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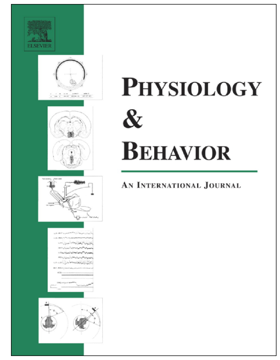

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Is heart rate variability affected by distinct motor imagery strategies?

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ABSTRACT

Although some studies have reported significant changes in autonomic responses according to the perspective-taking during motor imagery [first person perspective (1P) and third person perspective (3P)], investigations on how the strategies adopted to mentally simulate a given movement affects the heart rate variability (HRV) seem so far unexplored. Twenty healthy subjects mentally simulated the movement of middle-finger extension in 1P and 3P, while electrocardiogram was recorded. After each task, the level of easiness was self-reported. Participants' motor imagery ability was also assessed through the revised version of Movement Imagery Questionnaire (MIQ-R) and a mental chronometry index. The traditional measures of HRV in the time- and frequency-domain were compared between 1P and 3P tasks by using Student's t-test for dependent samples. The MIQ-R results showed that subjects had the same facility to imagine movements in 1P or 3P. The mental chronometry index revealed a similar temporal course only between 1P and execution, while the 3P strategy had a shorter duration. Additionally, the subjective report was similar between the experimental tasks. Regarding the HRV measures, the low frequency component, in log-transformed unit, was significantly higher ($p=0.017$) in 1P than 3P, suggesting a higher activity of the sympathetic system during 1P. This log-transformed HRV parameter seems to be more sensitive than normalized values for the assessment of the motor imagery ability, together with questionnaires, scales and mental chronometry.

Key-words: motor imagery strategies; heart rate variability; autonomic nervous system.

1. Introduction

The explicit mental simulation of actions, also named motor imagery, allows conscious access to the neural processes involved in the planning and preparation of a movement [1]. In fact, studies using neuroimaging techniques have observed that there is an important overlap in the brain circuits involved in imagination and execution of the same movement [2–6]. Consequently, motor imagery has been used as an important tool to understand the physiological processes related to motor representation.

Motor imagery can be experienced when someone mentally simulates as a spectator watching a scene in which an action is performed, involving mostly a visual representation of the action (i.e., visual imagery). Alternatively, it can also be experienced as if the subject feels the execution of an action, relying mostly on kinesthetic information about the movement (kinesthetic imagery) [1,7]. Moreover, the strategies adopted during motor imagery can be different among subjects. They can be asked to imagine a movement in different perspectives: first person (1P, also called internal or egocentric) or third person (3P, external or allocentric) perspectives [7]. First person imagery (1P) refers to the subject imagining himself doing the movement, while 3P refers to the subject imagining someone else doing the movement. Sirigu and Duhamel [8] have addressed this question by comparing the effect of a simple change in the phrasing of imagery instructions (1P or 3P perspectives). The authors proposed that, under instructions to seek the solution using imagery in 1P, subjects use primarily motor resources (kinesthetic), and under instructions to seek the solution using 3P perspective, they use primarily visual resources [8].

Previous research investigated neural and autonomic responses during these two different strategies of motor imagery. These studies reported the activation of brain areas as well as the ventilatory and blood pressure responses similar between execution and 1P, but not during 3P [4,6,9–13]. Nevertheless, less is known about how the motor imagery strategies affect the cardiac autonomic activity. Some studies, addressing this issue, investigated only the motor imagery 1P, comparing with execution of the same movement and/or with a rest condition [14–16]. In other studies, the imagery perspective (first or third person) was simply not determined, just the imagery modality (kinesthetic or visual) [17–19]. In addition, the measurement used to investigate the cardiac system modulation during motor imagery has been mainly the mean heart rate (HR). Wang & Morgan [9], for example, reported that the mean HR was not significantly different between the kinesthetic and the visual modalities.

