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Hemispheric Interaction in Simple and Complex Tasks: A Study of Interlimb Coordination

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Hemispheric Interaction in Simple and Complex Tasks: a Study of Interlimb Coordination

A thesis submitted in partial fulfillment of the requirement for the Degree of Bachelors of Science in the Department of Kinesiology from The College of William and Mary.

by

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Accepted for Honors

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## Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acknowledgements</td>
<td>ii</td>
</tr>
<tr>
<td>List of Figures</td>
<td>v</td>
</tr>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Experiment 1</td>
<td>10</td>
</tr>
<tr>
<td>Methods</td>
<td></td>
</tr>
<tr>
<td>Participants</td>
<td>10</td>
</tr>
<tr>
<td>Apparatus and Task</td>
<td>11</td>
</tr>
<tr>
<td>Procedures</td>
<td>12</td>
</tr>
<tr>
<td>Results</td>
<td>14</td>
</tr>
<tr>
<td>Discussion</td>
<td>14</td>
</tr>
<tr>
<td>Experiment 2</td>
<td>15</td>
</tr>
<tr>
<td>Methods</td>
<td></td>
</tr>
<tr>
<td>Participants</td>
<td>15</td>
</tr>
<tr>
<td>Apparatus and Task</td>
<td>15</td>
</tr>
<tr>
<td>Procedures</td>
<td>16</td>
</tr>
<tr>
<td>Results</td>
<td>16</td>
</tr>
<tr>
<td>Discussion</td>
<td>17</td>
</tr>
<tr>
<td>General Discussion</td>
<td>18</td>
</tr>
<tr>
<td>References</td>
<td>20</td>
</tr>
<tr>
<td>Figure Captions</td>
<td>27</td>
</tr>
<tr>
<td>Figures</td>
<td>28</td>
</tr>
</tbody>
</table>
## List of Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1</td>
<td>Illustration of Testing Apparatus</td>
<td>28</td>
</tr>
<tr>
<td>Figure 2</td>
<td>Experimental Conditions</td>
<td>29</td>
</tr>
<tr>
<td>Figure 3</td>
<td>Illustration of Simple Task Completion</td>
<td>30</td>
</tr>
<tr>
<td>Figure 4</td>
<td>Mean Reaction Time (ms) as a Function of Laterality</td>
<td>31</td>
</tr>
<tr>
<td>Figure 5</td>
<td>Mean Movement Time (ms) as a Function of Laterality</td>
<td>32</td>
</tr>
<tr>
<td>Figure 6</td>
<td>Illustration of Complex Task Completion</td>
<td>33</td>
</tr>
<tr>
<td>Figure 7</td>
<td>Mean Reaction Time (ms) as a Function of Laterality and Response Task</td>
<td>34</td>
</tr>
<tr>
<td>Figure 8</td>
<td>Mean Movement Time (ms) as a Function of Laterality and Response Task</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Task</td>
<td></td>
</tr>
</tbody>
</table>
Hemispheric Interaction in Simple and Complex Tasks

It is an indisputable fact that humans are capable of a practically limitless variety of complex movements. These movements often require the coordination of parts of the body in different tasks, usually involving distinct positioning of the upper and lower limbs. Some motions are pattern-based, such as the alternating coordination of limbs that propel one forward in walking, running, and swimming, while others are far more complex, and require task-dependent manipulation of the limbs to complete, such as typing on a keyboard, playing an instrument, or buttoning a shirt (Swinnen, 2002). While some behavior tendencies seem “preprogrammed,” such as the natural reflexes and movements present at birth, others require great amounts of effort and perhaps years of practice to perfect.

