Reduction of intracortical inhibition in soleus muscle during postural activity

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Short interval intracortical inhibition (SICI) decreases during voluntary contraction of the target muscle. It is unknown if this effect occurs also with postural contractions. We have compared the effects of voluntary and postural contractions on SICI in the soleus (SOL) muscle. We applied transcranial magnetic stimuli (TMS) in subjects under three tasks: Sitting at rest (Rest), sitting while activating the SOL muscle (Voluntary), or standing quietly (Postural). In control trials, we applied suprathreshold TMS to obtain unconditioned motor evoked potentials (MEP). In test trials, the same TMS was preceded by a subthreshold TMS at different interstimulus intervals (ISIs), to obtain a conditioned MEP. SICI and intracortical facilitation (ICF) were expressed as the decrease or increase in MEP size relative to unconditioned MEPs. There was significant effect of task in mean SICI or mean ICF in SOL. Mean SICI in SOL was 52% in Rest, and decreased to 21% in Voluntary and 15% in Postural. Mean ICF in SOL was 132%, and decreased to 113% in Voluntary and to 108% in Postural. Mean SICI in SOL was not different in Voluntary and Postural task. There was no effect of task in mean SICI or mean ICF in TA. Our results indicate that decrease of SICI with muscle contraction occurs to a similar extent with tonic voluntary and postural activation, suggesting that those contractions require similar type of cortical involvement. However, it cannot be excluded that some part of the SICI reduction with muscle contraction depends on changes in segmental excitability.
INTRODUCTION

Paired focal transcranial magnetic stimulation (TMS) provides a tool for the assessment of motor cortex excitability in health and disease (Kujirai et al. 1993; Hanajima et al. 1996, 1998; Ridding et al. 1995a; Tergau et al. 1999). In hand muscles at rest, a subthreshold stimulus causes inhibition of the response to a subsequent suprathreshold stimulus at interstimulus intervals (ISIs) between 1 and 5 ms (Kujirai et al. 1993). Such a short interval intracortical inhibition (SICI) is reduced when the test is done while maintaining a voluntary contraction of the target muscle (Ridding et al. 1995b). SICI is believed to take place at a cortical level (Kujirai et al. 1993). By extension, it is also believed that the decrease in intracortical inhibition during muscle contraction is due to a change in motor cortex excitability (Reynolds and Ashby 1999). Furthermore, active relaxation of hand muscles has been shown to increase SICI (Buccolieri et al. 2004). These observations indicate that the motor cortex increases or decreases the degree of SICI for specific muscles, depending on the task.

In the great majority of studies, cortical excitability has been examined in hand muscles. In the few studies dealing with leg muscles, SICI, as well as intracortical facilitation (ICF), were similar to those of hand muscles measured at rest (Kujirai et al. 1993; Stokic et al. 1997; Chen et al. 1998; DiLazzaro et al. 2001). Although there is evidence for task-related changes in the amplitude and latency of the motor evoked potential (MEP) induced by TMS in the tibialis anterior (TA) and the soleus (SOL) muscles (Brouwer and Ashby 1990; Ackermann et al. 1991; Valls-Solé et al. 1994; Chen et al. 1998; Pérez et al. 2004), the effects of voluntary contraction on SICI have not been investigated so far in those muscles. Particularly, no information is available regarding SICI in SOL in different behavioural contexts. It is widely accepted that the motor cortex has an important role in voluntary tasks (Ashe 1997), while subcortical motor structures participate more importantly in postural control (Prentice and Drew 2001). Indeed, several previous studies have suggested that the involvement of the motor cortex in voluntary tasks differs from postural tasks (Brouwer et al. 1989; Lemon et al. 1995; Schieppati et al. 1996). Tonic activation of SOL during standing is considered a postural task rather than a voluntary-driven muscle contraction. Since reproducible MEPs can be obtained with TMS
in leg muscles (Valls-Solé et al. 1994; Lavoie et al. 1995), we studied how SICI and ICF in SOL were modified during voluntary and postural contractions.

METHODS

Subjects

The study was carried out in 12 healthy volunteers, aged 23 to 52 years, who gave their consent for the tests. Eight subjects were studied in the Institute of Neurology at Queen's Square, London. The other 4 subjects were studied in the Hospital Clínic, Barcelona. The procedures were approved by the Ethical Committee of both Institutions.