Since heart beats are regulated by both sympathetic and parasympathetic branches of the autonomic nervous system (ANS) and the mean HR is determined by the balance between these two branches, many combinations of the activity levels of these two branches can produce the same mean HR [20,21]. Therefore, it would be desirable to use other measures sensitive enough to highlight modulations in the cardiac control during motor imagery. Heart rate variability (HRV) has become the conventionally accepted term to describe variations of both instantaneous heart rate and RR intervals [period between consecutive R waves in the electrocardiogram (ECG)], resulting in time series that are usually analyzed in time and frequency domains. This analysis provides a sensitive, quantitative and noninvasive assessment of the activity of the cardiac autonomic control through evaluation of both the sympathetic and parasympathetic systems [22,23].

In the present study we ask whether HRV is differently affected by distinct motor imagery strategies. Since sympathetic activity is known to increase during movement execution, and there is a strong similarity in the autonomic responses between execution and motor imagery in 1P [9], we hypothesize that motor imagery in 1P would promote greater sympathetic cardiac activity than in 3P strategy. Besides, considering that the parasympathetic system has antagonistic effects with respect to the sympathetic system, a lower parasympathetic cardiac activity during 1P would also be expected.

These findings could be used to understand individual differences during distinct strategies of motor imagery, since a combination of questionnaires, scales, mental chronometry and autonomic responses has been suggested in order to evaluate the motor imagery ability of subjects [5,6,24,25]. Moreover, the discovery of measures more sensitive to changes in the ANS could provide complementary information about the introspective state of the subjects during the mental simulation of movements performed in laboratory experiments or field tests.

2. Materials and methods

The data were collected simultaneously to a previous study about the effects of motor imagery on electroencephalographic (EEG) event-related potentials [26].

2.1 Participants

Twenty healthy men (mean ± standard deviation: 23 ± 2 years; 174.1 ± 5.3 cm; 72.2 ± 10.2 kg) participated in this study after having assigned a written informed consent according to the local ethics committee standards. All of them were right-handed [laterality index (right) = 0.84 ± 0.09], as assessed through the Edinburgh inventory [27], and reported no neurological or orthopedic diseases. Experimental procedures were in accordance with the Declaration of Helsinki.

2.2 Motor imagery ability

Initially, a modified version of the Movement Imagery Questionnaire (MIQ-R) [28] was applied to volunteers, in order to evaluate their ability to imagine movements in two different strategies: 1) feel themselves doing an action (1P perspective) or 2) imagine someone else performing the same action (3P perspective). Subjects imagined four different actions (right hip flexion with flexed knee while standing; jumping straight up in the air; right horizontal shoulder flexion; touching the toes by bending forward during standing position) using both perspectives (1P and 3P), summating eight randomized MIQ-R tasks. Then, participants should evaluate the easiness/difficulty to perform each task, using a seven-point rating scale; with score 1 corresponded to very hard to imagine, and score 7 corresponded to very easy to imagine. A general score ranging from 4 to 28 was obtained by summing the scores reported for each task during 1P or 3P imagery. In addition, a mental chronometry evaluation was also used to measure the subject's motor imagery ability [5,6,24]. The time spent for performing each MIQ-R task was recorded using a stopwatch and this time recorded corresponds to the interval between the command to start the task, given by the evaluator, and the verbal response of conclusion of the task, given by the subject. Then, for each MIQ-R task an index of similarity of mental chronometry proposed by Rodrigues et al. [29] was calculated:

$$Index\ MI = ((TMI - Texe) / (TMI + Texe)) \times 100$$

in which *MI* corresponds to the strategy (1P or 3P) of motor imagery used during the MIQ-R task and *T* corresponds to the time to imagine (*TMI*) or to execute (*Texe*) the task. A positive index means that imagination time is higher than execution time; negative index means that imagination time is lower than execution time; and the index equals zero means that the time to imagine and execute the tasks are equal. The four indexes calculated for each strategy were averaged, providing a general index of mental chronometry for 1P and 3P. Thus, both MIQ-R score and index of mental chronometry were used to verify the global capacity of participants to perform motor imagery tasks in different strategies (1P and 3P).

Finally, by the end of each experimental block (see below), participants should report (subjective report) the level of easiness/difficulty to perform the motor imagery task proposed in the experimental protocol, through a *Likert*-like scale; ranging from 1 point (extremely difficult) to 5 points (extremely easy). This subjective report was important to ensure that the subjects felt able to perform the actual experimental tasks.

