we intended to test previous claims of mind wandering-facilitated creative thinking, providing a better understanding of mind wandering functions.

Overall, results show that improvisations during self-reported unintentional mind wandering were characterized by increased musical creativity scores. This effect was evident in terms of ideational fluency, aesthetic coherence and contextually appropriateness. In conjunction, these findings support the hypothesis that mind wandering seems to facilitate creative performance in musical improvisation.

However, it is important to note that instances of mind wandering reported by musicians occur unfrequently and, mostly, unintentional. In both experimental conditions, mind wandering was reported approximately once every ten trials. In addition, mind wandering was predominantly unintentional and didn't differ in its various components (perceptual decoupling, mental navigation and mental improvisation) between conditions. The low frequency of mind wandering reports could be interpreted in light of some methodological constrains. First, the short duration and novelty of the musical tasks. Previous studies have shown that the propensity to mind wander tends to increase as a function of trial

length (e.g. Smallwood, Obonsawin, & Reid, 2002). In the present experiment, trial length may have not been enough for participants to familiarize themselves with either musical sheets or chord progressions, where the occurrence of mind wandering would have entailed significant performance costs. Therefore, task complexity could account not only for the relatively low occurrence of mind wandering, but also for high percentage of unintentional mind wandering, which has been shown to be more prevalent than intentional mind wandering in complex tasks (Seli, Risko, & Smilek, 2016).

A second aspect that may have contributed to infrequent mind wandering was the inclusion of a backing track, which, by instilling time constraints over musical performance, required participants to maintain and coordinate additional task-relevant information in awareness. Moreover, the rigidity and non-reactive nature of a backing track could have generated ambiguity as to whether to perform as a solo player, or as a soloist embedded in group performance, who in either case could not have improvised beyond the task-imposed harmonic structure. Indeed, previous work has shown that task constraints in a jazz improvisation performance can account for differences in the activity of executive control network and default mode networks (Pinho et al., 2015), in which more constrained tasks are responsible for an increased activation of the executive control network while lower-constraint tasks show evidence of default mode network activity. Hence, a presentation of chord progressions without a backing track could have enhanced not only the task's ecological validity, but also the occurrence of self-generated states. In sum, these factors may have increased the participants' reliance on controlled processing, which has been shown to supress mind wandering and perceptual decoupling (Smallwood & Schooler, 2006).

The most significant results were that improvisations with unintentional mind wandering attained significantly higher musical scores on both creativity measures, compared with on-task improvisations. More specifically, the occurrence of unintentional mind wandering increased the generation of original musical output, while at the same time enhancing effective implementation of original elements within a coherent and contextually appropriate aesthetic. These results go in line with recent theoretical formulations of mind wandering as closely associated with creative thinking (Christoff et al. 2016; Fox & Beaty, 2018). Fox and Beaty's dual-process model of mind wandering holds that mind wandering, similarly to creative thinking, relies on spontaneous thought generation of new ideas. However, according to these authors, differences between mind wandering and creative thinking ultimately reside in the end product: while the outcomes of creative thinking can be regarded as original and useful by an external frame of reference, the outcomes of mind wandering cannot, as its highly self-referential nature renders thoughts only useful to the wandering participant. The results of the present experiment may shed a new light on this formulation. Although research suggests that self-generated thoughts entail mostly self-

referential contents (Smallwood & Schooler, 2015), their presence explained a portion of the observed variance in originality and effectiveness of the end product, compared to more "useful" and theoretically creative task-related thoughts. Did self-generated thoughts per se directly inform musical performance, or was this association mediated by other components of mind wandering? The following results support the second alternative.

When the participants mind wandered, the degrees of perceptual decoupling and mental improvisation didn't significantly impact performance, despite the existence of nonsignificant positive correlation. On the other hand, the degree of mental navigation significantly impaired performance on all domains. These results suggest that the contents of mind wandering (e.g. mental navigation), as opposed to its process (e.g. perceptual decoupling), and dynamics (e.g. mental improvisation) (Gonçalves et al., 2020) did not play a role in mind wandering's positive modulation of musical creativity. In this sense, the usage of additional measures of cognitive functioning in future studies (e.g., the previously mentioned electroencephalographic theta/beta ratio, a reliable marker of attentional control and its fluctuations during the task) could provide further insights about the role of mind wandering's processual and dynamic components in the facilitation of musical creativity.

Surprisingly, while mind wandering contributed to creative performance, it didn't significantly impact the improvisation's overall quality. If the facilitation of generation and effective implementation of original elements within a musical language wasn't enough to produce higher quality improvisations, perhaps technical ability (e.g. command of the instrument, complexity of musical thoughts and ideas, theoretical advancement of compositions) could determine whether creative output causes a positive impact on the evaluators. In addition, there could be more to musical creativity than originality and effectiveness. Simonton (2012) suggested ‘surprise’ as a third factor, which would reflect how much new knowledge is gained once the idea is generated. Ultimately, the weight of each factor in the determination of creativity remains unclear in current literature, and while Simonton (2018) has devised a metric that assesses the creativity associated with any given factor combination, its development is still in the early stages.

In accordance with Rosen et al. (2016), the number of live jazz piano performances significantly predicted pianists’ improvisation ratings better than years of jazz piano experience. There was a significant positive correlation between the number of live performances and the musical scores from all rating scales, the strongest effect being observed for effectiveness. On the other hand, correlations between years of jazz piano experience and musical scores were nonsignificant.

Contrary to previous findings, eye-blink frequency wasn't significantly higher during instances of mind wandering, compared with on-task attention (reading task: Smilek, Carriere, & Cheyne, 2010; breath counting task: Grandchamp, Braboszcz, & Delorme, 2014). However, this result should be interpreted in the light of the probe's framing, which asked participants about the moment which immediately preceded the interruption, while eye-blink frequency was estimated for the 60 seconds that preceded the interruption. Ultimately, the measure eye-blink frequency is more well-adjusted to the musical evaluation's temporal interval than thought probes. Still, it provides little information about the participant's neurocognitive functioning without corroboration from more reliable measures (e.g., EEG, or self-reports of an overlapping time interval), as eye-blinking could be influenced by factors such as lack of sleep, use of contact lenses, temperature and humidity of the room or seasonal allergies (Eckstein, Guerra-Carrillo, Singley, & Bunge, 2016). Nonetheless, eye-blink frequency mirrored the results of self-reported mind wandering in regard to musical evaluations. High-creativity improvisations registered a significantly higher number of eye-blinks than low-creativity improvisations, while the same was not observed when comparing this difference between high and low-quality improvisations.

The present dissertation also demonstrated that a manual count of eyeblinks by two naive subjects, aided by two video sources, allows for a compromise between ecological validity and the need for a reliable measurement of eye-blink frequency in music performance. Although less time-consuming than a manual count, current eye-tracking software seems to be significantly more prone to report false positives in the context of musical performance. A possible solution could arise in head-mounted eye-tracking cameras, which have been recently used to assess gaze behavior in musical trios (Vandemoortele et al., 2018). While offering a relatively naturalistic measure of oculometric data, mobile eye-tracking is unaffected by head movements and could indeed be a reliable instrument for future studies of musical performance.

The presents results should be interpreted in light of several methodological limitations: reliance in self-report measures, small sample size and low frequency of mind wandering. What began as an exploratory study of EEG correlates of mind wandering and musical creativity in jazz improvisation, had to be adapted after the global pandemic of COVID-19 given the impossibility to use EEG and eye-tracking equipment. Thought probes, despite being regard as a reliable measure of mind wandering (Smallwood & Schooler, 2015), would have benefited from heterophenomenological corroboration by EEG measures (e.g. increased theta/beta ratio) and oculometric measures (e.g. increased eye-blink frequency; eye movements; pupillary dilation).

Regarding thought probes (e.g., "Indicate whether you mind was focused on the task immediately before the interruption"), while devised to provide a reliable account of mind wandering for the seconds that preceded interruption, could be questioned as to its validity to measure mind wandering throughout the entire 60 seconds which were subject to analysis in terms of musical performance. However, the alternative strategy, which would be to ask participants about their propensity to mind wander over a more extended period of time, has been associated with recency effects, with a bias towards the moments that immediately preceded interruption. Furthermore, since mind wandering usually occurs without meta-cognitive awareness (Christoff et al., 2007), the usage of retrospective strategies could have provided a less reliable account of the participant's mental states.