Stimulation and recordings

A double cone coil from a BiStim module connected to 2 magnetic stimulators (Novametrix 200; MagStim Company, England) was positioned in the best location for eliciting a motor evoked potential (MEP) in both muscles, and was firmly attached over the subject's head with elastic bands preventing further displacements. Recordings were performed with cup-shaped (1 cm diameter) placed 3 cm apart on the muscle belly, and were either digitized through Digitimer amplifiers and fed into a computer at a sample rate of 2500 Hz, or stored on a Synergy electromyograph (Oxford Instruments, Surrey, England), for off-line analysis.

Resting and active motor threshold intensities for SOL were determined in each subject using single stimuli. We considered resting motor threshold intensity the smallest stimulus intensity giving rise to a MEP which amplitude was larger than 50 µV in at least 3 out of 6 consecutive stimuli. We considered active motor threshold intensity the smallest stimulus intensity giving rise to a MEP which amplitude was larger than the background level of EMG activity in at least 3 out of 6 consecutive stimuli. In 5 subjects, we assessed active motor threshold separately for each task requiring muscle contraction (see below).
Procedure

The experiment was divided in 3 parts, according to 3 different experimental tasks: 1. Sitting at rest (Rest). 2. Sitting while performing a voluntary ankle plantar flexion of about one third of the maximum force (Voluntary) and 3. Standing (Postural). In Voluntary and Postural tasks subjects were instructed to maintain a similar degree of muscle contraction in SOL. For that purpose, they received visual and auditory feedback of their background EMG activity. Individual adjustments of the amount of EMG activity in SOL during the postural task were done by instructing the subject to lean forward to increase, or backward to decrease, the level of SOL EMG activity. In all three experimental tasks we delivered stimuli organized as control and test trials. In control trials, we applied TMS at an intensity of 120% of SOL resting threshold and obtained an unconditioned MEP. In test trials, we applied the same TMS preceded by a conditioning stimulus of an intensity of 95% of active motor threshold to obtain a conditioned MEP at ISIs of each ms between 1 and 15 ms. Control and test trials were randomly distributed in two consecutive blocks, totalling 60 test trials (4 trials per ISI) and 40 control trials for each of the three tasks. In tasks involving muscle contraction, the stimuli were delivered during a stable contraction, after at least 10 seconds from onset, and not more than 40 seconds before end, of contraction. Periods of rest were allowed between stimuli. The whole session lasted approximately 90 minutes.

Effect of MEP size on SICI

In another group of 4 subjects we examined the effects of a conditioning stimulus at the ISI of 2 ms on unconditioned SOL MEPs of similar size in Rest, Voluntary and Postural. For that purpose, we reduced the stimulus intensity during contraction to give rise to unconditioned MEPs which mean amplitude was to that of the unconditioned SOL MEPs obtained at rest.

Data reduction and statistical analysis.

In the raw traces, we measured amplitude as the largest difference between negative and positive peaks, and duration as the difference between onset and end of the evoked potential. Because MEP amplitude changes are considered to parallel those of the area
(McDonnell et al. 2004), and the SOL MEPs were predominantly polyphasic, we chose to use MEP area measured on rectified responses for all analyses regarding task-induced changes in MEP size. The area was computed from the first negative deflection to the last return to baseline of the rectified MEP.

In control trials, we calculated the means (and SD) for amplitude and area of the unconditioned MEPs induced by TMS in TA and SOL for each individual, which were assigned the value of 100%. In test trials, we calculated the MEPΔ area as the percentage area difference between conditioned and unconditioned MEPs, for each individual and ISI, according to the formula:

$$\text{MEPΔ}(\%) = \left[\frac{\text{MEP}_c - \text{MEP}_u}{\text{MEP}_u}\right] \times 100$$

where,

- $\text{MEPΔ}(\%)$ = percentual MEP change relative to unconditioned MEP
- $\text{MEP}_u$ = mean unconditioned MEP area
- $\text{MEP}_c$ = conditioned MEP area

This formula gives negative values for MEP reduction and positive values for MEP increase. Except in figures, for clarity, we expressed MEP Δ (SICI or ICF) in absolute values.

