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Mental Practice in Music Memorization: an Ecological-Empirical Study

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ABSTRACT

Mental Practice (MP) refers to a complex network of strategies for improving musical performance without physically performing at the instrument. The present study represents an attempt to describe cross-individual differences in the use of different MP strategies, allowing direct predictions on which strategies are more likely to be effective. Sixteen pianists were studied while memorizing piano pieces. Each subject memorized two pieces of comparable length and difficulty, one by MP and the other by Physical Practice (PP), on two different days according to standardized protocols. During MP subjects were free to apply any practice strategies they preferred except for physically playing a real piano (ecological approach). Practice and performances were video-documented; performances were judged by independent expert raters. Participants reported their practice strategies in researcher-developed questionnaires. MP alone produced successful musical learning. MP, even combined with PP, produced poorer performance compared with PP alone. MP outcomes were significantly influenced by the strategies applied. These results directly impact on musicians' daily schedule and managing of health-risk factors, since valuable performance results can be achieved by combining optimally designed mental practice with short physical practice focused on strengthening the internal representation of the piece.

I. INTRODUCTION

Mental Practice (MP) is generally defined as the cognitive rehearsal of a task in the absence of overt physical movement (Driskell, 1994). Broader definitions include also emotional and mental training for performance preparation (e.g. relaxation training, meditation, visualization of prescribed images, see Mahoney and Arnkoff 1978 for a review); yet, it should be noted that such techniques differ substantially from those for skill acquisition and rehearsal, in terms of both means and goals. Our focus in the present study was rehearsal strategies and skill acquisition. MP has been investigated as a potentially useful practice technique in different fields, including sportsmen training (Feltz & Landers, 1983), stroke rehabilitation (Braun, 2006) and music (Theiler & Lippman, 1995; Cahn, 2007). Converging evidence from different fields showed that MP has a moderate and significant impact on performance, and that the effects of mental practice are weaker than the effects of Physical Practice (PP), (Gabriellson, 1999). Efficacy of MP increases as the task involves cognitive or symbolic skills and with subject's expertise with the specific task (Driskell, 1994). Moreover, several studies have shown that proper combinations of MP and PP may lead to results that are close or equal to PP alone (Feltz & Landers, 1988). In the field of music performance, MP is used and taught at least since the contribution of the great piano teacher Karl Leimer and his most famous pupil Walter Gieseking (Leimer & Gieseking, 1932; Barry and McArthur, 1994; McMillan, 2005). According to Leimer, by MP "…the piece can be perfectly performed and this in a most astonishingly shorter time" (Leimer & Gieseking, 1932). Mental practice techniques for musicians include formal analysis of the score, listening to recording of the piece, auditory imagery of the pitches, movement imagination (visually and/or kinaesthetically), visual imagery of the score (Klöppel, 1996). Only few studies up to date were specifically addressed to test the effectiveness of MP in music performance; overall results show that mental practice is better than no practice but not as affective as actual practice (Lim & Lippman, 1991; Highben & Palmer, 2004). MP with an auditory model showed better results compared to MP alone (Lim & Lippman, 1991; Theiler & Lippman, 1995). Combination of MP and PP appears to be particularly effective in the field of music, as shown by several experiments using different tasks and instrumentalist (Ross, 1985; Coffman, 1990; Kopiez, 1990; Theiler & Lippman, 1995; Cahn, 2007), leading to performance that are close or even indistinguishable from those following PP, also depending on the task (Theiler & Lippman, 1995). All these data come from highly-controlled experimental situations that implied significant constraint to the practice situation and/or to the experimental subjects. First, *subjects were always forced to a specific MP strategy* that was chosen by the experimenter independently from task-related and individual-related features. In fact, MP has been reduced to: analytical pre-study of the score or listening to recording of the piece followed by analytical study (Rubin-Rabson, 1937); auditory plus kinesthetic imagery (Ross, 1985; Cahn 2007); imagery of sounds while pressing silent keys or imagery of the feeling of the movements