The ease with which skills are performed and acquired generally corresponds to principles highlighted in studies of interlimb coordination, and especially bimanual coordination—that is, movements of homologous limbs (hand with hand or foot with foot) together in a motion that completes a task. While understanding limb coordination may initially seem straightforward, further inspection reveals the multifaceted nature of motor control. Take for instance, as Swinnen points out, the movement of one hand tapping on a surface at a constant rate, a fairly simple task (Swinnen, 2002). That task becomes far more difficult when the other hand is instructed to also tap on the surface, but at an increasingly fast rhythm. But there is more than just a temporal limit on movement; coordination constraints are also often spatial in nature. Swinnen notes the difficulty in trying to draw an ellipse with one hand, and a triangle with the other. Like the finger-tapping exercise, while each of these tasks separately can be performed with
ease, together as a single task, it requires much more practice. Thus, the inherent laws
governing single-limb movements do not have jurisdiction over interlimb coordination,
reflected in the need for practice (Swinnen, 2002; Kelso, Putnam, & Goodman, 1979).
That practice, which eventually makes the movement easier to perform, exemplifies the
neural plasticity capable of overcoming interference, or the inherent neurological
constraints that must be razed and resculpted before a foreign movement can become an
acquired skill. Musicians, for example, spend years overcoming coordination constraints
until patterns develop that allow seemingly-complex movements to be performed
effortlessly. The means by which the brain handles such constraints in the attempt to
complete a task is the focus of this paper. More specifically, the role of the anatomical
and functional components of interlimb coordination, and the means by which those
components process the information culminating in a movement, will be examined.

Few could dispute the importance of the corpus callosum in the evolution of
interlimb coordination. The corpus callosum serves as the great mediator along the divide
of the right and left cerebral hemispheres, transferring information from one side to the
other (Bloom & Hynd, 2005). But these hemispheres were not always so specialized; the
development of the corpus callosum has allowed the two hemispheres of the brain to
evolve from redundant perceptual systems to an integrated unit where cognitive and
perceptual systems cooperate harmoniously. In time, humans experienced a dramatic shift
in their cognitive abilities, due greatly to the corpus callosum; since perceptual abilities
could be maintained in one hemisphere, the brain’s abilities could expand cognitively
without a loss of function—a “no-cost extension” (Gazzaniga, 2000). From that point
onward, lateral specialization—or the division of work between the left and right
brains—could ensue, simply because the redundancy of the hemispheres was the only component being reduced. The left hemisphere developed more advanced cognitive abilities, while the right hemisphere secured its specialized role for perception. Natural selection favored such development clearly because two hemispheres working together via the corpus callosum only improved skill acquisition and mental capacity; the hemispheres could work together to create a better decision-making entity (Gazzaniga, 2000).

The underlying nature of limb interaction is still disputed, but the basic role of the hemispheres (and especially the corpus callosum) in that interaction is worthy of examination, as are the principles that seem to govern the resulting movement and skill. Although the corpus callosum clearly mediates communication between hemispheres, the nature of that interaction remains in question. Thus far, there are two main views of interhemispheric communication: excitation and inhibition (Daselaar & Cabeza, 2005).

It is important at this point to emphasize the difference between neural inhibition and excitation, as opposed to functional inhibition and excitation. On the neural level, excitation refers to a neurotransmitter’s effect on its receptor, causing the increased firing rate of one neuron, which in turn causes an increased firing rate in the neuron on which it synapses (Bloom & Hynd, 2005). Neural inhibition, conversely, corresponds to an increased firing rate in one neuron causing a decreased firing rate in the neuron on which it synapses. The corpus callosum contains both excitatory and inhibitory neurons (Lassonde, 1986), but because gamma aminobutyric acid (GABA), the most common neurotransmitter in the brain, is predominantly inhibitory, neural inhibition in the hemispheres is far more predominant (Smock, 1999; Matsumura, Sawaguchi, & Kubota,
1992). However, this inhibitory view is complicated by the fact that there are large
groups of excitatory fibers in the callosum (Yazgan et al., 1995). Still, this neural
configuration does not necessarily correspond to a neurotransmitter’s behavioral role
(Yazgan et al., 1995). On the functional level, however, one is referring to “whether
processing that involves specific regions of one hemisphere tends to activate [as with
excitation] or suppress [as with inhibition] processing in similar regions of the other
hemisphere” (Hellige, 1993) through callosal communication with the hemispheres
(Chiarello & Maxfield, 1996). Because the functional level is much harder to discern
from the neural level, there is naturally much more dispute concerning the inhibitory and
excitatory role of the callosum.