A second limitation was the small sample size. While comprising an heterogenous group of experienced and mostly professional musicians, a bigger sample would have provided an increased statistical power, while potentiating the occurrence of mind wandering.

Summing up, our results suggest that the positive relationship between mind wandering and creativity also extends to artistic performance domains, showing that increased mind wandering was associated with higher levels of musical creativity during jazz improvisation. Futures studies should try to replicate the current results, using an increased sample size, increased time of improvisation blocks and relying on diverse methods that may contribute to a more reliable mind wandering assessment (self-report; EEG, eye-tracking).

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## Appendix A

Musical demographic questionnaire (in portuguese)

| | | | |
|---|---|---|---|
| **Sexo** | ☐ Feminino | ☐ Masculino | |
| **Idade atual:** | | | |
| **Mão dominante** | ☐ Direita | ☐ Esquerda | ☐ Ambidestro |
| **Idade de início de treino musical:** | | | |
| **Tens algum curso de formação superior em música?**<br>**Se sim, qual?** | | | |
| **Anos de experiência com improvisação (piano):** | | | |
| **Nº de performances jazz ao vivo (qualquer instrumento):** | | | |
| **Nº de performances jazz ao vivo (só piano):** | | | |
| **Instrumento principal:** | | | |
| **Nº médio diário de horas de prática musical:** | | | |
| **Nº médio mensal de dias de prática musical:** | | | |
| **Outras observações acerca da tua formação musical que consideres relevante:** | | | |

**Appendix B**

Chord progressions from the musical improvisation condition

Source: Rosen et al. (2020)

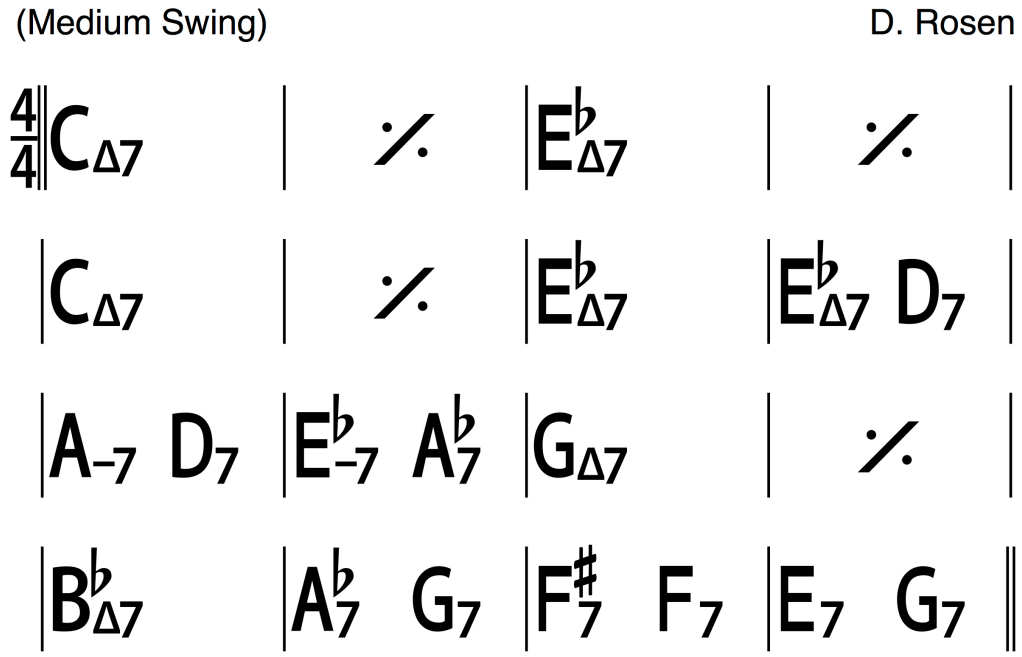



*Figure B1.* Chord progression 1

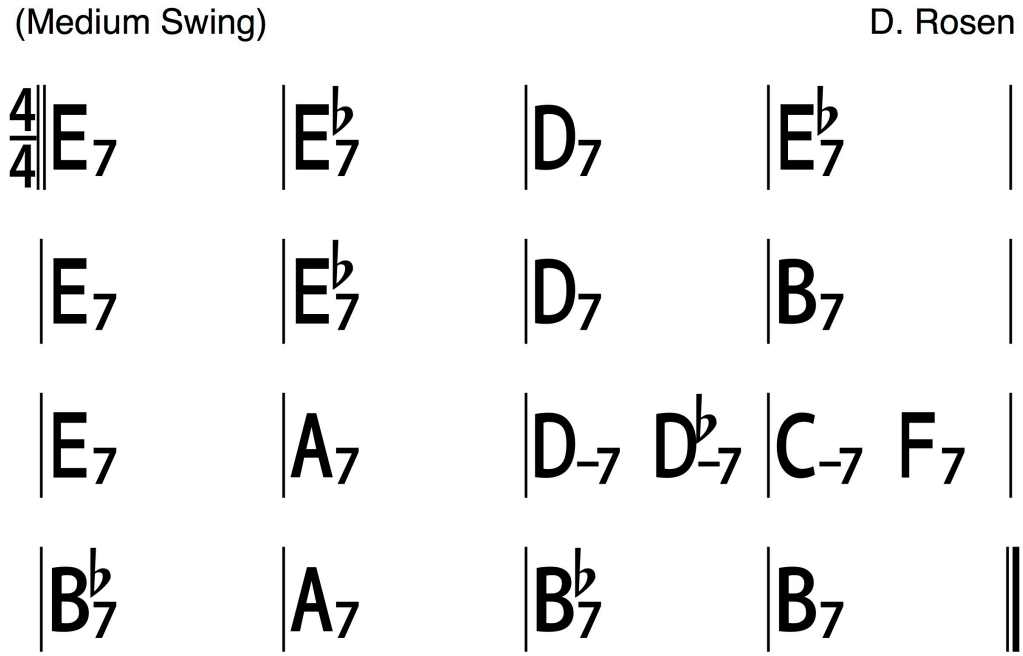



*Figure B2.* Chord progression 2

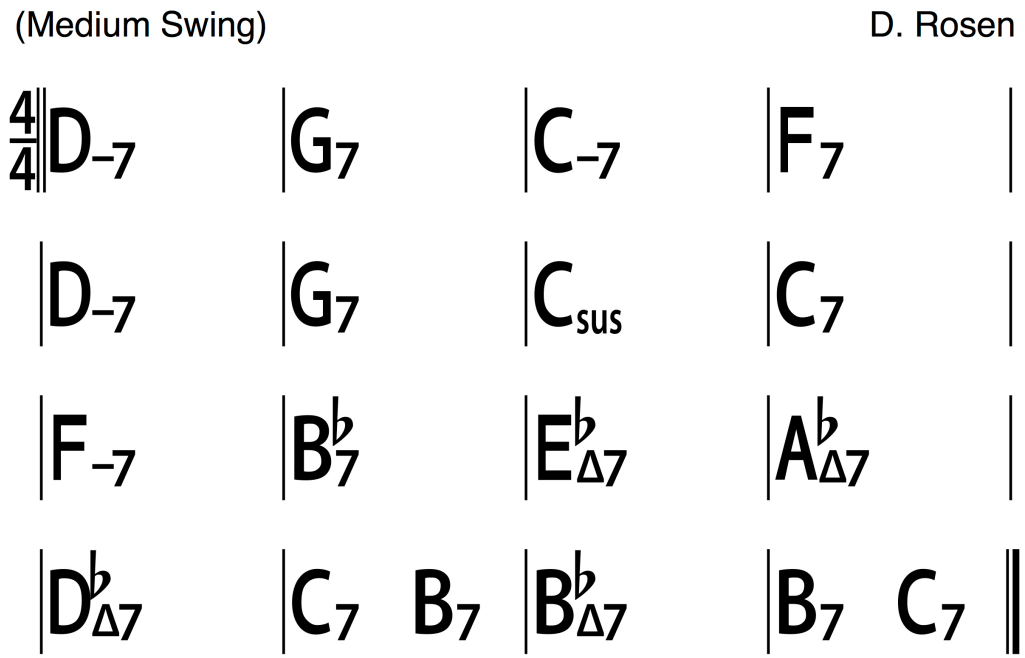



*Figure B3.* Chord progression 3

## Appendix C

Musical sheets from the musical reproduction condition

Source: Bártok (1987)