while actually hearing the sounds or auditory plus kinesthetic imagery in the absence of any feedback (Highben & Palmer, 2004); visual plus auditory plus kinesthetic imagery, with or without auditory model (Lim & Lippman, 1991; Theiler & Lippman, 1995). Second, subjects were often asked to *practice in unnatural situations*: depending on the study, subjects had to avoid MP strategies other than the one prescribed (Highben & Palmer, 2004); they had to avoid any overt movement of the hand/fingers (Cahn, 2007; Ross, 1985) and avoid humming (Lim & Lippman, 1991); when included, audio-recorded version of the piece to be practiced played at fixed time intervals (Theiler & Lippman, 1995) or even continuously played for the entire practice time (Lim & Lippman, 1991; Highben & Palmer, 2004); subjects had very limited time windows to implement their MP (Cahn, 2007); participants had to practice the piece a fixed amount of times, without stopping or correcting mistakes (Highben & Palmer, 2004). The rationale of experimental control that lies behind all these constraints is reasonable and agreeable, and these controlled studies have proved valuable and converging results. At the same time, it seems important to consider that some of these constraints may have significantly altered the MP processes compared to those which are applied in musician's daily life, producing partially ambiguous or distorted results. Trying to suppress automatic MP activities and finger movements, not humming, having to listen to eventually undesired auditory stimuli, avoiding pauses and error corrections or having very little time to practice mentally are all operations that have a cognitive (and sometimes even emotional) cost. This cost is not related with MP as exerted by musicians in real life. Moreover, as a result of the manipulation mentioned above, the experimental control is much likely to decrease, instead of increasing; in fact, there is no way to predict the individual differences in: how effectively undesired MP strategies have been switched off; the cognitive cost paid for this switching off; the practice strategy actually used; preferences, habits and ability in the strategy actually applied. The present study was primarily designed to answer these limitations: we designed a MP condition in which experimental subjects were completely free to use any MP strategy they desired, without any constraint, and with an amount of time that was found most effective in past research (Driskell, 1994). This included the possibility to move (e.g. fingers, hands), as a commonly-used strategy of practicing away of the instrument by many musicians and as expressly suggested by practical guides to mental practice in sports (Rushall, 1991). Such a situation may allow to complement former results with data coming from a more ecological situation: which is the power of MP when it is freely used? Have the former studies' constraints limited someway subjects' ability to apply MP? Studying a free-MP condition rises the opportunity to answer another research question, which constitutes the second focus of the present study: how do musicians use MP? To our knowledge, there has been no systematic description of the actual use of MP in musicians; yet, such a description would answer important questions like for example: which strategies are most commonly used? For which purposes are they used? Are there common MP pattern across different people? Are some MP patterns more effective than others? Do musicians with certain imagery profiles get better results when they apply certain MP patterns? How can future research be re-shaped on the basis of this knowledge? Music memorization is just one of the many fields of application of MP and, as stated by Theiler & Lippman, surely not the most frequent one; nevertheless, conscious of the limitations of this choice, we decided to apply a music memorization paradigm for the present study, because of the greater clarity of results it allowed, in comparison to paradigms allowing score-reading performance. In fact, this made possible to select two perfectly comparable music excerpts that had no specific technical difficulties (that would have brought an uncontrolled source of variability between subjects); such "plain" pieces would have been too much easily sight-readed in a non-memory performance task. A certain degree of experimental control was therefore maintained in this part of our design. However, music memorization was not the only focus of the present study. We additionally investigated musical expressiveness and global evaluations that were independent from the quantity of music memorized.

II. MATERIALS AND METHODS

A. Participants

Sixteen pianists (8 males, 8 females) were recruited from the University of Music and Drama, Hannover, Germany. They had a mean age of 26 ± 4 years (range = 18 to 36) and they had at least 15 years of individual piano instruction (mean = 20 ± 4; range = 15 to 26).