2.3 Experimental protocol

During the experimental procedure participants were blindfolded. They were requested to remain seated comfortably with arms supported and instructed not to move theirs arms, legs or head. The experimental protocol consisted in two blocks: 1) the subjects had to mentally simulate the movement of right middle-finger extension using the 1P perspective, feeling themselves executing the movement; and 2) they had to simulate the same movement using the 3P perspective, visualizing a scene in which the movement was performed by another person (Fig. 1A).

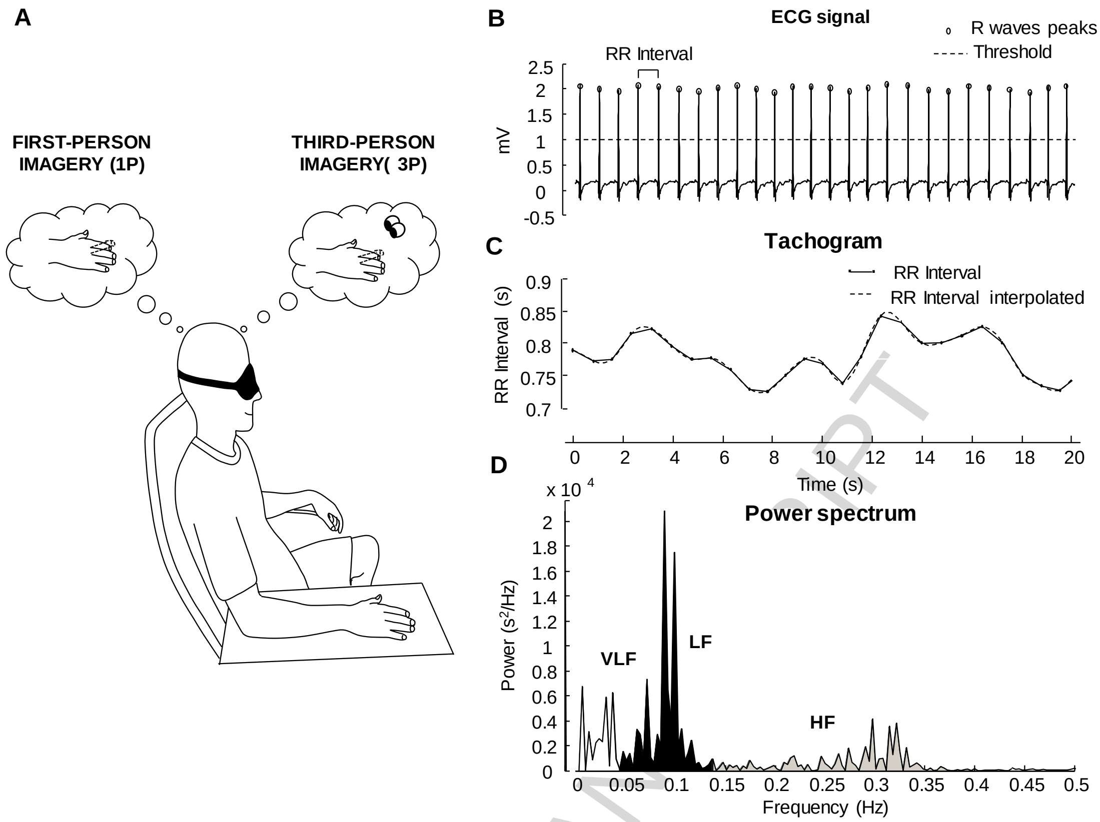

Fig 1. Experimental protocol and data processing. (A) Schematic representation of the experimental procedure, where the subjects were asked to imagine finger extension movements in first (1P) or third (3P) person perspective; (B) example of R wave peak detection of the ECG signal; (C) RR intervals time series resampled in regular intervals by cubic spline interpolation (frequency of 4 Hz), resulting in a smoothed time series; (D) HRV power spectrum divided into three frequency bands: high frequency (HF) (0.15-0.4 Hz); low frequency (LF) (0.04-0.15 Hz); and very low frequency (VLF) ($\leq$ 0.04 Hz).