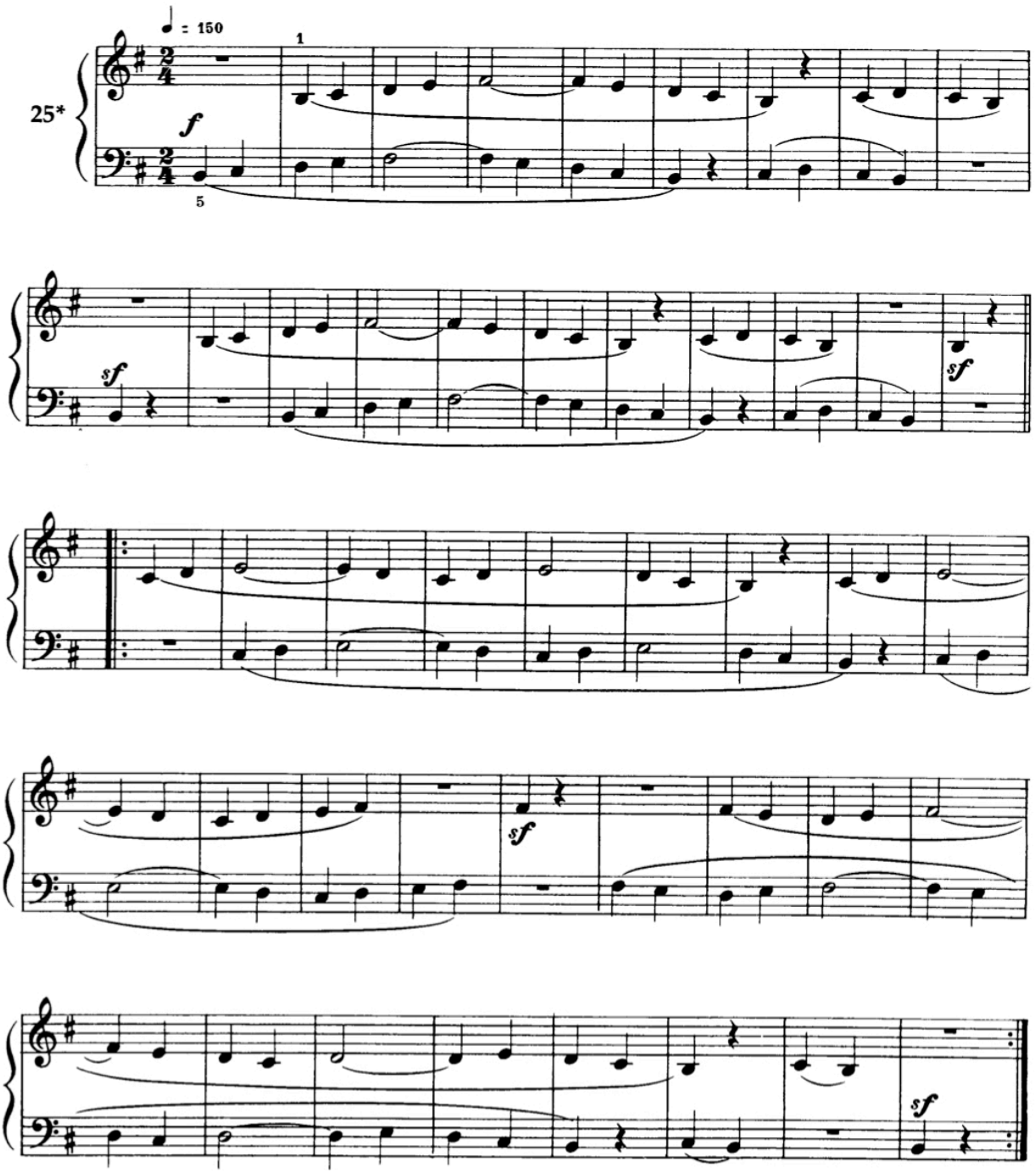



*Figure C1.* Musical sheet 1

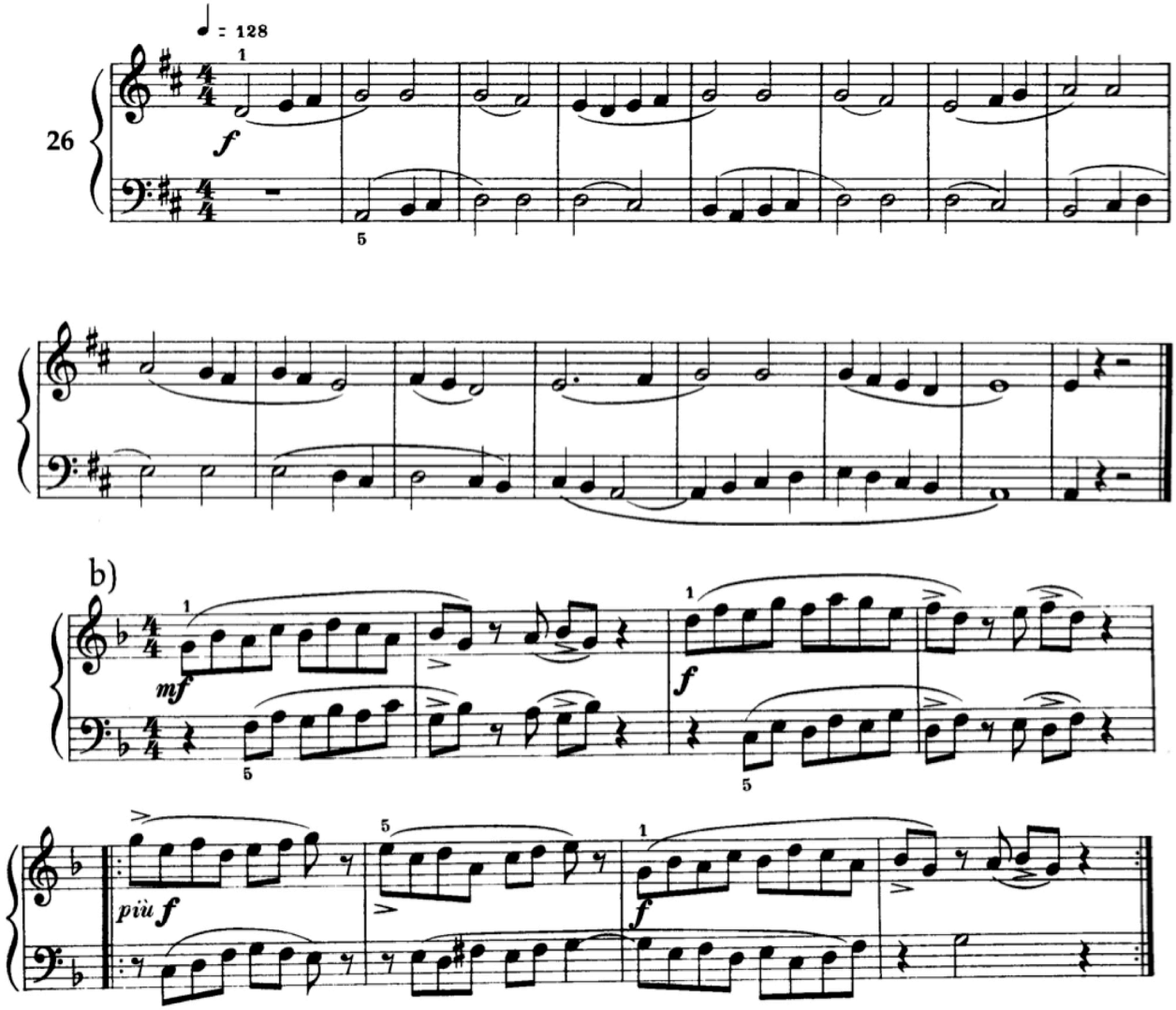



*Figure C2*. Musical sheet 2

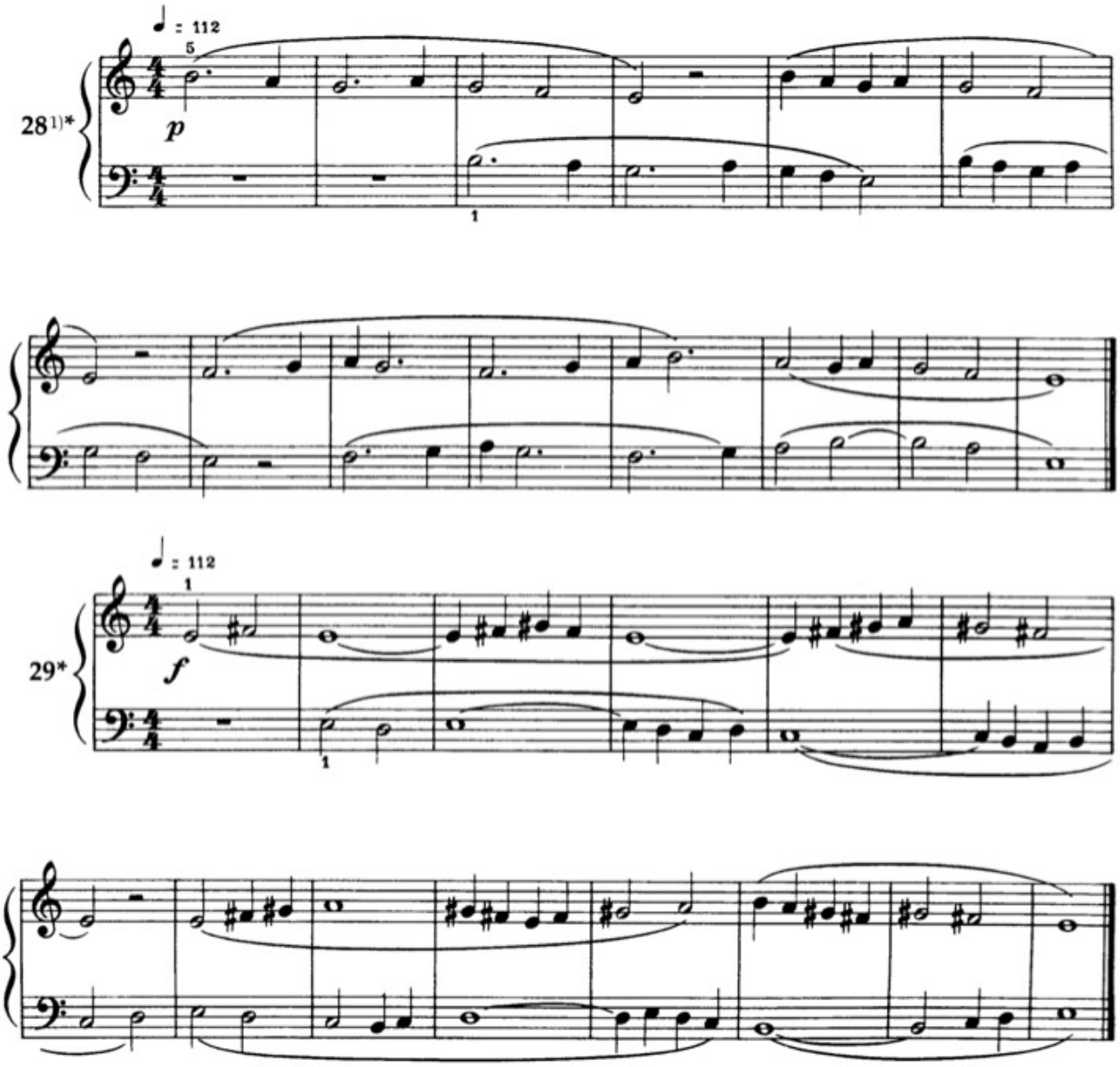



*Figure C3*. Musical sheet 3

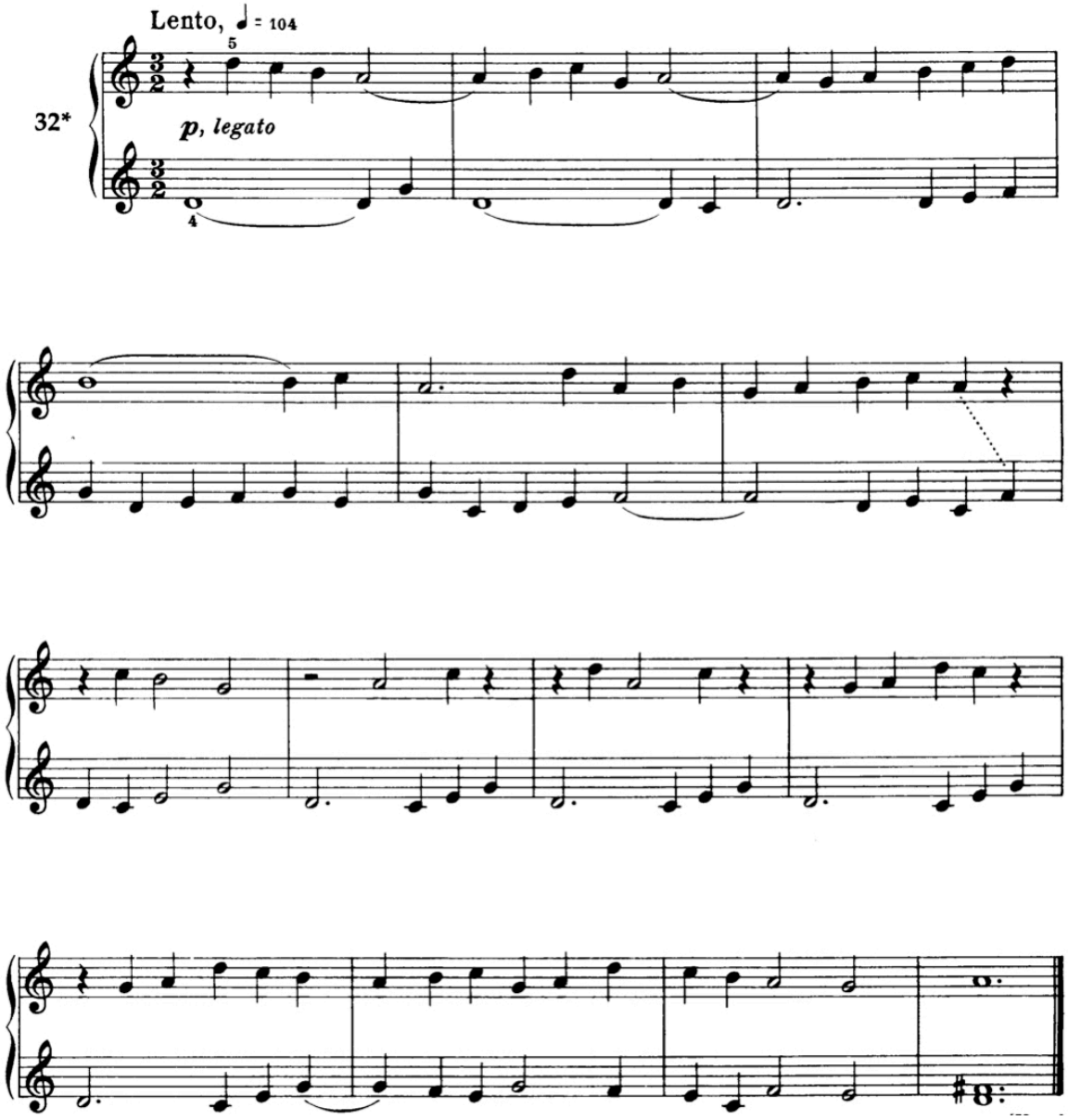



*Figure C4*. Musical sheet 4

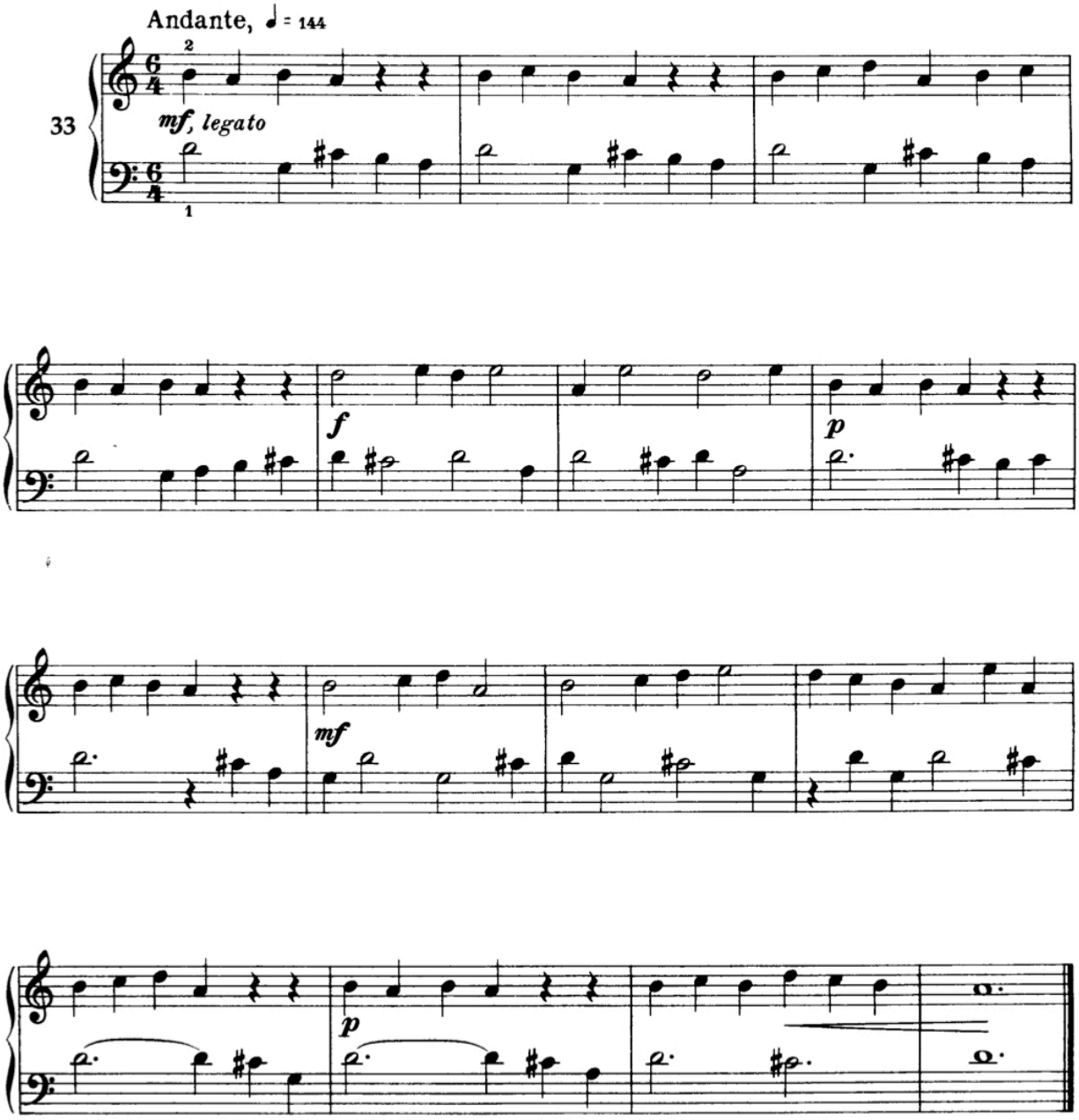



*Figure C5*. Musical sheet 5

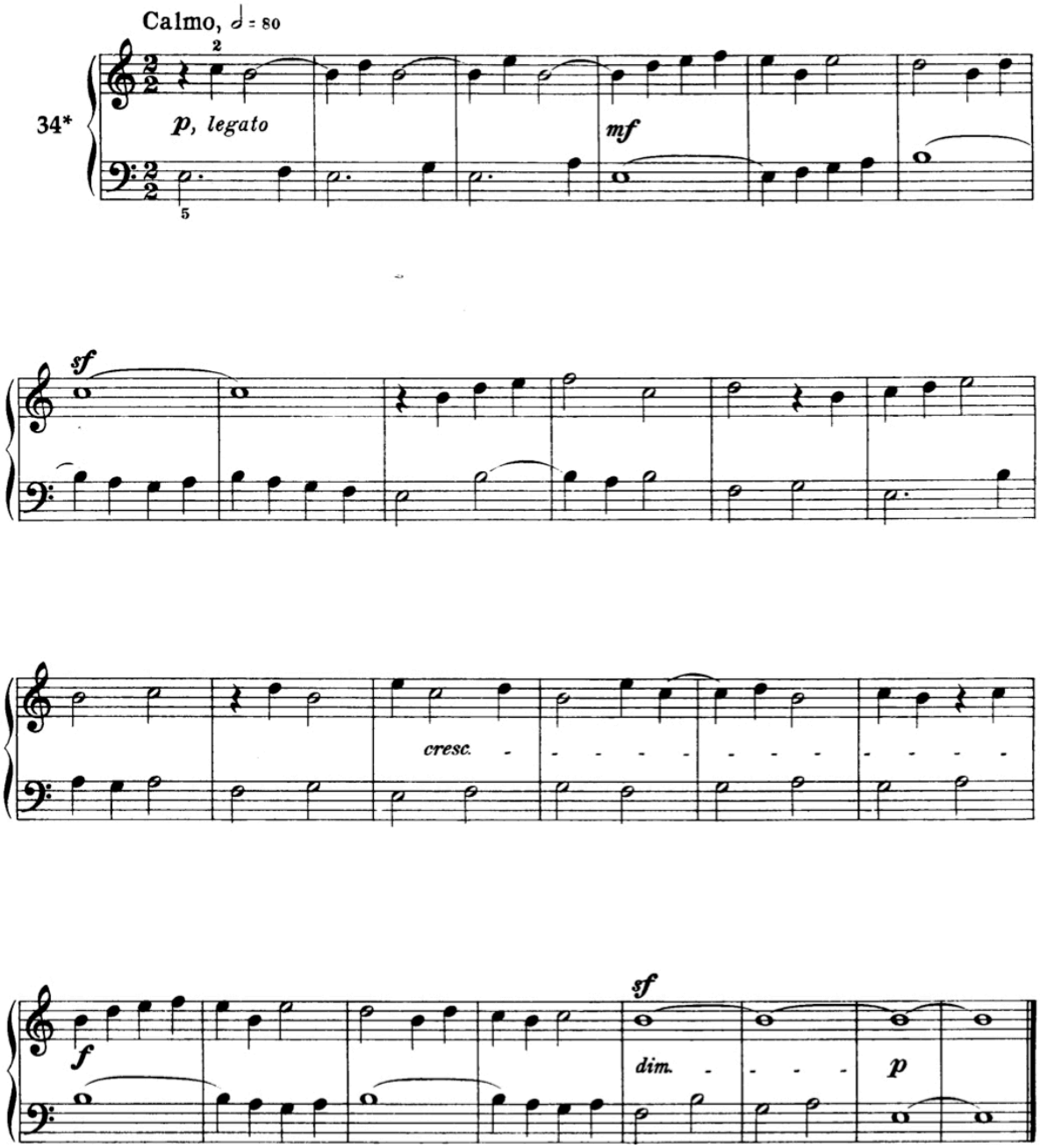