B. Procedure

Each subject was asked to memorize two pieces of comparable length and difficulty, one by mental practice (MP) and the other by physical practice (PP), on two different days. The musical pieces were the first half of two sonatas composed by Domenico Scarlatti (1685-1757), in A major and in C major, of 19 bars each; the pieces were slightly modified to have the highest degree of comparability, without altering the original musical context. Despite high similarity in general structural form, the two sonatas had still several subtle differences, for example in the complexity of the quatrains of sixteen notes (sometimes slightly higher for the one of the two sonata). These differences were preserved to keep the two pieces clearly differentiated, but were leveled due to balanced assignment to the two practice conditions. In fact, the assignment of the two pieces to each condition (MP or PP) was counterbalanced between the subjects, so that half of the sample studied the A major sonata by MP and the C major sonata by PP, and the other half of the sample did the opposite. Half of the sample had the MP trial on the first day, the other half on the second day. Subjects were randomly assigned to their protocol. For both MP and PP, before the start of the practice session, subjects listened to a metronome that was set at 80 bpm; subjects were asked to conform their final performance to this tempo. During MP, subjects were seating comfortably in front of a table, with the score of the piece to be studied and a pencil. Instructions for MP were as follows: "You can freely use whatever practice method you prefer, except for physically playing a real piano". A MIDI recording of the piece was also available to the subjects, which were free to listen to it, to pause and resume it as many times as they wished. Subjects were allowed to write on the score as well as to move their fingers. During PP subjects played on a Wersi Digital Piano CT2 (Halsenbach, Germany), using the Standard Piano timbre. Instructions for PP were as follows: "We ask you to focus on physically practicing the piece, ignoring any mental images you have as you practice, not stopping to mentally rehearse the music and avoiding formal analysis of the piece". For both MP and PP, subjects had thirty minutes to study the respective piece (Phase 1-3); subsequently they had to perform it on the MIDI-piano by memory twice. Subjects were not forced to memorize the whole piece; they were free to play as far as they could, but they were explicitly asked to give a performance coherent with the score, thus avoiding improvisation, repetitions or jumping from different bars of the piece. Only the better performance, within the two recorded, was selected for further evaluation; this selection was done by the first author, according to the following objective and hierarchical criterions: 1) RWT score (see below), 2) number of interruptions. Following these two performances, subjects had ten more minutes to keep on studying the same piece (Phase 4). Subjects who had previously studied by mental practice were now free to combine mental strategies with real piano playing (MP+PP); subjects who had previously studied by physical practice were asked to keep on practicing in the same way, thus avoiding mental rehearse, imagery or formal analysis (PP+PP). Finally, subjects performed by memory twice; again, only the best performance was selected for further evaluation (see above). Subjects doing MP on the first day were allowed to freely familiarize for a couple of minutes with the MIDI keyboard before the starting of the experiment. This was done to avoid unexpected discomfort, due to imperfect physical piano-like feeling during the performance, after a pure mental practice. Two performances, instead of one, were recorded each time to control for the variability in individual fluctuations emerged in the pre-test phase of the experiment. Especially after MP, some subjects were giving much better performances at the first recording, probably due to recency memory effect (Baddeley, 1992b), while some others were giving better performances at the second recording, due to initial disorientation on the instrument after a pure mental practicing. During both practicing conditions, subjects were also asked to use concurrent Thinking Aloud (Ericsson & Simon, 1993). To avoid massive interference with the ongoing memorization task, thinking aloud was not required in the continuous way employed in other studies (Richardson & Whitaker, 1996); instead, subjects were asked to verbalize only when changes in their mental strategies occurred, to give a concise description of what they were doing in that moment and then to keep on silently studying until something again changed in their way of practicing. On the first day, a short trial for thinking aloud was employed using a different piece (that was the same for all subjects) before the start of the experiment.