A simple finger extension task was chosen because EEG signals were acquired simultaneously with the ECG signals, as previously reported [26]. As the authors investigated not only imagery tasks but also an execution task, large movements with the body could not be chosen due to possible interference in the EEG signal quality. The order of blocks was counterbalanced between subjects and the moment in time when subjects should have performed the tasks was determined through an external auditory cue. Fifty-five auditory cues were presented per block with unequal probability: 90% standard sound vs. 10% rare sound. A high pitch served as frequent standard sound

[1000 Hz, 70 dB sound pressure level (SPL)]. A low pitch served as rare sound (300 Hz, 70 dB SPL). Subjects were instructed to perform the task whenever they heard the high pitch. Thus, imagined movements were repeated fifty times per block and the speed to imagine the movement was not pre-set. Rare sound was included to enhance the volunteer's alertness. A familiarization period with eight auditory cues was performed before each block to ensure that the instructions were understood. Each specific instruction was reinforced before the corresponding block. All auditory stimuli lasted 100 ms and were presented employing the Presentation (Neurobehavioral System, USA) software. The interval between the stimuli varied randomly from 4500 to 4700 ms to enhance attentional demand. Total duration of each block, with 50 valid events, was about five minutes, as recommended by "Task force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology" [23] for short-term recordings. The interval between the blocks was about two minutes.

2.4 Electrophysiological recordings

ECG activity was recorded with a pair of Ag/AgCl surface electrodes (8 mm diameter) located into precordial derivation V5. Simultaneously, surface electromyography (EMG) signals were sampled (Ag-AgCl electrodes, 8 mm diameter and 2 cm inter-electrode distance) from the extensor digitorum muscle of the subjects' right hand following standard protocol [30], to ensure that no overt movement was present during the imagery tasks. ECG and EMG signals were acquired with the Biopac Systems (Goleta, CA; model MP 100 analog-to-digital converter of 12 bits; sampling frequency: 1,000 Hz).

2.5 Data processing

The ECG signals were analyzed "off-line" through MATLAB (Mathworks, USA), considering the entire period of five minutes recorded, which included all auditory cues during the motor imagery tasks.

After a visual inspection of the ECG signal, time series of RR interval (tachogram) were obtained from R wave peaks, identified through a threshold-based algorithm (Fig. 1B). For temporal and spectral analysis, each signal was resampled in regular intervals by cubic spline interpolation, with frequency of 4 Hz (Fig. 1C). From RR interval time series, the temporal parameters calculated were the root mean square of successive differences between RR intervals (RMSSD) and the mean HR, which is the mean of instantaneous heart rate in beats per minutes. For frequency-domain analysis of the HRV, the power spectral density was calculated through Fast Fourier Transform (FFT) of the time series of RR intervals. Then, the absolute values of the power of the three main spectral components of HRV signal were calculated (Fig. 1D): high frequency (HF; frequency range: 0.15-0.4 Hz); low frequency (LF; frequency range: 0.04-0.15 Hz); and very low frequency (VLF; frequency range $\leq$ 0.04 Hz), recommended by "Task force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology" [23]. After normalization, the contribution of the low (LFnu) and high (HFnu) frequency for the HRV signal was calculated, which corresponds to the relative value of each power component (LF and HF) in proportion to the total power minus the VLF component. The logarithmic transformation of the same frequency components of low (LFlog) and high (HFlog) frequency was also calculated, as well as the ratio between the absolute values of both frequency components (LF/HF ratio). These classical parameters were measured in order to verify the specific contribution of the parasympathetic and sympathetic systems based on HRV during the imagery tasks. In addition, the mean HR was also calculated for the purpose of showing that this usual parameter is not sensitive enough to highlight modulations in the cardiac system during motor imagery.

For EMG analysis, the root-mean-square (RMS) of the EMG signals was calculated and the difference between values in post- and prestimuli (1s) periods was computed for each imagery task (1P and 3P).