On one hand, several lines of evidence support hemispheric excitation as the
dominant form of communication across cerebral hemispheres. Largely, evidence for
excitation comes from split brain studies, neuroimaging studies, studies of motor-evoked
potentials (MEPs) in the nondominant hand, and cross-species callosal comparisons.

Callosotomy studies demonstrate the facilitatory nature of hemispheric interaction.
The effectiveness of callosotomies on halting the spread of epilepsy across the corpus
callosum, for example, suggests that the callosum must be pruned to prevent
information—or more specifically, seizures—from being readily transmitted between
hemispheres (Roberts, 1999). Moreover, split-brain patients often display functional
deficiencies, such as with naming tasks, which suggest an arrest of sharing in the brain,
rather than an initial suppression (Banich, 1995a). As a caveat, however, Bloom and
Hynd (2005) note that these studies are difficult to control, as callosotomies in these
studies were preceded always by severe intractable epilepsy and often by intense anti-
epileptic medication, which may confound the study (Bloom & Hynd, 2005); moreover, such studies have also produced results that suggest an improvement in motor performance in some bilateral tasks, rather than a deficit (Gazzaniga & Sperry, 1966; Wyke, 1971; Franz et al., 1996; Ohtsuki, 1994).

However, several other lines of evidence provide stronger support for facilitation. Reaction time studies in normal subjects, for example, have unveiled a tendency called redundancy gain, where two homologous limbs moving together have a faster reaction time than the sum of the reaction times of the individual limbs; since each hemisphere controls the contralateral limb, a faster reaction time employing both hemispheres would imply that information is shared along the corpus callosum (Miller & Nes, 2007; Miller, 2007).

A large source of support for excitation also comes from neuroimaging studies, showing that with increased task complexity, the neural activity of the brain becomes more symmetric and indicates that the callosum mediates neural recruitment when a task becomes too difficult to handle with only one hemisphere (Weissman & Banich, 2000; Banich, 1998).

Hand studies using motor-evoked potentials have also yielded results favoring excitation. When a subject’s dominant hand flexor digitorum indicis is flexed, Ziemann and Hallett (2001) noted that MEPs increase in the nondominant hand. This pattern shows increases in MEP amplitude when the complexity of the finger task increases. Logically, it seems as if representations of the dominant hand have “crossed over” to the nondominant hand, facilitating movement (Ziemann & Hallett, 2001).
Perhaps one of the most interesting sources of excitation support comes from studies of callosal size. Under the assumption that lateralized behavior requires a greater recruitment of inhibitory fibers to control the brain, resulting in a larger corpus callosum, one would expect dolphins, for example, which have unilateral sleep cycles and complex, lateralized behaviors, to have larger corpus callosi. However, as Rattenborg and colleagues note, dolphins have a smaller callosum than their brain volume and function would suggest (Rattenborg, Amlaner, & Lima, 2000). This trend is also held in primate magnetic resonance imaging (MRI) studies; Hopkins and Rilling studied forty-five primates and saw that increases in laterality were associated with smaller callosi (Hopkins & Rilling, 2000).

A number of experimental approaches, including cross-species comparisons and clinical studies, have further supported the theory of functional excitation. From this evidence, it seems logical to conclude that excitation is the means by which hemispheric communication occurs.

On the other hand, there is significant evidence supporting the theory of inhibition in hemispheric interactions. Much of the evidence comes from studies involving input manipulation, but other imaging studies and clinical cases have also garnered favor for inhibition.

One study examined subjects given lexical decision tasks, or tests where subjects classify stimuli into “words” and “nonword” categories; based on the fact that distinct stimuli presented to each hemisphere were subject only to intrahemispheric processing, they concluded that the brain is capable of suppressing communication between hemispheres when using each individually is more efficient for the task at hand (Banich
& Belder, 1990). Another study also investigated the role of changes in visual field stimuli; subjects processed upright and inverted letter stimuli faster when presented in each hemisphere, but not both, suggesting that the hemispheres are insulated from each other, and the advantage seen was the result of a reduction in interhemispheric interference (Hellige, 1993).