C. Questionnaires, interviews and additional tests

Before entering the study, each subject confirmed that he/she did not know the two musical pieces and filled a preliminary questionnaire assessing his/her familiarity with MP strategies. During both PP and MP, every ten minutes (10 minutes = 1 phase) subjects were asked to fill a short questionnaire (*Ten Minutes Questionnaire*, TMQ) regarding the mental strategies they were eventually using. Subjects had to rate on a Likert-scale from 1 ("not at all") to 5 ("very often") how often they were using the following strategies: "Mentally hearing the sound of notes", "Mentally feeling the movement of fingers/hands", "Mentally visualizing the movements of fingers/hands", "Mentally visualizing the score", "Harmonic analysis of the piece", "Rhythmical analysis of the piece", "Melodic analysis of the piece". A similar questionnaire, without the harmonic/rhythmical/melodic questions, was administered after the performance also, to reconstruct which mental strategies were used while performing. Following the last performance, a short interview was conducted to reconstruct, this time by free recalling, which strategies were used during the forty minutes of practice and how deeply the piece had been formally analyzed. At the end of the experimental session, a test for auditory imagery (AIT) was administered. We developed a test based on the task described by Highben & Palmer (2004) in mental practice research: participants were shown a single-line melody (9-12 pitches) and heard a similar melody, which was the same as the notated melody or had a difference of one pitch. The stimuli were modified by shifting one notes by 1 or 2 semitones; the total number of changes that moved up or down in pitch were balanced. Twelve of the sixteen melodies presented had a one-note difference. The sixteen melodies were presented by loudspeakers, and subjects were told to identify wrong notes. The embedded melodies test used by Brodsky et al. (2003) was not employed because it has no proof of external validity (this test has been constructed using tradition Jewish melodies and never standardized out of this culture). Individual differences in mental imagery were tested by administering the standardized questionnaires USOIMM77 (Antonietti & Colombo, 1996), MIQ-R (Hall & Martin, 1997) and VVSQ (Antonietti & Gioletta, 1995). USOIMM77 has been developed to assess the spontaneous occurrence of mental visualization in thinking; MIQ-R has been developed for examining movement imagery ability, both kinesthetic and visual; QSVV has been developed to measure the cognitive disposition to use visual or verbal thinking strategies.

D. Data collection

All practice sessions and performances were filmed by a digital video camera. Recorded videos of the 30 minutes of MP (Phase 1-3) were used to quantify the time each subject spent in the following overt behaviors: 1) moving the fingers only (Mov); 2) singing only (Sing); 3) listening to the audio reproduction of the piece only (List); 4) moving the fingers while singing (MovSing); 5) moving the fingers while listening to the audio track (MovList); 6) moving the fingers, independently from other concomitant overt operations (TotMov); 7) singing, independently from other concomitant overt operations (TotSing); 8) listening to the audio track, independently from other concomitant overt operations (TotList). The time spent in these operations was expressed in seconds, and was quantified by the first author. Note-by-note recording of the performances were acquired with the MIDI keyboard. Mistakes-detection was done manually by the first author. Wrong notes were defined as any notes not corresponding to the prescribed note on the original score; an omitted note, as well as an undesired additional note, was treated as a wrong note. MIDI data were used to compute two objective parameters of performance:

1. the absolute Number of Notes Played (NNP);
2. the ratio between the absolute number of wrong notes played and NNP (RWT).

Since RWT was combining both the information about correctness and length, it was considered a global and objective indicator of performance. DVD recordings of the performances were independently evaluated by three professional musicians (one pianist and piano teacher, one pianist, one flutist). The professional experience of these evaluators ranged from 30 to 50 years in their fields.

Raters were blind as to which practice condition preceded the recorded performances and were provided with the written scores. All performances were rated on four dimensions: 1) Correctness of notes; 2) Articulation and Phrasing; 3) Dynamics and Expression; 4) Global rate.

The first three features are typically examined during piano performance auditions and competitions, and have been used in past research on MP (Theiler & Lippman, 1995); an additional "Global rate" was collected to provide a concise score that could incorporate all aspects of music performance. Raters judged these dimensions on a Likert-scale ranging from 1 ("schlecht", poor) to 7 ("exzellent", excellent). For the "Correctness of notes" dimension, raters were asked to take into consideration not only the correctness according to the score (already computed in RWT), but also how well the notes, even wrong notes, fitted into the context. The "Global rate" dimension had to be regardless of the quantity of music played. For each of the six parameters of performance (NNP, RWT, Correctness of notes, Articulation and Phrasing, Dynamics and Expression, Global rate), a corresponding "MPminusPP" score was computed as the difference between the score obtained by each subject after MP and the score obtained after PP. "MPminusPP" score therefore expressed the difference between post-MP and post-PP performance qualities.