*Figure C6.* Musical sheet 6

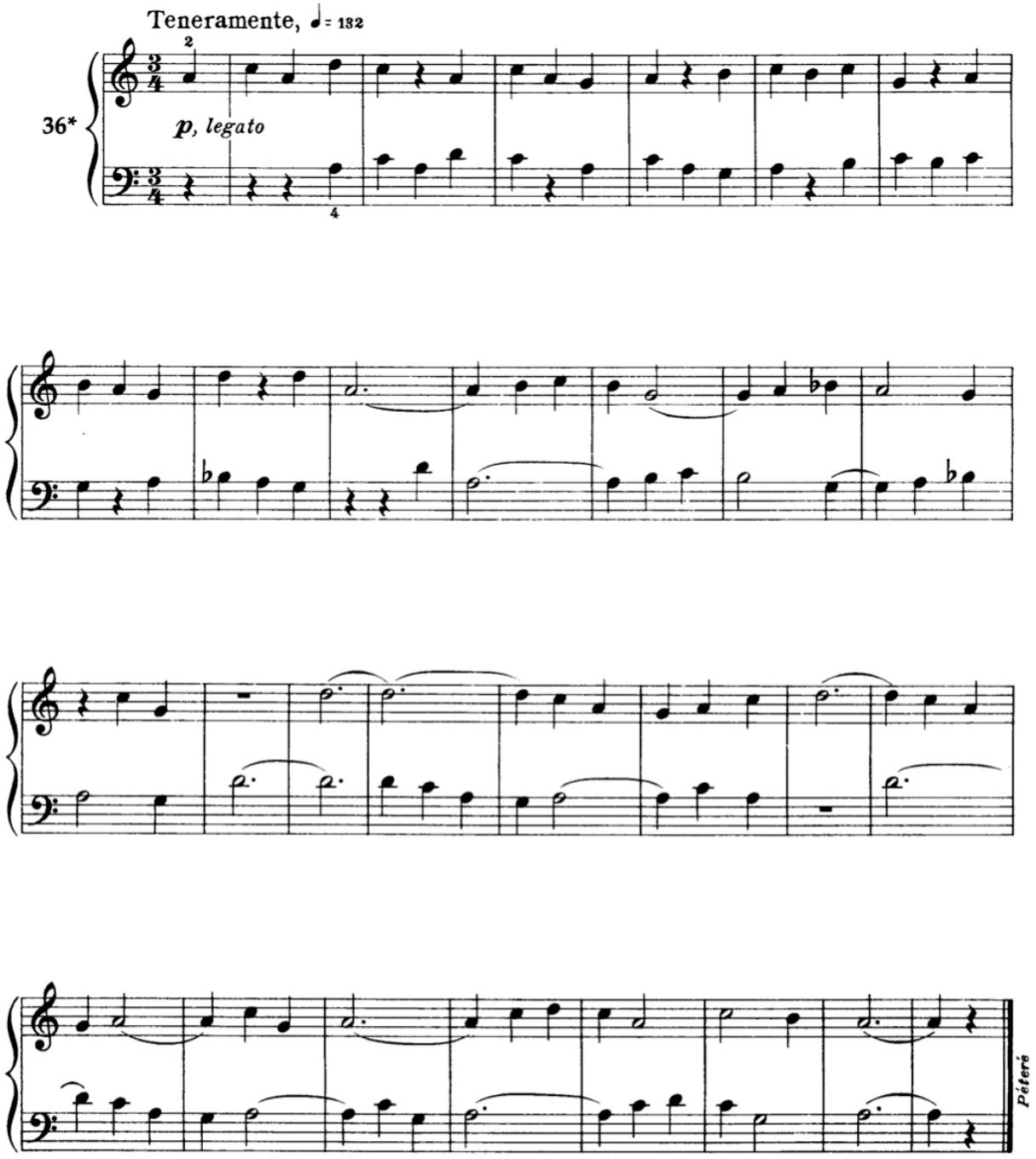



*Figure C7.* Musical sheet 7

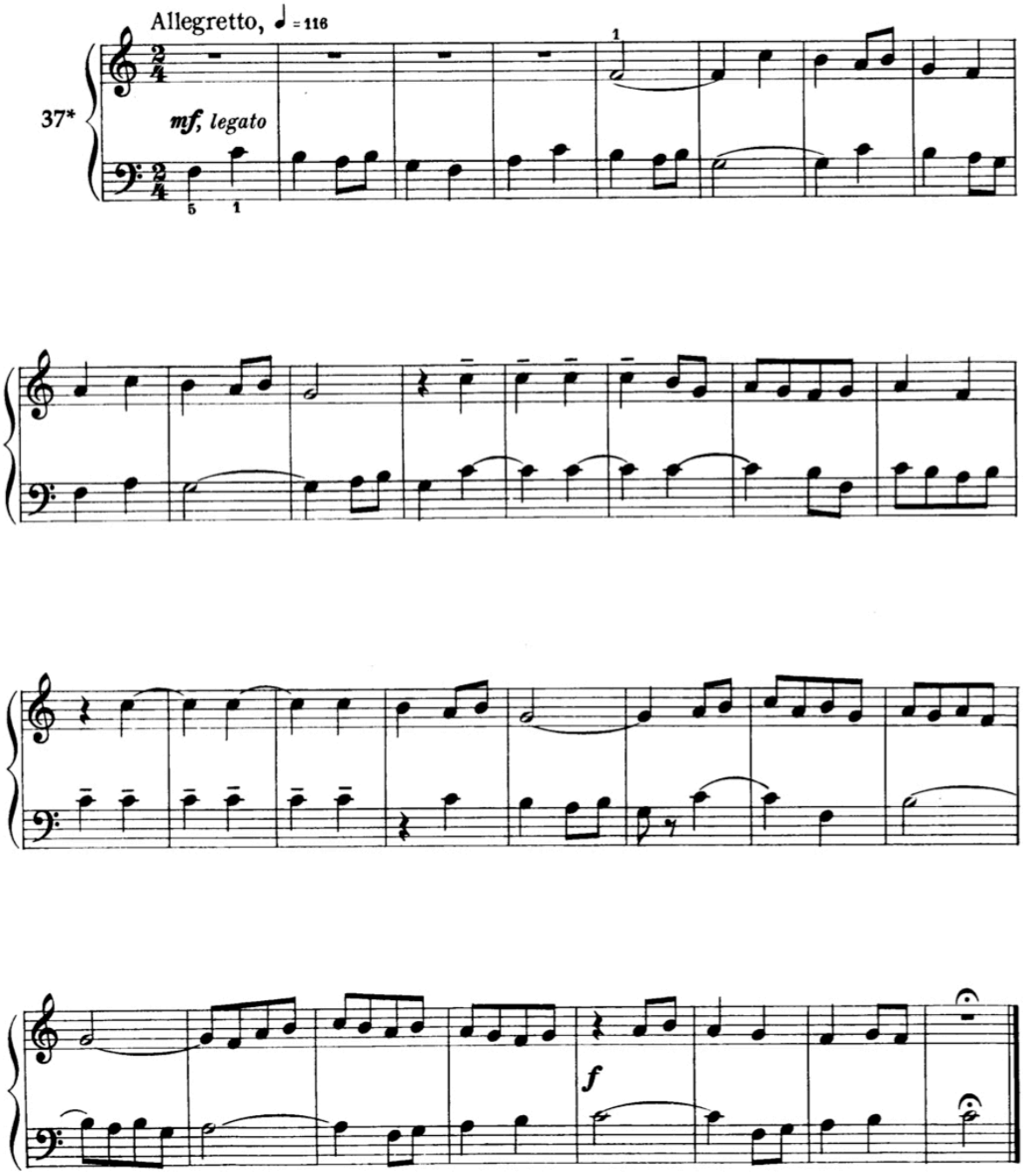



*Figure C8*. Musical sheet 8

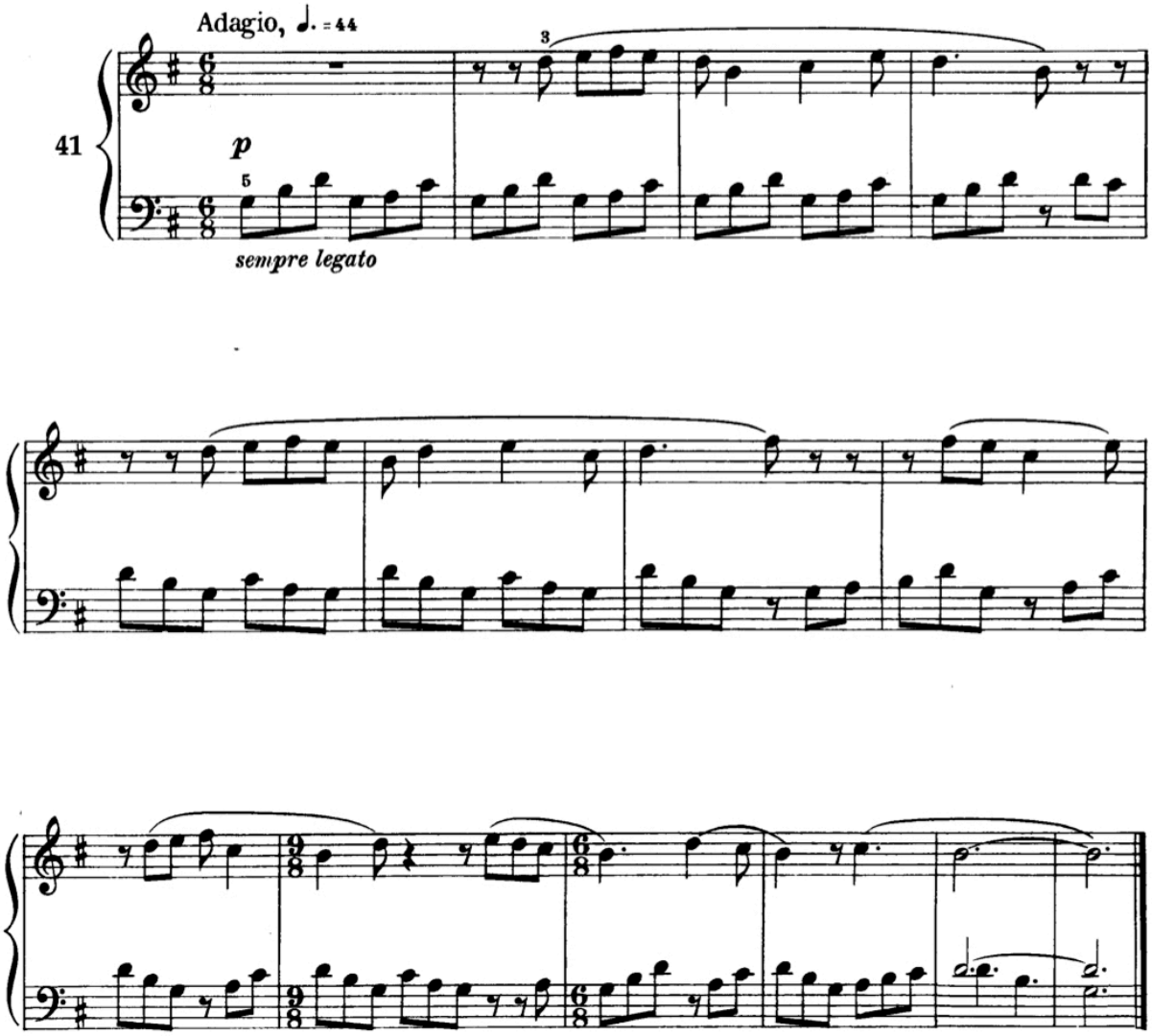



*Figure C9*. Musical sheet 9

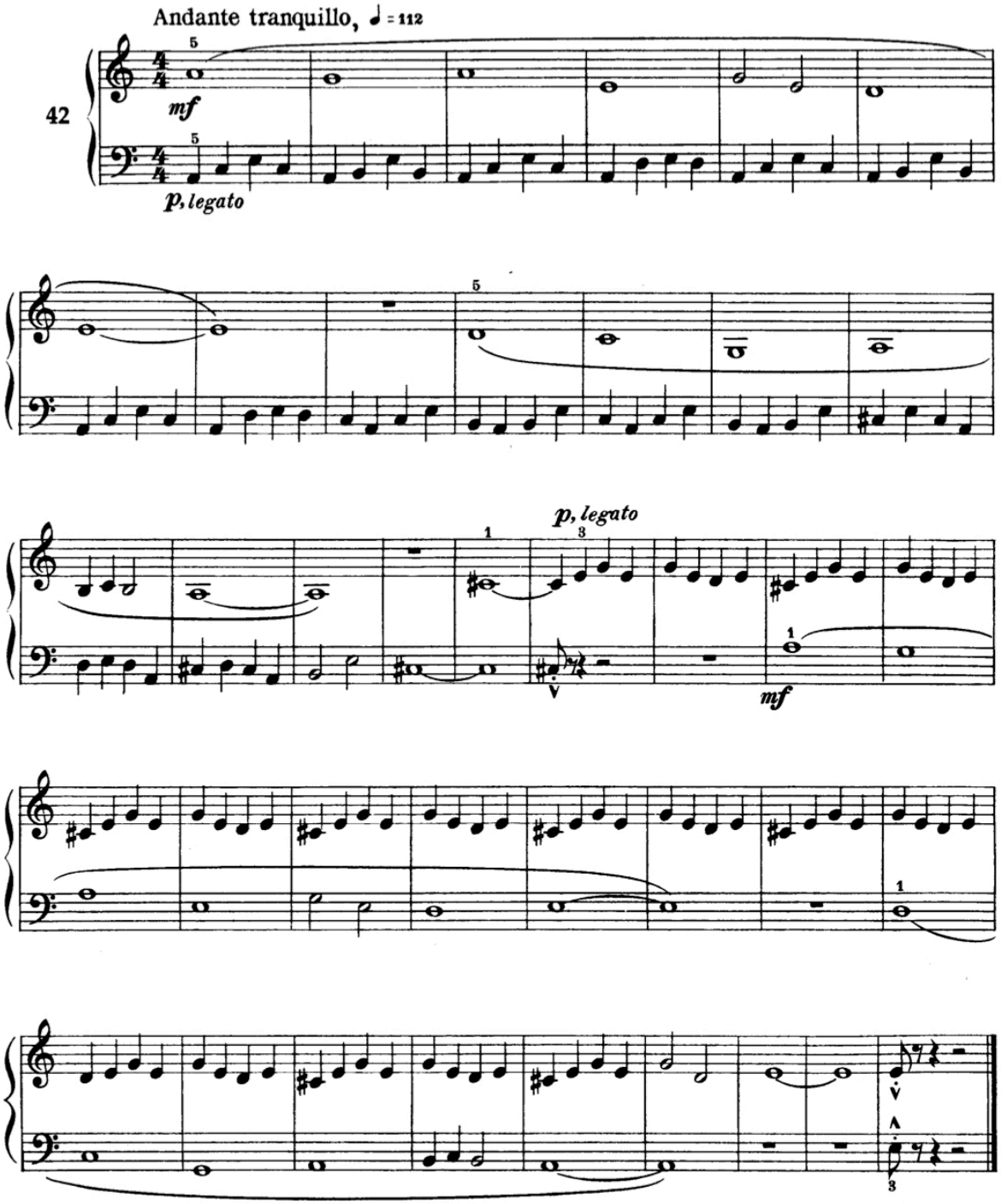



*Figure C10*. Musical sheet 10

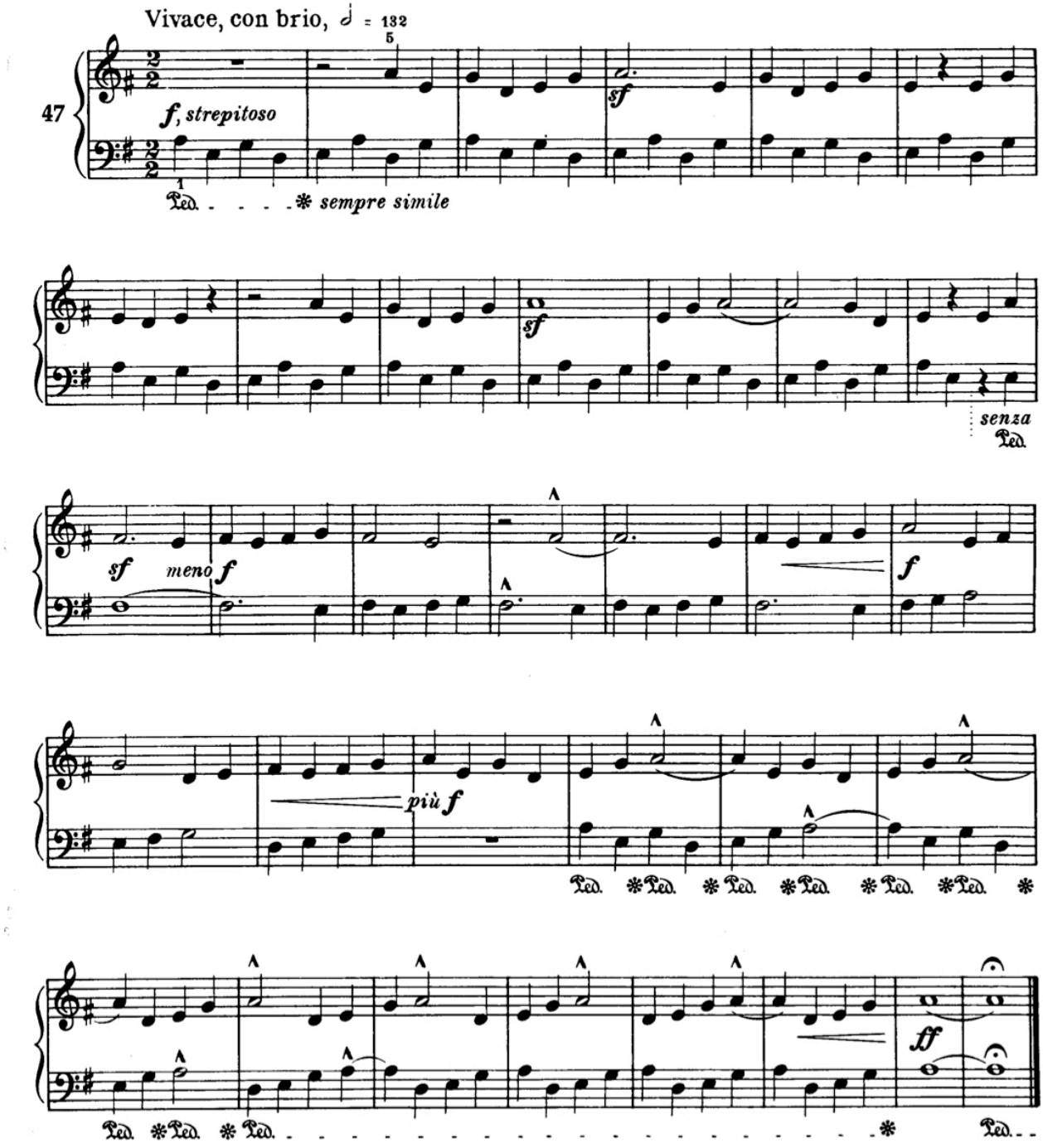