Dichotic listening studies also primarily evoke support for interhemispheric inhibition. In dichotic listening studies, two contradictory statements are simultaneously projected into the ears of a subject, one statement per ear. Each ear relays the information to both hemispheres, but the contralateral (opposite-side) connections are much stronger and faster than the ipsilateral (same-side) ones. In these studies, since the language center is in the left hemisphere and the contralateral connections to the right ear are stronger than the ipsilateral connections in the left ear, subjects demonstrate a right-ear advantage for language. This phenomenon can largely be explained by inhibition; it has been proposed that the corpus callosum serves an inhibitory function, so that the information sent to the left and right auditory centers of the brain can be processed separately, preventing confusing, contradictory information from being relayed across hemispheres, and subjects are thus able to complete the task (Bryden, 1988).

These results are also replicated in neuroimaging studies; when competing character stimuli are presented to visual hemifields, and subjects are asked to identify the stimuli, they are more successful with unilateral presentation (Fink et al., 2000). The pattern of results is most likely due to the activation of one hemisphere, as opposed to two.
The inhibitory effects of the corpus callosum are not limited to human subjects; they actually generalize across species. Callosotomized rats, for example, are more likely to commit muricide, or the predatory hunting of mice, in response to decreased functional inhibition once maintained by the callosum (Denenberg et al., 1986), which on average kept the average of muricidal laboratory rats at less than twelve percent (Karli, 1956).

Inhibition has also been investigated using transcranial magnetic stimulation (TMS). Several studies affirm that ipsilateral limb control is regulated by an inhibitory influence of the primary motor cortex (Brown et al., 1996; Ferbert et al., 1992; Meyer, Roricht, & Woiciechowsky, 1995), and others have even gone so far as to characterize the nature of the callosal fibers mediating the inhibitory pathway (Meyer, Roricht, & Woiciechowsky, 1998). One study examined the differences in inhibition in the proximal versus distal arm muscles using motor-evoked potentials, showing that levels of inhibition vary greatly and the degree of inhibition does not follow a linear proximal-to-distal slope (Harris-Love et al., 2007).

Mirror movements can also be explained by interhemispheric inhibition. Mirror movements are symmetrical motions that occur in children, fatigued adults, and people with pathological conditions where motor areas of the brain are bilaterally activated during unimanual tasks, resulting in one hand “mirroring” the one performing the task (Geffen, Jones, & Geffen, 1994). This movement is attributed to a decrease in inhibition, associated with an increase in the effort required to complete a unimanual task (Liepert et al., 2001; Muellbacher et al., 2000).

Perhaps the greatest evidence for inhibition results from pathological motor deficiencies. For example, schizophrenics have been noted to have excessive production
of subcortical dopamine, causing suppression of inhibitory projection in the cortex 
(Swerdlow & Koob, 1987), resulting in gait and motor abnormalities (Walker, 1994). Interestingly, the receptor for the predominantly inhibitory neurotransmitter GABA is expectedly low in schizophrenics (Benes, 2000). Motor deficits are also presented in cases of multiple sclerosis, where prolonged transcallosal conduction time is correlated with disease duration, possibly due to demyelination of callosal fibers (Schmierer, 2000). That demyelination in turn affects the speed of interhemispheric communication. Lack of communication, and specifically inhibition, characterizes the progression of motor disability prevalent in later stages of the disease (Ringo et al., 1994).

Support for functional inhibition clearly spans a great variety of studies. Given the evidence across disciplines, inhibitory callosal communication, like excitation, seems a reasonable paradigm for examining limb coordination.

While the competing theories of excitation and inhibition both have a plethora of supporting research, those examinations also suffer from a confounding error: the number of limbs when examining bimanual versus unimanual coordination. For example, Miller’s investigation of the redundancy gain phenomenon was a direct comparison of one effector versus two effectors (Miller, 2007), and this tendency permeates much of the literature (Kerr, Mingay, & Elithorn, 1963; Jeeves, 1969; Jeeves & Dixon, 1970; Di Stefano et al., 1980; Ohtsuki, 1981b). None of the reviewed literature held the number of effectors constant. This is surprising, given that, as stated previously, the laws of unimanual coordination do not govern those with bimanual constraints (Swinnen, 2002; Kelso, Putnam, & Goodman, 1979). As a result, the need for a reexamination of the
underlying principles of hemispheric interaction while holding constant the number of
effectors is indisputable.