E. Statistical methods

A measure of inter-rater reliability was obtained by correlating (Pearson correlations) all ratings of two raters with each other, respectively (Table 1). Within-subjects comparisons for post-MP vs post-PP performances were computed by mean of Wilcoxon non-parametric test. Pearson correlation coefficients were computed to verify associations between practice strategies or individual imagery abilities and MP outcomes. Analysis of variance (ANOVA) and multivariate analysis of variance (MANOVA) were applied to predict MP outcomes on the basis of practice strategies.

III. RESULTS

A. Inter-rater reliability

Table 1. Inter-rater reliability (Pearson Correlations)

	Raters A, B	Raters A,C	Raters B,C
Correctness of notes	.813	.755	.785
Articulation and Phrasing	.558	.621	.710
Dynamics and Expression	.533	.623	.699
Global score	.708	.706	.839

Compared with previous studies (Lim & Lippman, 1991; Theiler & Lippman, 1995), inter-rater reliability was considered high enough to warrant averaging the three raters' independent judgments for each performance score (Table 1).

B. MP

After 30 minutes of MP subjects were able to perform by memory on average 242 ± 110 notes (range: 112-387), corresponding to the 63 ± 28% of the piece. Mean RWT (Ratio wrong notes/total notes played) score was .17 ± .17 (range: 0 - .62). Mean scores for NNP, RWT and expert raters are reported in Table 2.

C. MP vs PP

After 30 minutes of practice, PP was superior to MP for all the six scores of performance: NNP (Wilcoxon test: $z = -2.38$, $p = .017$), RWT ($z = -2.84$, $p = .004$), Correctness of notes ($z = -3.23$, $p = .001$), Articulation and Phrasing ($z = -3.12$, $p = .002$), Dynamics and Expression ($z = -3.26$, $p = .001$), Global Score ($t = -3.1$, $p = .002$). When considering the half sample with the highest score at the AIT (score > 90%), there were no more significant differences between MP and PP in the NNP (Wilcoxon test: $z = -1.134$; $p = .257$).

D. MP+PP vs PP+PP

No significant differences were found between MP+PP and PP+PP in the two objective-MIDI scores of performance: NNP (Wilcoxon test: $z = -1.24$, $p = .214$), RWT ($z = -1.5$, $p = .134$). PP+PP data on these dimensions were conditioned by a moderate roof-effect, given the non-significant differences between PP and PP+PP data (Wilcoxon test for NNP: $z = -1.75$; $p = .08$; RWT: $z = -1.91$; $p = .056$). The human-raters' evaluations detected statistically significant differences between MP+PP and PP+PP in all the four domains (Wilcoxon test for Correctness of notes: $z = -2.54$, $p = .011$; Articulation and Phrasing: $z = -2.47$, $p = .013$; Dynamics and Expression: $z = -2.33$, $p = .02$; Global score: $z = -2.78$, $p = .005$). As shown in Table 2, these differences are, on average, always smaller than 1 (Max = .9, for Dynamics and Expression; Min = .6, for Correctness of Notes). Roof effect in PP was absent in the human-ratings, except for Articulation and Phrasing, showing no significant difference between PP and PP+PP (Wilcoxon test: $z = -.56$, $p = .576$). When considering the half sample with the highest score at the AIT (score > 90%), there were no significant differences between MP+PP and PP+PP in Dynamics and Expression (Wilcoxon test: $z = -1.691$; $p = .091$).

Table 2. Performance Scores

	NNP °	RWT °	Correct.Notes*	Art&Phras*	Dyn&Expr*	Global*
MP	242 ± 110	.17 ± .17	3.9 ± 1.3	3.5 ± 1.1	2.8 ± 0.9	3.7 ± 1.2
PP	326 ± 101	.08 ± .11	5.3 ± 1.3	4.8 ± 1.3	4.2 ± 1.5	5 ± 1.4
MP+PP	319 ± 96	.07 ± .08	5.3 ± 0.9	4.1 ± 0.8	3.9 ± 0.9	4.8 ± 0.8
PP+PP	349 ± 86	.04 ± .04	5.9 ± 1	4.9 ± 1.3	4.8 ± 1.3	5.5 ± 1.1

NNP = Number of notes played; RWT = ratio between the absolute number of wrong notes played and NNP; Correct.Notes = Correctness of notes; Art&Phras = Articulation and Phrasing; Dyn&Expr = Dynamics and Expression; Global = Global score; ° = MIDI evaluation; * = foreign raters evaluation.