We used one factor ANOVA to determine whether there was a significant effect of ISI on the conditioned MEP area in Rest, and the Bonferroni’s post-hoc analysis to identify ISIs with significant inhibition (SICI) or facilitation (ICF). We averaged the mean values of all ISIs with significant SICI and significant ICF for each muscle and task, and performed a one-factor ANOVA to determine whether there were differences due to task. Finally, we calculated the differences between Rest and Voluntary as well as between Rest and Postural for each of the ISIs exhibiting SICI in SOL, and used a one-factor ANOVA to determine the effect of the factor ISI on SICI for each task. For all comparisons, significance was set at p<0.05.

RESULTS

Stimulus intensities for conditioning and test stimuli were very variable among the subjects of the study, ranging from 42% to 64% for the conditioning stimulus and from
58% to 96% for the test stimulus, expressed in percentage of the maximum power of the stimulator. The active motor threshold measured separately for Voluntary and Postural was not different in the 5 subjects tested (t-test; p=0.02).

Comparison of control MEP between tasks

Table 1 shows a summary of the mean data obtained in control trials. Mean MEP amplitude and area were significantly different between tasks for SOL (F[2,33]=21.6; p<0.0001 for amplitude, and F[2,33]=27.0; p<0.0001 for area), but not for TA (F[2,33]=0.5; p=0.6 for amplitude, and F[2,33]=0.7; p=0.5 for area). Post-hoc analysis showed that the differences in SOL were due to a larger amplitude and area in Voluntary and Postural in comparison to Rest (p<0.05 for all comparisons). In the 4 subjects in whom we examined the TA during ankle dorsiflexion, the MEP amplitude and area were significantly larger (paired t-test; p<0.05) during contraction (mean=72%; SD=5.5%) than at rest.

Effects of conditioning stimuli on TA and SOL MEPs in Rest

The area of the test MEP was significantly influenced by the presence of a preceding conditioning low intensity stimulus in each of the subjects of the study. Examples from a representative subject are depicted in Figure 1A. Statistical analysis showed a significant effect of conditioning stimuli on MEP area (ANOVA; F[15,176]=24.7; p<0.0001 for SOL and F[15,176]=12.1; p<0.0001 for TA). Post-hoc analysis indicated that differences were due to significant SICI at ISIs 1 to 5 ms in SOL and 1 to 3 ms in TA and to a significant ICF at ISIs 11 to 15 in SOL and 13 to 15 in TA. Figures 2A (TA) and 2B (SOL) show the percentage change in area of the conditioned MEP at all ISIs at rest (filled squares). Mean SICI was 50.1% (SE=3.4%) in TA and 51.9% (SE=2.3%) in SOL. Mean ICF was 149.8% (SE=7.4) in TA and 135.6% (SE=4.2%) in SOL.

Effects of Voluntary and Postural tasks on SICI and ICF

SICI and ICF were noticeably reduced in Voluntary and Postural in comparison to Rest in SOL but not in TA, in all subjects (see Figure 1B,C for the results obtained from a representative subject and Figures 2A and 2B empty circles and empty triangles). Mean SICI in SOL reduced to 21.4% (SE=4.2%) in Voluntary and to 14.6% (SE=3.9%) in Postural, while they were not changed with respect to Rest in TA, with values of 46.3% (SE=2.8%) for Voluntary and 44.7% (SE=3.1%) for Postural (Figure 3). There were
significant differences between tasks regarding mean SICI and mean ICF for SOL (F[2,177]=30.4; \(p<0.001\), and F[2,177]=9.5; \(p<0.001\), respectively) but not for TA (F[2,105]=0.8; \(p=0.46\) for SICI, and F[2,105]=2.4; \(p=0.09\) for ICF). The post-hoc analysis showed that the mean SICI in SOL was significantly reduced in Voluntary and Postural with respect to Rest (\(p<0.05\) for both comparisons), and that there were no differences between Voluntary and Postural (\(p>0.05\)).

Additionally, we analysed the possibility that the factor ISI had an effect on the decrease of SICI in SOL during contraction. To do that, we calculated the difference in SICI between Rest and Voluntary, and between Rest and Postural, and used again a one-factor ANOVA to compare individual SICI at ISIs 1 to 5 ms for each task. The analysis showed a significant effect of ISI for both, Voluntary (F[5,66]= 2.74; \(p=0.02\)), and Postural (F[5,66]= 7.8; \(p=0.001\)). Post-hoc analyses of differences between ISIs showed that the decrease in SICI in SOL was significantly larger in ISI 2 ms than in the other ISIs in Voluntary, and it was significantly larger in ISIs 2, 3, 4, and 5 ms with respect to ISI 1 ms in Postural.