Experiment 1

The role of the cerebral hemispheres in bimanual motor control, given the fact
that previous studies have not held the number of effectors constant and that bimanual
and unimanual coordination constraints are not analogous (Swinnen, 2002; Kelso,
Putnam, & Goodman, 1979), is an area in need of reexamination. In the present study,
reaction time (RT) and movement time (MT) were taken under ipsilateral and
contralateral conditions. The first experiment was designed to reevaluate hemispheric
interference while holding the number of effectors constant using a simple RT/MT time
task. The question of whether callosal inhibition or excitation mediates cerebral
interaction can be determined by the results of the mutually exclusive contrasting
predictions of the study. If excitation is the dominant viewpoint, then interhemispheric
communication should dominate, and contralateral RTs and MTs should be faster than
ipsilateral ones. On the other hand, if inhibition is the salient theory, then
intrahemispheric factors will play the dominant role in movement, and consequently,
ipsilateral movement will predominate with a faster RT and MT.

Methods

Participants

Participants (n = 19) between the ages of eighteen and twenty-two (mean age =
19.3) were recruited from the College of William and Mary. Due to research suggesting
semi-professional dancers and musicians have reduced hemispheric inhibition and the
increased ability to coordinate limbs simultaneously and disconnectedly as a result of
routine practice, students with extensive practice in interlimb coordination activities, such as playing an instrument, were excluded from the study (Ridding, Brouwer, & Nordstrom, 2000). Subjects signed a waiver in accordance with the standards of the Human Subjects Committee prior to participation in the study, and were naïve to the purpose of the tasks performed. After testing, subjects were debriefed as to the nature of the study.

**Apparatus and Task**

Please refer to Figure 1 for a conceptual illustration of the apparatus. Subjects were seated in an apparatus measuring 152.4 cm tall, 99.06 cm wide, and 91.44 in deep, onto which a dual screen monitor was attached to present the stimuli and view stimulus onset for analysis. The stimuli were presented at eye level at a distance of approximately 63.5 cm away from the subject. The distance between the higher and lower task bars was 12.7 cm, with a center bead bisecting that distance, onto the outside of which subjects would align their limbs at the start of each trial. Minor modifications were made in distance from the apparatus and chair height to accommodate full finger flexion and extension, as well as full foot dorsiflexion and plantarflexion for each individual subject.

Data collection was executed using a Fastec Imaging camera at a rate of 250 frames per second with a shutter speed of 4 ms. The camera was approximately 203.2 cm away from the apparatus and elevated 86.36 cm off of the ground with a tripod. Ample lighting was provided to enhance the quality of the video feed and visibility of the subject. In addition, subjects were also asked to place reflective tape over their second distal phalanges of the hands (index fingers) and distal phalanges of the halluci (big toes) to aid in visualizing the effectors during analysis. Index fingers were taped as opposed to the pollici (thumbs) because the while the former is more analogous to the halluci, the latter
exert perceptual dominance in daily activities. All data was collected using SuperLab 4.0 for stimulus presentation and Fastec Inline Monitoring Systems (FIMS) 3.0 for video feed download. Data was analyzed using Xcitex MiDAS 2.0 Imaging Software, Microsoft Excel, and SPSS.