*Figure C11.* Musical sheet 11

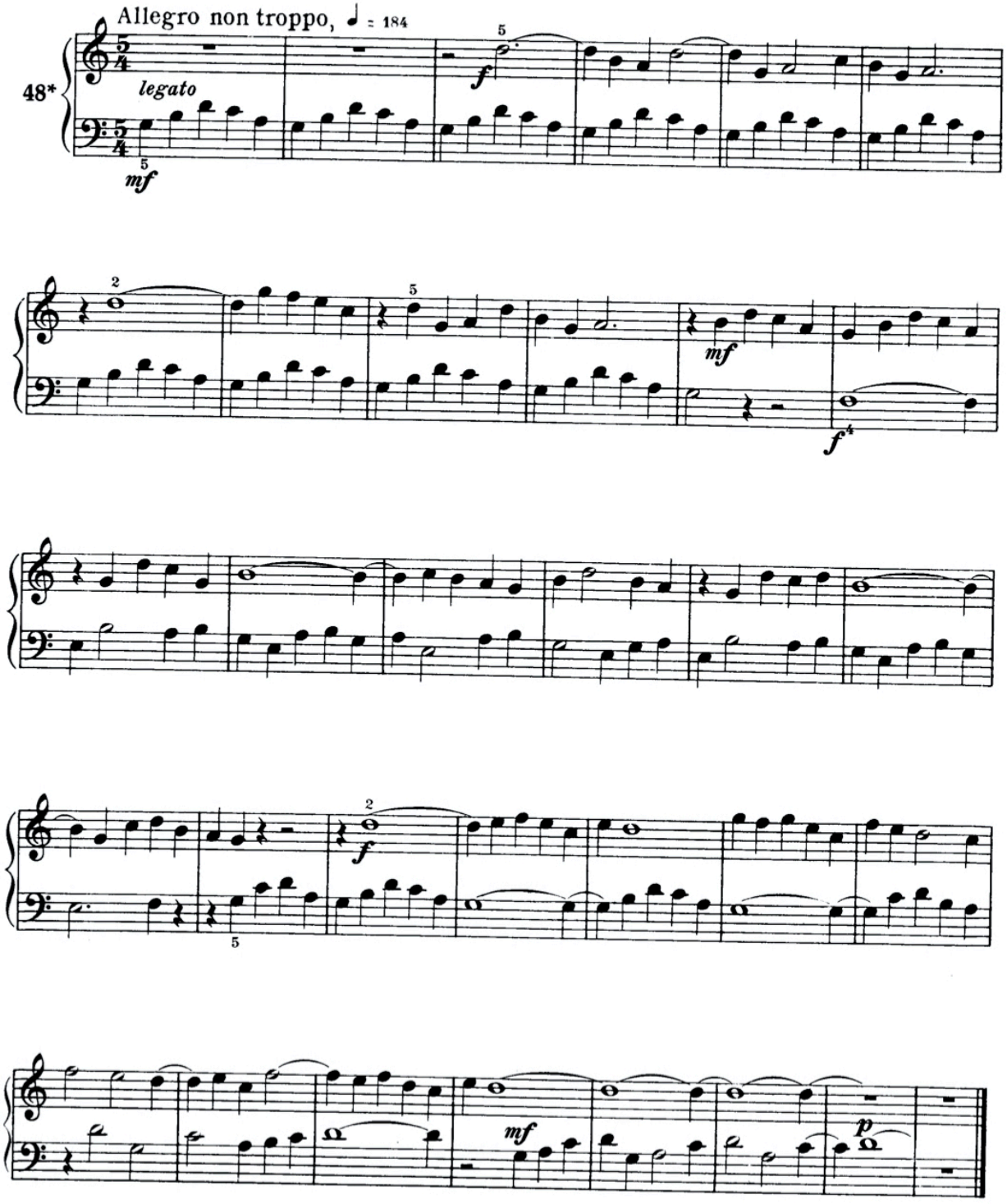



*Figure C12*. Musical sheet 12

## Annex

### Comissão de Ética para a Investigação em Ciências Sociais e Humanas

Identificação do documento: CEICSH 027/2020

Relatores: Emanuel Pedro Viana Barbas Albuquerque e Marlene Alexandra Veloso Matos

Título do projeto: *Mind wandering e criatividade musical: Correlatos neurofisiológicos e comportamentais em contexto de improvisação jazz*