SICI on test SOL MEPs of similar size

In 4 subjects, the stimulus intensity used to elicit the control MEPs during contraction was reduced until we obtained control SOL MEPs of an area similar to that obtained at rest (ANOVA,F[2,9];\(p>0.05\) for each subject). Table 2 shows the mean results for latency and area of the MEPs. It is worth noting that even though there were no differences in area, muscle contraction in Voluntary and Postural tasks both led to a significant shortening in MEP latency. The test was done at an ISI of 2 ms, which was chosen as it showed the greatest SICI reduction in Voluntary and Postural tasks (data above and Figure 2B). In all subjects, muscular contraction, either in Voluntary or Postural, had the effect of reducing SICI to the same extent as with MEPs of different size. The mean SICI in Rest was 60% (S.E.=1.7), 23% (S.E.=0.9) in Voluntary, and 21% (S.E.=1.2) in Postural.
DISCUSSION

Postural activation of leg muscles is an essential feature of the standing posture. The human SOL is tonically active during standing, and changes its level of activity depending on postural requirements (Nardone and Schieppati 1988). Contrary to other limb muscles, SOL receives few direct corticospinal projections suggesting no need for fractionated muscle control, a fact that underscores its role in posture (Muir and Lemon 1983; Brouwer and Ashby 1990). Corticospinal input to leg muscles in standing has been scarcely investigated (Lavoie et al. 1995). Many studies indicate that the excitability of the motor pathway to leg muscles undergoes significant increases while standing in comparison to sitting at rest (Nielsen et al. 1993; Valls-Solé et al. 1994; Goulart et al. 2000). This suggests that, similar to voluntary contractions, postural contractions of leg muscles are associated with a marked increase in the population of spinal motoneurons at a near-threshold excitability state (Schneider et al. 2004). This is consistent with the notion that direct corticospinal projections to the SOL may indeed exist, although they are only active in certain conditions (Ackerman et al. 1991; Valls-Solé et al. 1994; Lavoie et al. 1995). Our present results provide confirmation for these observations by showing a significant increase in the amplitude and area of the unconditioned MEPs recorded in SOL during either Voluntary or Postural in comparison to Rest.

There is now good evidence that SICI is caused by an interaction within the cortex between inhibitory neurones activated by the conditioning pulse and corticospinal output activated by the test pulse. Direct recordings of the descending corticospinal volleys evoked by the test pulse (Nakamura et al. 1997; Di Lazzaro et al. 1998, 2003), indicate that the conditioning stimulus reduces the amplitude of late I-waves evoked by the test pulse. This leads to a smaller overall descending volley and smaller MEPs in peripheral muscle. Our present data show that the magnitude and time course of SICI in SOL at Rest are similar to those reported in hand muscles (Kujirai et al. 1993; Ridding et al. 1995b) and in previous studies targeting different leg muscles (Stokic et al. 1997; Chen et al. 1998).

Muscle contraction is known to decrease SICI, an effect that has been considered to reflect selective focussing of cortical excitability on specific muscles (Ridding et al. 1995b; Roshan et al. 2003; Zoghi et al. 2003). Our results show that SICI decreases in SOL not only in the Voluntary task, but also, and to and equal extent, in the Postural task. At first
sight this suggests that both tasks lead to similar changes in the excitability of intracortical inhibitory circuits, with the implication that voluntary and postural tasks engage similar circuits in the motor cortex, in apparent disagreement with the classical notion that voluntary tasks are more dependent on cortical control while postural tasks depend on subcortical activity (Georgopoulos et al. 1992; Prentice and Drew 2001).