2.6 Statistical analysis

The normality of the data was checked using the Shapiro-Wilk test. The Wilcoxon matched paired test was employed to compare the scores of the MIQ-R, in 1P and 3P, and the subjective report of each experimental task. For the index of mental chronometry, the comparison between 1P and 3P was performed by using Student's t-test for dependent samples, and each index was compared with a reference value (zero) by using Student's t-test for single sample. All parameters (HR, RMSSD, LFnu, HFnu, LFlog, HFlog and LF/HF ratio) were also compared between 1P and 3P tasks by using Student's t-test for dependent samples, in function of their normal distribution. Additionally, the coefficient of variation of each parameter was calculated in order to check the level of variability. The RMS values of the EMG signals were analyzed by means of a two-way repeated measures ANOVA with task (1P and 3P) and periods (post- and prestimuli) as factors. All analyses were performed with the software STATISTICA 7.0 (StatSoft, USA). Data are expressed in mean (standard deviations) or median (lower-upper quartiles). Statistical threshold was set at $p \leq 0.05$. Cohen's d was used in order to determine the effect sizes.

3. Results

3.1 Motor imagery ability

There was no significant difference between imagery strategies for MIQ-R scores [median (lower – upper quartiles): 1P = 23 (19-24); 3P = 22 (18-24); p = 0.084; with a Cohen's *d* = 0.3; Fig.2A]. Similarly, the scores of the subjective report showed no difference between the different strategies used during the mental simulation of the movement of right middle-finger extension [median (lower – upper quartiles): 1P strategy = 4 (3-4); 3P strategy = 3.5 (2-4); p = 0.07; with a Cohen's *d* of 0.5; Fig.2B]. The mental chronometry indexes, instead, were significantly different [t (1,19) = 2.81; p = 0.011; Cohen's *d* =0.4] between the MIQ-R tasks in the 1P (-1.38 ± 8.73%) and in the 3P perspective (-5.25 ± 9.72%; Fig.2C). Moreover, although the mental chronometry index in the 1P imagery was not significantly different from the reference value (zero; t (1,19) = 0.7; p = 0.49), the index in the 3P imagery was significantly different from zero (t (1,19) = 2.42; p = 0.026).