E. MP performance: correlations and predictors

The score at the Auditory Imagination Test (AIT) was correlated with all MP performance indicators except for Dynamics and Expression: NNP (Pearson correlation: r = .455, p = .038), RTW (r = -.428, p = .049), Correctness of Notes (r = .443, p = .043), Articulation & Phrasing (r = .456, p = .038), Global Score (r = .475, p = .031). Subjects with higher AIT score got higher score in all these performance indicators. Both Mentally Hearing the sound of notes and Mentally Feeling the movements as reported in the TMQ predicted the RWT score: subjects that reported to mentally hear the sound of notes or to mentally feel the movements more often during practice had a better RWT during performance (Univariate ANOVA: RWT by HearTMQ, FeelMovTMQ; Corrected Model: F = 12.6, p = .003; HearTMQ: F = 15.3, p = .008; FeelMovTMQ: F = 7.9, p = .011). Mentally Feeling of movements also predicted the RWT-MPminusPP score: subjects that reported to mentally feel the movements more often during MP got a post-MP RTW closer to the post-PP one (Corrected model: F = 6.48, p = .017; FeelMovTMQ: F = 8.03, p = .011). Mentally feeling the movements was correlated with none of the overt behaviors Mov, MovList, MovSing. Mental Visualization of Movements predicted the NNP scores: the more subjects reported to mentally visualize their movements during practice, the less notes they were able to play during performance (One-Way ANOVA for NNP: F = 4.12, p = .05; Pearson Correlation: r = -.538, p = .016), and a greater difference between MP and PP emerged (NNP-MPminusPP: F = 5.93, p = .021; r = -.503, p = .023). The time spent moving fingers (without any other concomitant overt strategy) predicted the RWT score: the more subjects moved their fingers during practice, the better was their RWT score (One-Way ANOVA: F = 643.85, p = .031). The time spent listening to the audio recording (without any other concomitant overt strategy) correlated with all MP performance indicators except for NNP: subjects that listened more to the audio recording during practice got worse results during performance (Pearson Correlation for RWT: r = .439, p = .045; Correctness of notes: r = -.61, p = .006; Articulation and Phrasing: r = -.489, p = .027; Dynamics and Expression: r = -.551, p = .013; Global rate: r = -.47, p = .033). These correlations were specifically linked to listening to the audio recording without any other overt behavior; in fact, they disappeared when considering the time spent listening independently from other concomitant overt behaviors. For the RWT score only, a significant cause-effect relationship could be detected (One-Way ANOVA: F = 22.78, p = .001); this relationship was significant also for listening to the audio recording independently from other concomitant overt behaviors (One-Way ANOVA: F = 16.93, p = .007). The time spent singing (without any other concomitant overt strategy) negatively correlated with the Dynamics and Expression score: subjects that sang more during practice received a lower score on their Dynamics and Expression during performance (r = -.436, p = .046). The effect was specifically linked to singing without any other overt behavior (it disappears when considering the time spent singing independently from other concomitant overt behaviors).