**Procedures**

Subjects were given a brief description of the experiment, excluding any information that would bias their performance. This was followed by a simulation of the desired motions for the task, as well as how the apparatus worked and how the stimuli were to be presented. Subjects were instructed to focus on the center of the crosshairs on the screen that separated the display into four equally-sized quadrants. Arrows in each quadrant corresponded to the limb movement required to complete the task. (For example, an arrow in the top right quadrant indicated a right hand movement, while an arrow in the bottom left quadrant indicated a left foot movement). Please refer to Figure 2 for a list of specific conditions. The conditions were presented in a random order. A round of practice was provided to accommodate subject acclimation to the apparatus and task. This bout was not recorded on video, but the three to six following bouts were recorded as data. Limb instructions consisted of equal numbers of ipsilateral tasks (right hand, right foot (RHRF); left hand, left foot (LHLF)) and contralateral tasks (right hand, left foot (RHLF); left hand, right foot (LHRF)). The limb instructions were first presented with the crosshairs, and were removed after 5000 ms, with the crosshairs remaining. After a randomized variable foreperiod of 1200, 1600, or 2000 ms, a stimulus appeared at the center of the crosshairs, at which point the subject would initiate a task response. Subjects for the first experiment were asked to complete a simple task. For the simple task,
subjects were instructed to demonstrate flexion of the index finger and large toe of the appropriate limb in an ipsilateral or contralateral fashion as fast as possible until the effector made contact with the respective lower task bar (see Figure 3).

RT and MT were recorded for each trial at a time just prior to stimulus onset, and ended upon completion of the task, approximately 2000 ms later. RT refers to time between stimulus onset and movement initiation. Stimulus onset was indicated on the monitor display. Movement initiation was determined by when movement of the taped finger or toe began. This definition was problematic, as intention of movement could clearly be seen with movement of the subjects’ wrists or other associated appendage, but for analysis purposes, movement initiation was limited to the taped part of the limb.

MT is defined as the time between movement initiation and movement completion. Movement initiation is defined the same as above, and movement completion was determined to be when the taped appendage touched the bottom bar.

A folder was created for each participant in order to store the downloaded feed for each trial on a 500 gigabyte portable hard drive. Six hard drives were used to store collected data. Once the video feed was collected with the FIMS 3.0 program, the data were analyzed in Xcitex MiDAS 2.0 data acquisition software. Using a frame-by-frame scroll through the feed with a time display, the stimulus onset, hand and foot movement onset, and touching of the bars could be determined. These data points were then entered in a spreadsheet for Microsoft Excel, from which the reaction time and movement time of each limb per trial could be calculated. The data from each of the individual limbs for the given tasks were then collapsed to reflect ipsilateral and contralateral tasks. (For example, right hand, right foot (RHRF) and left hand, left foot (LHLF) movement and reaction...
times were collapsed into the ipsilateral category). Data for the Excel spreadsheet were then entered into the Statistical Package for the Social Sciences (SPSS), a statistics software program. Descriptive statistics and tests of within-subject and between-subject analysis of variance (ANOVA) were performed for each dependent variable in a one-way ANOVA across laterality and a two-way ANOVA (2x2) response (simple versus complex) by laterality (ipsilateral versus contralateral).

**Results**

A one-way analysis of variance (ANOVA) with repeated measures was used to analyze the data for each dependent variable (RT and MT in ms) across Laterality (contralateral and ipsilateral). The significance level for each ANOVA was $p \leq 0.05$. The one-way ANOVA for RT across Laterality was significant, $F(1, 406) = 12.53, p < 0.05$, indicating that contralateral RT ($M = 252.48$ ms) was slower than ipsilateral RT ($M = 229.51$ ms) (see Figure 4). The one-way ANOVA for MT across Laterality was also significant, $F(1, 412) = 10.15, p < 0.05$, indicating that contralateral MT ($M = 112.60$ ms) was slower than ipsilateral MT ($M = 93.40$ ms) (see Figure 5). Hence, these analyses demonstrated that it takes less time to initiate and control ipsilateral responses compared to contralateral responses.

**Discussion**

The purpose of this study was to measure the RT and MT of ipsilateral and contralateral conditions, which indicates the degree of intra- versus interhemispheric inhibition in motor control. This was tested with a simple RT/MT task eliciting ipsilateral and contralateral limb responses while holding the stimuli and number of effectors constant, since for any task, two limbs were always being used. The pattern of results
indicates that ipsilateral movements were faster in both RT and MT, which supports the inhibition account of hemispheric communication for simple tasks.