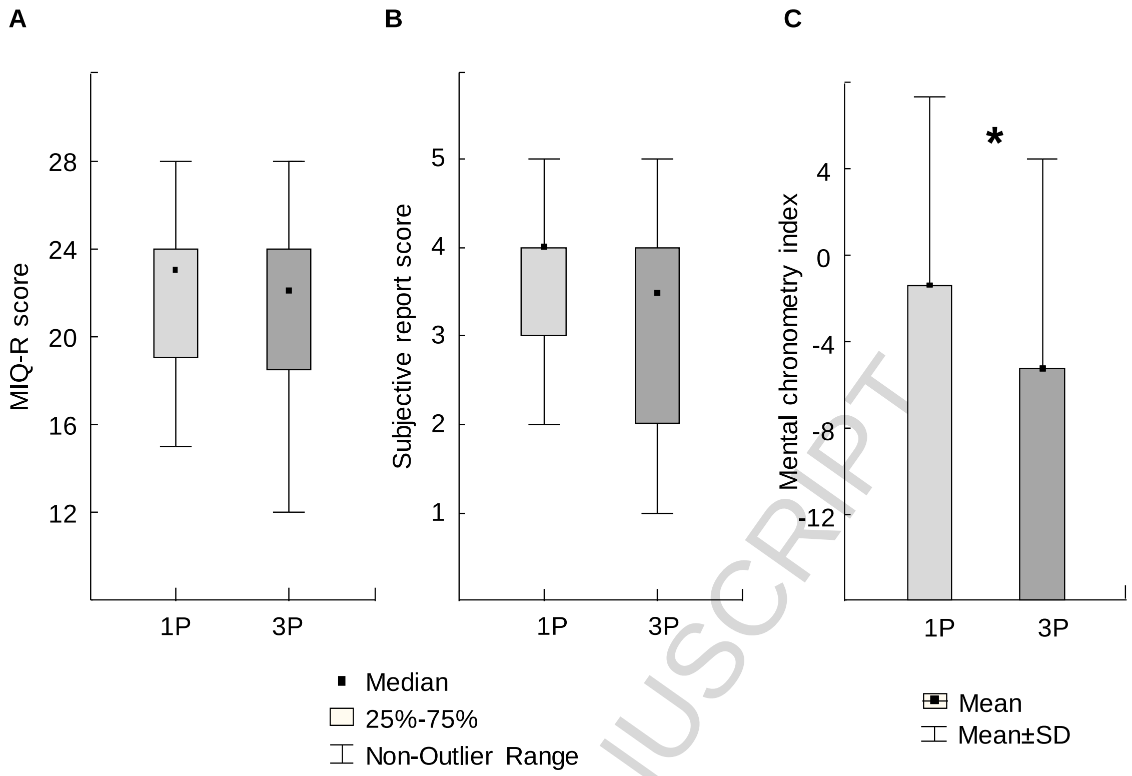

Fig 2. Motor imagery ability results. (A) MIQ-R score calculated through four different actions imagined by subjects using both 1P and 3P perspectives; (B) Score given by subjects associated to the level of easiness/difficulty to perform the motor imagery task proposed in this study (finger extension) in 1P and 3P perspectives; (C) Index of the time spent for performing each MIQ-R task. Asterisks indicate significant differences between 1P and 3P (*p*<0.05).

3.2 EMG

There was no difference between tasks (p = 0.42), analyzed periods (p = 0.96) nor interaction [F (1,38) = 0.073; p = 0.78] between factors in the RMS value. Therefore, no overt movement and related muscle activity were present during the imagery conditions, as expected.

3.3 Heart rate variability

Comparison of HRV measurements between motor imagery tasks revealed that only the LFlog parameter was significantly higher (t (1,19) = 2.61; p = 0.017) in 1P than 3P imagery. The other parameters were not significantly (p>0.05) different between the conditions (Table 1).

Table 1
Mean heart rate and HRV measures during motor imagery tasks in first (1P) and third (3P) person perspectives.

	1P	COV (%)	3P	COV (%)	p value	Cohen's d
HR (bpm)	66,34 (7,46)	11,24	66,28 (7,63)	11,52	0,86	0.01
RMSSD (ms)	39,44 (17,66)	44,77	38,22 (19,29)	50,48	0,22	0.07
LFnu (%)	57,71 (16,93)	29,33	55,45 (18,58)	33,50	0,18	0.13
HFnu (%)	42,29 (16,93)	40,02	44,55 (18,58)	41,70	0,18	0.13
LFlog	2,54 (0,23)	8,87	2,48 (0,23)	9,19	0,02*	0.26
HFlog	2,39 (0,39)	16,45	2,37 (0,41)	17,40	0,29	0.05
LF/HF ratio	1,77 (1,12)	63,24	1,76 (1,53)	87,19	0,96	0.01

Data are presented as mean (Standard Deviation). COV: coefficient of variation; HR: mean heart rate; RMSSD: square root of the mean of the sum of the squares of differences between adjacent RR intervals; LFnu: normalized units of the low frequency components; HFnu: normalized units of the high frequency components; LFlog: log transformation of the low frequency components; HFlog: log transformation of the high frequency components; LF/HF ratio: ratio between the absolute values of LF and HF frequency components. * significant difference between conditions at p < 0.05.

4. Discussion

When a subject mentally simulates a movement, he/she can evoke kinesthetic and/or visual representations of that imagined action. Distinct neural and autonomic responses have been associated with these different modes of motor imagery [4,6,9–12,26,31]. However, as far as we know, no study investigated whether the cardiac control systems (sympathetic and parasympathetic) are differently affected by distinct motor imagery perspectives. Since previous studies observed different autonomic responses when subjects imagined a movement in 1P and 3P perspectives [4,6,9–13], it would be expected that the cardiac control systems would also be differently affected according to the perspective-taking to mentally simulate a movement. Through HRV analysis we found that the LFlog was greater during 1P than 3P perspective. This result may reflect a greater sympathetic activation when kinesthetic representations in 1P are evoked to mentally simulate a movement. Consequently, this means that cardiac autonomic regulation is susceptible on the sensory strategy (kinesthetic or visual) employed to simulate a movement and that HRV seems be an appropriate method to show these subtle strategies.

