## Asymmetric interlimb coupling strength in rhythmic bimanual coordination

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# Summary

The majority of the manual tasks that we perform involve some degree of coordination between limb movements. In such instances of interlimb coordination the two limbs do not move independently, but interact. These interlimb interactions become readily apparent when simultaneously performing different (sub)tasks with each of the limbs, like patting the head with one hand and rubbing the tummy with the other. In the focal task of this thesis (i.e., rhythmic bimanual coordination with the two upper limbs moving at the same frequency) the interlimb interactions result in attraction to particular coordination patterns rendering them intrinsically stable. For this type of coordination, previous studies demonstrated that handedness and laterally focused attention (i.e., focusing on one limb at the expense of the other) induce asymmetries in the overall coordinative performance. These effects were accounted for by an asymmetric version of the well-known HKB-potential, which describes the stability properties of the phase difference between limbs (i.e., the relative phase dynamics) induced by the coupling between the limbs. Given these findings, handedness and laterally focused attention were proposed as potential sources of asymmetry in the interlimb interactions. The work reported in this thesis examines the relation between (the stability of) interlimb coordination and asymmetries in the strength of interlimb interactions.

The first experiment, presented in Chapter 2, examined the hypothesis that the effects of handedness on bimanual isofrequency coordination, in particular the phase advance of the dominant limb, result from an asymmetry in interlimb coupling strength with the nondominant limb being more strongly influenced by the dominant limb than vice versa. Phase adjustments in both limbs in response to mechanical perturbation of the bimanual coordination pattern and during frequency-induced phase transitions confirmed this hypothesis for both right- and left-handed participants. In the right-handers these adaptations were made predominantly by the nondominant limb in both situations, whereas this tendency did not reach significance in the left-handers, implying that the asymmetry in coupling strength was less pronounced in the latter group. In the right-handers, the degree of asymmetry also depended on movement frequency.

Chapter 3 reports an experiment in which right- and left-handers made voluntary switches from in-phase to antiphase coordination and vice versa, at four different frequencies. As in the study reported in Chapter 2, the results revealed that the intentional switches were primarily mediated by phase adaptations in the nondominant hand, indicating a handedness-related asymmetry in coupling strength. Again, the asymmetry was less pronounced in left-handers than in right-handers, albeit that in this study the asymmetry was significant for both groups of participants. Furthermore, the asymmetry was larger for switches from antiphase to in-phase coordination (i.e., in the same direction as spontaneous transitions) than for switches in the reverse direction, suggesting that (the expression of) the handedness-related asymmetry in coupling strength was weakened by intentional processes associated with the required voluntary switches.

In line with the suggestion of Peters (1989, 1994) that expressions of handedness in bimanual coordination reflect an inherent attentional bias, previous findings showed that attentional asymmetries affect bimanual coordination in a manner similar to handedness. Motivated by these studies, the experiment reported in Chapter 4 examined whether attentional asymmetries modulated the underlying asymmetry in coupling strength. Both left-handers and right-handers performed in-phase and antiphase coordination, while focusing attention on either limb. Using the same method as in Chapter 2 (i.e., mechanical perturbations), the degree to which the limbs were influenced by each other was determined. As in Chapter 2, the results revealed that the nondominant limb was more strongly affected by the dominant limb than vice versa. Moreover, consistent with Peters' proposition, the handedness-related asymmetry in coupling strength was reduced when attention was focused on the nondominant limb. In contrast to previous findings, however, the commonly observed phase lead of the dominant limb was decreased rather than increased when attention was focused on this limb. This unexpected result was explained in terms of the additional finding that attentional focus also induced a difference in amplitude between the limbs, which was argued to result in a difference in their respective preferred frequencies and, thus, in a phase advance of the limb moving with the smaller amplitude.

The validity of this explanation was examined in Chapter 5, which reports three experiments in which amplitude disparity and attentional focus were manipulated in a controlled fashion, both alone and in conjunction. Whereas variations in amplitude disparity had the expected effects, the results revealed no compelling evidence for the suggestion that the effects of attentional asymmetry on relative phase dynamics are mediated by an asymmetry in coupling strength. These findings indicate that attentional focus affects interlimb coordination through differences between the dynamics of the two components (here: via amplitude disparity), thereby militating against Peters' suggestion that the effects of directed attention on interlimb coordination are comparable to those of handedness.

The final chapter discusses the thesis' main findings and implications. Although both handedness and asymmetric attentional focus were associated with an asymmetry in interlimb coupling strength, these asymmetries appeared to have distinct effects on interlimb coordination. This implies that previous applications of the prevailing dynamical model – that was developed to account for the effects of handedness on the relative phase dynamics – in the context of attentional asymmetries, were based on invalid assumptions. Furthermore, it is underscored that, theoretically, asymmetries in the strength of the interlimb interactions as such may reside in the coupling processes themselves, but may also result from differences between the limbs' movements. All in all, the thesis demonstrated that besides analysis of the collective behavior (i.e., the relative phase dynamics), complementary levels of analysis are essential to fully capture the intricate relation between interlimb coupling and coordinative stability.