Experiment 2

The purpose of experiment 2 was two-fold: to replicate the findings of the first experiment, and then to extend those findings to a complex response. It has been well-documented that reaction time is affected by task complexity (Henry & Rogers, 1960; Schmidt & Lee, 2005). After replicating the first experiment, we then wanted to see if the pattern of results found in experiment 1 would generalize to a complex task. As with experiment 1, if excitation is the dominant theory, then interhemispheric communication should dominate, and contralateral RTs and MTs should be faster than ipsilateral ones. On the other hand, if inhibition governs the response, then intrahemispheric factors will play the main role in movement, and consequently, ipsilateral movement will predominate with a faster RT and MT. A review of literature did not indicate any interaction-based predictions.

Methods

Participants

For the second experiment, participants (n = 10) between the ages of eighteen and twenty-two (mean age = 19.4) were recruited from the College of William and Mary. The exemption guidelines were the same for both experiment 1 and experiment 2.

Apparatus and Task

No changes were made to the apparatus for experiment 2.
Procedures

The procedures for the second experiment were identical to the first experiment, except that for experiment 2, subjects completed both a simple and complex task. The complex task stimuli were identical in presentation to those of the simple task, but subjects were instead instructed upon appearance of the stimuli to complete a flexion of limbs to the bottom bar, followed by an extension to the top bar, and then another flexion to the bottom bar with a single, rapid motion in a “down-up-down” fashion (see Figure 6). For complex tasks, movement initiation was defined the same way as in experiment 1, and movement completion was defined as when the effector touched the bottom bar for the second time. Trials where subjects touched the bottom bar for the second time but failed to reach the top bar were considered errors and excluded from analysis. For the complex task study, the simple task was replicated, with half of the trials beginning with the bouts for the simple task, and half beginning with the complex task.

Results

A 2 x 2 repeated measures ANOVA was used to analyze data for each dependent variable. The two factors were Response (simple and complex) and Laterality (contralateral and ipsilateral). The dependent variables were RT and MT. The significance level for both ANOVAs was p ≤ .05.

Reaction Time

The analysis for the two-way interaction of Response x Laterality, F(1,72)<1, failed significance. The main effect of Response was significant $F(1,72) = 42.43, p<.05$, indicating that simple responses ($M = 245.26$ ms) elicited faster RT than complex responses ($M = 301.49$ ms). Furthermore, the main effect of Laterality was significant,
F(1,72) = 7.45, \( p < .05 \). This analysis indicated that ipsilateral responses (\( M = 265.98 \) ms) produced faster RT than contralateral responses (\( M = 280.76 \) ms). Thus, these analyses demonstrated that it takes less time to initiate simple as compared to complex responses and it takes less time to initiate ipsilateral responses compared to contralateral responses (see Figure 7).

**Movement Time**

The analysis for the two-way interaction of Response x Laterality, \( F(1,72) = 1.67, p > .05 \), failed significance. The main effect of Response was significant \( F(1,72) = 1443.121, p < .05 \), indicating that simple responses (\( M = 90.71 \) ms) required less MT than complex responses (\( M = 554.25 \) ms). Furthermore, the main effect of Laterality was significant, \( F(1,72) = 4.53, p < .05 \). This analysis indicated that ipsilateral responses (\( M = 311.03 \) ms) required less MT than contralateral responses (\( M = 333.93 \) ms). Finally, these analyses demonstrated that it takes less time to control simple as compared to complex responses and it takes less time to control ipsilateral compared to contralateral responses (see Figure 8).

**Discussion**

Experiment 2 also examined intra- versus interhemispheric inhibition. Experiment 1 was replicated and then applied to a complex task to see if the effects would generalize. The results indicate that simple RTs and MTs are faster than complex RTs and MTs, and that ipsilaterial RTs/MTs, as in experiment 1, are faster than those of contralateral tasks. These findings are consistent with the interhemispheric inhibition theory for motor coordination.
General Discussion