4.1 Motor imagery ability

The MIQ-R scores and the mental chronometry were only used in order to perform a global evaluation of the participants' motor imagery ability. The results of MIQ-R showed that subjects had the same facility to imagine movements using 1P or 3P perspective. The MIQ-R scores obtained in our study, similar to those found by others [5], indicate that the participants can be considered as "good imagers". Good imagers usually show higher activity in the brain regions that play a critical role in the generation of mental images [5]. The analysis of the mental chronometry index showed the 1P imagery had almost the same temporal course as the executed movement (index not different from zero), while performance of 3P mode required shorter duration (given by the negative index). Indeed, previous studies have shown that the mental simulation of movements in 1P has temporal characteristics equivalent to the actual execution of the same movement, suggesting a similar neural substrate [19,29,32–35]. Thus, mental chronometry results indicate that both strategies (1P and 3P) probably differ in the neural mechanisms of generation, as previously demonstrated [4,6,10–12].

The subjective report was applied to ensure that subjects felt able to perform the specific experimental task, i.e., imagery of a finger extension movement. The results of the subjective report, rated after each experimental task, support that the subjects were able to easily imagine the proposed movement in both conditions. Nevertheless, observing the p-value (0.07) of this analysis, which was close to significance, and the Cohen's d value (0.5), considered as “moderate” effect size [36], these results suggest it was even easier to the subjects to perform the motor imagery in 1P than in 3P perspective. Lastly, by means of brain activity analysis, previous results [26] confirmed the subjects evaluated in this study were able to perform both the 1P and the 3P imagery tasks.

4.2 Motor imagery and physiological responses of ANS

Wang & Morgan [9] were pioneers in the investigation of imagery modalities (kinesthetic vs. visual) effects upon autonomic activity. They have observed that, for a physical exercise like elbow flexion lifting a dumbbell, the ventilatory responses were significantly greater during motor imagery in kinesthetic than in visual modality. However, responses in systolic and diastolic pressures were similar between modalities. Grangeon et al. [37] showed similar electrodermal responses between the execution and the kinesthetic imagery of a movement sequence. Demougeot et al. [16] observed that execution and imagination (kinesthetic modality) of cyclic movements of the wrist, considered by the authors as a movement which does not require effort, did not produce important alterations of the mean HR as compared to the rest. However, as discussed previously and observed in our results, the measure mean HR has limitations and may not provide consistent results.

4.3 Motor imagery and HRV

The HRV analysis is a robust and validated methodology to evaluate the cardiac control system. Variations in the distribution of the power and the central frequency of LF and HF components may reflect changes in autonomic modulations of the heart period. The parasympathetic activity has been reported as the main contributor to the HF component [22,23,38,39]. The interpretation of the LF component has been more controversial in the literature. Some studies reported as a marker of sympathetic modulation [38], while other considered the LF component as a parameter that includes both sympathetic and vagal influences [22,39,40]. Consequently, the ratio between LF and HF frequency components (LF/HF ratio) has been considered as the sympatho/vagal balance or as the reflection of sympathetic modulations.

Since the parasympathetic system has an important influence on HF components, the HFnu, HFlog and RMSSD parameters could reflect modulations in this system. Thus, based on the fact that there is a strong similarity in the autonomic responses between execution and 1P [9,16,37] and that the parasympathetic system has antagonistic effects with respect to the sympathetic system, we expected lower values from these parameters during the 1P than 3P imagery of the finger movement. However, there was no significant difference between these strategies. These findings may be interpreted as an equal activity of the parasympathetic system between 1P and 3P perspectives. Although these results were against our expectation, they can be explained by the complex relation between the autonomic systems. Even if the sympathetic and parasympathetic branches of the ANS have antagonistic effects, they can be activated independently and an increase of sympathetic activity may not necessarily be compensated by a decrease in the parasympathetic activity [41].

Nonetheless, the results related to the LF parameters (LFnu and LFlog) must be more carefully interpreted, due to the controversial studies in literature. LF components have been considered as markers of sympathetic modulation [38]. If so, we could conclude that the higher LFlog values indicate that the sympathetic system was more activated in the 1P than 3P imagery. However, other studies argued that LF components are influenced by both sympathetic and vagal systems [22,39,40]. In this case, our results of the LFlog still suggest the sympathetic system had more activity when the 1P strategy was adopted to mentally simulate the finger movement, since the HF parameters showed that the parasympathetic system was similarly activated during both strategies. Hence, any difference observed in the LF components between the strategies can be related to changes in the sympathetic, and not in the parasympathetic system. Thus, motor imagery in 1P perspective seems to be more associated with the sympathetic activity [42].