However, there are several other factors that could complicate this interpretation. It is possible that active motor threshold depends on the type of task. If this were the case, the relative inhibitory effect of the conditioning stimulus could have been different for Voluntary and Postural tasks. However, we found no indication for such possibility in the 5 subjects in whom we specifically determined the active motor threshold in the two types of muscle contraction. Another important methodological issue in our experiments was that, due to the facilitatory effect of contraction on the SOL MEPs, SICI was assessed on larger MEPs during contraction than at rest. The same problem was addressed by other authors (Ridding et al. 1995b; Roshan et al. 2003), who reported that differences in the size of the test MEP (above a certain amplitude) have little effect on the amount of SICI. However, small MEPs, generated by near-threshold stimuli are prone to short-interval ICF because of facilitatory I-wave interaction (Roshan et al. 2003). This effect is likely to be cortical in origin (Ilic et al. 2002) and has been reported in leg muscles (Chen and Garg 2000). Because the size of our unconditioned SOL MEPs at rest was rather small, facilitatory I-wave interaction (Ziemann et al. 1998, Chen and Garg 2000; Hanajima et al. 2002) could have indeed been an artefact in our results. However, control data obtained in subjects in whom the test intensity was adjusted to produce SOL MEPs of similar size during rest and activity showed that voluntary and postural contractions decreased SICI by the same amount, suggesting that differences in the amplitude of the MEP were not an important factor in the contraction-related changes in SOL SICI.

Another possible confounding factor is that, as first noted by Hanajima et al (1998), voluntary contraction can also lead to reduced SICI because of changes in spinal excitability. This is because at rest, spinal motoneurones do not discharge on receipt of the first corticospinal volley evoked by the test pulse; they require temporal summation with later volleys before threshold is reached. Thus, SICI, which reduces the amplitude of the later I-wave volleys, has a particularly dramatic effect on the number of motoneurones that
fire, and hence the MEP is highly suppressed. However, in the active state, spinal motoneurones are excitable and discharge on receipt of the first descending volleys. As observed in the present data, this shortens the onset latency of the MEP compared with that at rest. Because early descending volleys discharge some motoneurones, the proportional contribution of the later I waves to the final MEP is smaller than at rest. Thus, when SICI reduces the later I waves, it causes less MEP suppression than at rest. As a result, SICI appears to be reduced during contraction.

The precise contribution of this spinal effect is difficult to estimate since it depends on the recruitment of motoneurones by the descending volleys. However, since Postural and Voluntary tasks in the present experiments activated SOL to the same degree, they could both share at least some common spinal mechanism of SICI suppression.

The explanations put forward so far for SICI reduction by muscle contraction include changes in afferent sensory feedback or changes related to motor output. Many observations support a role for sensory afferences on contraction-related SICI reduction (Ridding and Rothwell, 1999; Rosenkrantz and Rothwell, 2004). However, the role for afferent feedback in the SICI reduction observed in our experiments is in question since the composition and extent of the sensory volley reaching the central nervous system is likely to be different in Voluntary and Postural tasks. Alternatively, motor outputs may explain most of the changes in SICI during contraction. Indeed, there is evidence that motor output in the absence of changes in afferent feedback can reduce SICI, as shown by Reynolds and Ashby (1999) during the response time preceding a dynamic contraction.

Our finding of similar SICI modulation in postural and voluntary contractions suggests similar cortical involvement in both tasks, and speaks in favor of a motor cortical role in postural control. Cells in the motor cortex firing during cocontraction of antagonistic muscles have been documented (Humphrey and Reed 1983), long latency reflexes recorded from some leg muscles and elicited during postural adjustments have a transcortical route (Petersen et al. 1998), and animal recordings from subcortical structures during postural adjustments do not exclude a cortical origin of postural commands (Prentice and Drew 2001). Thus, it is possible that the motor cortex has a role in postural control of SOL, particularly in the generation of fast postural adjustments needed to re-equilibrate the centre.
of gravity (Nardone and Schiepatti 1988). Evidence showing that postural compensatory responses are cortically mediated has been recently presented (Taube et al. 2006).

In conclusion, our findings are in keeping with a similar change in the excitability of the structures of the motor cortex responsible for SICI in SOL during tonic voluntary and postural contractions of SOL. This observation suggests that the motor cortex contributes to some extent to maintain the muscle contraction required for postural tasks. However, we cannot exclude the possibility that some part of the decrease in SICI found in our subjects was due to the fact that the descending waves being suppressed with SICI are relatively less important than earlier waves for bringing the more excitable spinal motoneurons to fire during contraction.
GRANTS

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REFERENCES


Prentice SD and Drew T. Contribution of the reticulospinal system to the postural adjustments occurring during voluntary gait modifications. *J Neurophysiol* 2001;85:679-698.