Experiments 1 and 2 were designed to reevaluate the area of hemispheric interaction while holding constant the number of effectors in an ipsilateral-contralateral RT/MT task. Unlike past studies (Miller 2007; Grefkes et al., 2008; Kerr, Mingay, & Elithorn, 1963; Jeeves, 1969; Jeeves & Dixon, 1970; Di Stefano et al., 1980; Ohtsuki, 1981b), the present study ensured that all movements were made with the same number of effectors, ruling out the possibility of a confounding artifact interfering with the results. None of the reviewed literature included motor output studies accounting for the effector confound. Experiment 1 showed that ipsilateral movements, governed predominantly by the single contralateral hemisphere, were faster than contralateral movements, which needed to employ both hemispheres for execution of the task. These results, generalized to the complex tasks, seen in experiment 2. The findings for both experiments were consistent with interhemispheric inhibition, as opposed to excitation, as the dominant approach to callosal interaction with the homologous cerebral hemispheres in motor control.

The present research suggests that interhemispheric inhibition predominates over motor control; paradoxically though, these conclusions are not completely out of line with research favoring excitation. As previously stated, the brain is a cost-effective information processor, and would not expend valuable energy from both hemispheres on a simple task (Weissman & Banich, 2000). Certainly, interhemispheric communication is far more essential as task complexity increases (Kreuter et al., 1972), and while many studies cite increasing complexity to be in the realm of excitation (Hellige, 1993), one study suggests that even in complex tasks, functional inhibition is applicable (Meyer,
Roricht, & Woiciechowsky, 1998). It may even be that what is perceived as excitation may just be less relative inhibition governing a response (Ziemann & Hallett, 2001).

In light of the problems with the current paradigms examining coordination, more research is needed to determine how lateral specialization of the hemispheres and the integration during the execution of a task affects motor control. Clearly, the corpus callosum plays a large role. This has been evidenced by much of the defense for inhibition: lexical decision tasks, dichotic listening studies, neuroimaging, cross-species comparisons, TMS evaluation, mirror movements, and pathological conditions; as well as those for excitation: callosotomies, neuroimaging, MEP studies, and observations of callosal size across species. The volume of past evidence along the divide of excitation and inhibition suggests that this role of the corpus callosum, as well as the rules governing effector control, is multifaceted. Indeed, interlimb coordination in general is complex, and its area of study is in need of reevaluation. Only then will the nature of the system responsible for regulating the nearly-infinite variations of human movement be better-known.
References


Figure Captions

Figure 1: Illustration of Testing Apparatus.

Figure 2: Experimental Conditions.

Figure 3: Illustration of Simple Task Completion.

Figure 4: Illustration of Complex Task Completion.

Figure 5: Mean Reaction Time (ms) as a Function of Laterality. Error bars represent ±1 SEM.

Figure 6: Mean Movement Time (ms) as a Function of Laterality. Error bars represent ±1 SEM.

Figure 7: Mean Reaction Time (ms) as a Function of Laterality and Response Task. Error bars represent ±1 SEM.

Figure 8: Mean Movement Time (ms) as a Function of Laterality and Response Task. Error bars represent ±1 SEM.
Figure 1
**Laterality**

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Figure 3

Ipsilateral

Contralateral
Figure 4

The figure shows a comparison of reaction times (in ms) between ipsilateral and contralateral laterality. The contralateral condition has a significantly higher reaction time compared to the ipsilateral condition.
Figure 5

The graph shows the movement time (in ms) for ipsilateral and contralateral laterality.

- Ipsilateral: Movement Time (approximately 90 ms)
- Contralateral: Movement Time (approximately 110 ms)
Figure 6

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<th>Ipsilateral</th>
<th>Contralateral</th>
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[Diagram showing hemispheric interaction in simple and complex tasks]
Figure 7

![Graph showing reaction time (ms) for simple and complex tasks by laterality (ipsilateral and contralateral). The graph indicates higher reaction times for complex tasks compared to simple tasks, with a greater difference in reaction times for the contralateral condition.](image-url)
Figure 8

The figure shows a bar graph depicting the movement time (ms) for different laterality conditions (Ipsilateral and Contralateral) and response types (Simple and Complex). The bars indicate that complex tasks generally result in higher movement times compared to simple tasks, particularly for contralateral responses.