With respect to the LF/HF ratio, usually it is a reliable index of sympathetic-parasympathetic balance. However, unlike our expectations, this parameter did not show significant difference between 1P and 3P motor imagery strategies. By observing the coefficient of variation (CV) values of the LF/HF ratio (table 1), it is clear that the data show a huge variability. This may be the reason why only the LFlog parameter revealed different modulations of the autonomic cardiac system between motor imagery strategies, even using a task requiring little effort (movement of extension of the middle finger). Thus, the controversial results between LFlog and LFnu and LF/HF ratio parameters can be explained by the use of logarithmic transformation, i.e., LFlog showed a lower CV related to the LFnu and the LF/HF ratio (table 1). The logarithmic transformation reduced the data variability, increasing the probability to find different responses between the tasks. These results agree with Nunan et al. [43], which showed a large discrepancy of results of HRV during short-term recordings. The measures in the frequency domain, specifically, are those that have greater variety of values among studies. Therefore, methods that minimize data variability, as the logarithmic transformation, could be the best way to study the cardiac autonomic responses.

4.4 Study limitation

One clear limitation of this study was the choice of a simple finger extension movement due to the simultaneous acquisition of EEG signals performed in previous complementary study [26], that also investigated an execution condition. This experimental approach does not allow the execution of large movements, due to potential interference of the body motion on signal quality. It is possible that complex and/or whole-body movement, requiring a higher effort, could be more robust in showing differences in autonomic regulation between motor imagery strategies. Decety et al. [19], for example, have shown that, during the motor imagery of a leg exercise with two distinct loads (15 and 19 Kg), the maximal HR and the partial pressure of carbon dioxide were significantly lower with the lighter load, showing that the autonomic responses were higher with the increase of the effort. Probably, the mental simulation of more vigorous body movements would confirm our findings and, perhaps, reveal other features of cardiac regulation during motor imagery that were not identified in the present study. However, the identification of modulation in HRV for motor imagery strategies, even to movements requiring little effort, demonstrated that these measures are sensitive enough to detect discrete changes in the ANS and, therefore, should be used in substitution to HR.

5. Conclusion

Our results suggest that distinct patterns of cardiac activity emerge depending on the motor imagery strategy adopted by the subject, with an increased activity of the sympathetic system during 1P with respect to the 3P perspective. These novel results show that, as well as during the execution of movements, the sympathetic branch of the autonomic system seems to contribute foremost to the 1P motor imagery task. This resemblance between actual execution and motor imagery in 1P reinforces the predominance of somatic-motor resources employed during introspective states of mental simulation of actions in this perspective. Moreover, our findings indicate that through motor imagery in 1P is possible to access the neurophysiological mechanisms responsible for the preparation and programming of actual movements.

The HRV analysis was able to identify this discrete difference between the motor imagery strategies, even during an effortless action. The logarithmic transformation of HRV parameters seems to be a more sensitive analysis than the normalized values and the mean HR. These results may have important implications for studies that use autonomic responses as a mean to evaluate the efficiency of mental rehearsal, either to evaluate individual imagery ability or to use autonomic responses as a tool to control and evaluate motor learning [5,6,15,24,25]. The differences in cardiac activity found in our study between the motor imagery strategies also shows that one must be careful about the instruction given to participants, in order to avoid unreliable results difficult to be interpreted. Finally, we suggest the HRV analysis could be used to evaluate the efficiency of mental rehearsal during motor imagery tasks, taking into account the fundamental recommendations for this kind of analysis [23].

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HIGHLIGHTS

- We aim to investigate whether cardiac activity depends on motor imagery strategy.
- Heart rate variability was measured during motor imagery in 1P and 3P perspectives.
- Cardiac sympathetic activity was greater during 1P than 3P imagery.
- Logarithmic transformation seems to be the most sensitive method for HRV analysis.