Table 1. Data on MEPs obtained in control trials in tibialis anterior (TA) and soleus (SOL) for all subjects (n=12).

<table>
<thead>
<tr>
<th></th>
<th>Rest</th>
<th>Voluntary</th>
<th>Postural</th>
</tr>
</thead>
<tbody>
<tr>
<td>TA latency</td>
<td>31.6 ± 0.2</td>
<td>31.2 ± 0.4</td>
<td>31.5 ± 0.2</td>
</tr>
<tr>
<td>TA amplitude</td>
<td>229 ± 16.6</td>
<td>218 ± 19.4</td>
<td>246 ± 22.9</td>
</tr>
<tr>
<td>TA area</td>
<td>5908 ± 421.2</td>
<td>6532 ± 584.8</td>
<td>5515 ± 736.2</td>
</tr>
<tr>
<td>SOL latency</td>
<td>35.9 ± 0.3</td>
<td>33.7 ± 0.3</td>
<td>33.5 ± 0.3</td>
</tr>
<tr>
<td>SOL amplitude</td>
<td>96 ± 11.5</td>
<td>262 ± 25.5</td>
<td>278 ± 25.1</td>
</tr>
<tr>
<td>SOL area</td>
<td>1789 ± 215.1</td>
<td>6639 ± 690.2</td>
<td>7402 ± 710.7</td>
</tr>
</tbody>
</table>

Values are mean ± SE, for onset latency (in ms), and area (µV*ms).
Table 2. Comparison between control MEP area and latency in the 3 experimental tasks, in the 4 subjects in whom we reduced the intensity of TMS during contraction to match with the size of the MEP at rest.

<table>
<thead>
<tr>
<th></th>
<th>Rest</th>
<th>Voluntary</th>
<th>Postural</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control latency</td>
<td>35.8 ± 0.5</td>
<td>33.2 ± 0.7</td>
<td>33.1 ± 0.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Control area</td>
<td>3843.7 ± 175.1</td>
<td>4103.1 ± 277.4</td>
<td>3991.2 ± 261.3</td>
<td>&gt;0.05</td>
</tr>
</tbody>
</table>

Values are means ± SE. Values for latency of the MEP are expressed in ms Values for area of the MEP are expressed in µV*ms.
FIGURE LEGENDS

Figure 1: Examples of recordings from tibialis anterior (TA) and soleus (SOL) in a single subject. Upper graphs in each panel show superimposition of individual trials and lower graphs show their averaging. Graphs in the left columns are control (unconditioned) trials and those in the right columns are test (conditioned) trials at the interval of 2 ms. A) Rest. Note the decrease in size of all action potentials in the right side column in comparison to the left side column. B) Voluntary. Note that the decrease in the size of the action potentials is limited to the TA recordings. C) Postural. Note that, like in (B), the decrease in size occurs in the TA but not in the SOL. Vertical calibration is different for TA (0.2 mV) and for SOL (0.1 mV) in all recordings. Horizontal calibration is 20 ms.

Figure 2: Inhibition and facilitation of MEPs at each interstimulus interval (ISI) in Rest (filled squares), Voluntary (empty circles), and Postural (empty triangles) for TA (A) and SOL (B). The axis of abscissae represent the ISIs tested from 1 to 15, in milliseconds. The axis of ordinates represents the mean percentage change in MEP area [MEP $\Delta$ (%)] of the conditioned MEP relative to the unconditioned MEP, in all 12 subjects. Negative values indicate inhibition (SICI) while positive values indicate facilitation (ICF). In TA the MEP $\Delta$ (%) are unaffected by the experimental task at virtually all ISIs while in SOL there is a clear decrease in the amount of inhibition at short intervals or in the amount of facilitation at longer intervals.

Figure 3: Mean SICI (left-side columns in upper and lower graphs) and Mean ICF (right-side columns in upper and lower graphs) in the three tasks of the study. Each bar represents the grand mean obtained after combining values of mean MEP $\Delta$ from those ISIs in which there was significant inhibition or facilitation of MEPs. Significant differences between tasks are marked with an asterisk.