Equipa de Investigação: Pedro Torres Palhares, estudante do Mestrado Integrado em Psicologia, Escola de Psicologia, Universidade do Minho; Professor Doutor Óscar F. Gonçalves (orientador), Escola de Psicologia, Universidade do Minho

### PARECER

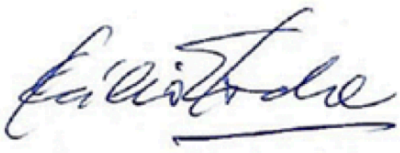
A Comissão de Ética para a Investigação em Ciências Sociais e Humanas (CEICSH) analisou o processo relativo ao projeto de investigação acima identificado, intitulado *Mind wandering e criatividade musical: Correlatos neurofisiológicos e comportamentais em contexto de improvisação jazz.*

Os documentos apresentados revelam que o projeto obedece aos requisitos exigidos para as boas práticas na investigação com humanos, em conformidade com as normas nacionais e internacionais que regulam a investigação em Ciências Sociais e Humanas.

Face ao exposto, a Comissão de Ética para a Investigação em Ciências Sociais e Humanas (CEICSH) nada tem a opor à realização do projeto, emitindo o seu parecer favorável, que foi aprovado por unanimidade pelos seus membros.

Braga, 23 de abril de 2020.

O Presidente da CEICSH



(Acílio Estanqueiro Rocha)