IV. DISCUSSION

The present study was designed: 1) to assess the effectiveness of Mental Practice in the context of an ecological setting; 2) to describe how different musicians use different MP strategies, with which results. Data related to the effectiveness of MP are in line with past research: MP generated successful learning, even in a highly demanding task as memorizing a novel piece of music in 30 minutes of time. It may be disputable to compare directly our results with Lim & Lippman's, due to the differences not only in the "open" vs "close" setting for MP, but also in the subjects' expertise, in the musical excerpts, in the time of practice, in the expert raters; it generally appears that mental practicing in our "open" situation has not lead to results that are superior to those collected in more controlled setting. A striking similarity between ours and Lim & Lippman's results appears in the ratings for Articulation and those for Dynamics, suggesting that short sessions of pure MP generally leads to immediate performances by memory that are musically no more than sufficient, lying around a score of 3 on a 1-7 rating scale. MP, even with a reasonable amount of time available, produced a poorer performance compared to PP, in agreement with preceding findings (Lim & Lippman, 1991; Highben & Palmer, 2004). Despite the general inferiority of MP compared to PP, the effectiveness of MP appears to be strongly influenced by subjects' familiarity with the basic mental practice operations. For subjects with good aural skills, MP resulted as effective as PP in the number of memorized notes (even if with a significantly lower accuracy in MP), indeed a key goal of the present study, given the memorization task. This finding closely fits with the observation of Highben & Palmer that aural skills aided pianists' ability to memorize music that was learned in the absence of sound (Highben & Palmer, 2004). Moreover, the present study allowed to describe an even wider connection between aural skills an MP capability, including also musical dimensions such as articulation and phrasing. The combination of 30 minutes of MP followed by 10 minutes of PP produced a poorer performance compared to 40 minutes of PP. These differences, although significant, are qualitatively small, and become even smaller for subjects with higher aural skills. Past research has shown that proper combination of MP and PP led to unnoticeable differences in performance, compared to an equal amount of PP alone (Ross, 1985; Coffman, 1990; Kopiez, 1990; Lim & Lippman, 1991; Theiler & Lippman, 1995; Cahn, 2007); strictly, this result was not replicated in the present study, even if the trend reported here is still tightly in line with previous studies. Several different factors could partially account for these differences, like the length of the piece to be memorized, the memorization task itself, the not perfect agreement among our raters (see inter-rater reliability for "Articulation & Phrasing" and "Dynamics and expression"). In general, it can be concluded that an "open" MP situation does not necessarily leads to better results compared with a more controlled one; interacting with subjects' aural skills and familiarity with MP, unguided MP may lead expert subjects to completely display their power, and hesitant subjects to get confused and misled. Allowing subjects to mental practice in an open situation gave us the opportunity to study the relations between practicing strategies and performance results. In terms of cognitive operations, mentally hearing the sound of notes was the most important and predictive single strategy our subjects could apply while mental practicing. This observation is in agreement with a bulk of teaching and pedagogical literature (Leimer, 1931; Gordon, 1997), and is implicit in almost all scientific research projects done before on MP. The present data provide, to our knowledge, the first direct and empirical confirmation of this hypothesis. Another single mental strategy that revealed to be effective was mentally feeling the movements; interestingly, the use of this strategy was predicting the MP performance not only *per se*, but also in relation to the PP performance (as computed by the MPminusPP-RWT score), minimizing the differences in the results of the two ways of practicing. The mental generation of motor and auditory feedbacks allowed subjects to create motor, auditory and bimodal auditory-motor traces that could be later retrieved to guide performance, also capitalizing on already stored mental representations of chunks of movements (e.g. scales, arpeggios, jumps, fingerings schemes) and sounds (e.g. chords, melodic and harmonic schemes and progressions). Mentally visualizing the movements showed detrimental effects on the quantity of music that could be memorized during MP. The low number of subjects does not allow the formulation of strong interpretations on this observation; still, visualizing the movements appears as a somewhat superfluous operation that is more likely to distract, instead of deepening musician's ongoing learning. Considering the overt behaviors, moving the fingers while mental practicing globally led to better performance from memory. This observation empirically supports the suggestion of hinting the movement while mental practicing, coming from both sport (Rushall, 1991) and music (Leimer, 1931) applications. Still, it should be noted that massively moving fingers was the strategy used by all the higher and the lower-proficient subjects of our sample (as shown by the high standard deviation for Global score in subjects that massively moved their fingers during MP, Table 5). Even if at sample level moving fingers leads to better results, it has a completely different meaning and impact on performance depending on the specific subject; for some subjects, moving fingers seems to lead to stable and reliable traces that allow optimal performance; for other subjects, it seems a blind and mechanical short-cut that produces a blurred and weak learning. Further research is probably needed to clarify the specific role of this strategy, that up to date has been completely neglected; our data point out the importance of allowing subjects to move their fingers during mental practice. Evaluating the relation between the time spent with listening to the audio recording of the piece and performance results led to an apparently paradoxical result: subjects that listened more to the audio recording during practice got worse results during performance. Past research has repeatedly and convincingly shown that MP with an auditory model leads to better results, compared to MP alone (Lim & Lippman, 1991; Theiler & Lippman, 1995). An interesting explanation can be drawn considering the differences between previous experimental designs and ours. Lippman's conclusions derived from a within-subjects design, showing that for the same person doing MP with an auditory model is better than doing MP without. This within-subjects contrast was absent in our design, that instead contrasted in a between-subjects fashion the listeners vs the non-listeners, showing that the latter get better results. The combination of the two sources of information allows an interpretation of the puzzle: listen to an auditory model is indeed a strategy that effectively improves MP, because it fosters the coding of an internal representation of the piece, as shown by Theiler & Lippman (1995); subjects that are capable to build stronger internal representation of the piece are therefore able to give better post-MP performance; at the same time, these subjects are much less likely to rely on external models, that are more time-consuming and might even be conflicting with their own's (Lim & Lippman, 1991). A similar conclusion can be drawn for the apparently puzzling negative correlation between the time spent singing and the Dynamics and Expression score. Musical experience teaches that "try out singing it" is a powerful tool to improve musical feeling and expressiveness. Our data show that subjects that need more overt singing result in less convincing musical feeling; this may happen because better musicians are able to shape their expression and to hear this singing clearer in their mind, which is again less consuming and provides a tighter connection with the other formats of internal representation. Altogether, ours and Lippman's results may generate a practical implication for musicians' practice habits: listening to recordings of the piece and/or singing while practicing are both valuable practice strategies *as far as* they are applied to build up and strengthen the mental representation of the music; when used *per se*, without an explicit focus on their internal-imaginative growing counterpart, they risk to become just time- and energy-consuming habits without a clear benefit. While providing new insights in the meaning and possible applications of MP, this study presents several limitations:

- subjects' selection: despite the effort to select subjects with the preliminary questionnaires, only few of our subjects proved real familiarity with MP strategies; on the contrary, some other may have underestimated their resort on MP, since, as for any other self-report measurement, it is questionable if subjects have access to the information whether or not they applied MP-related strategies and to which extent;
- subjects who are experienced in MP and used to apply MP in their everyday piano practice might even be unable to perform the "pure " PP implied in the present study;
- small sample size, proportionate for a preliminary study but not for conclusive results;

Such limitations may interestingly guide the next steps for further research on MP, such as:

- to select subjects not only by general self-reports, but also with diaries quantifying the daily resort on MP and objective measurements (like those provided by AIT, solfege, sight-reading, improvisation); a detailed entry-file would allow to keep even low-experienced subjects and to make separate analyses for subjects with different skill levels;
- to expand the sample size would allow to deepen and make more informative this results, allowing cluster analyses and, with sample size around n = 50-80 multi-level modeling.

V. CONCLUSION

In conclusion, showing the functioning of MP represents an interesting challenge for experimental psychology; but, most of all, this field represents a vital resource for musicians daily schedule, managing of health-risk factors and well being. First of all, mental practice allows developing internal representations of the music to be played; this is much likely to induce deeper comprehension and richer connections among information; understanding and anchoring the incoming information with the already stored ones are strong basis for feeling the emotional message in the music; understanding and emotional feeling are themselves a strong basis for willing and motivation. MP therefore appears as a powerful tool for all musicians interested in deepening their comprehension and feeling of the music to be played, as well as for those searching for joy and motivations. Last, but not least, mental practice allows reaching a determinate level of performance without (necessarily) moving a finger. In the present experiment, this level was on average between the 50% (RWT) and the 70% (Global score) of that achieved by PP; the present experiment studied subjects with incomplete MP skills, engaged in a completely unfamiliar (and not particularly lifelike) task; it is therefore likely that this level would be higher for better trained subjects, facing a familiar task. But even if the level would be only 50% of the PP's one, this would be an effective tool for any musician facing time-constraints, and a vital one for those struggling with (or willing to avoid) physical diseases and musicians' injuries resulting from repetitive strain. In fact, MP allows practicing anywhere, at any time, with no kind of burden for the body; the cost is that it is not as effective as PP; this open a wide window of solutions to combine MP and PP to optimize the time available (e.g. travels within a tournée), and let injured musicians actively face their disease and not completely abort their career despite the need to drastically reduce the time of practicing.

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