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On the Perceptual Control of Bimanual Performance

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ABSTRACT. The author compares some critical findings of F. Mechsner and his colleagues with related results from other laboratories to point out that when higher levels of representation are available, those levels might come to be the focus of attention and control motor actions by overriding constraints at lower levels of the system.

Key words: complex bimanual actions, conceptual, representation

F. Mechsner (2004) raises the interesting question of whether perceptual-cognitive control is all that matters for the organizational processes of movement. He suggests that motor commands are never addressed at any stage of the process but are automatically tuned according to perceptual and cognitive processes. In my view, Mechsner's thesis and the experiments conducted by him and his colleagues are elegant and thought provoking. I regard both the strengths and weaknesses of Mechsner's thesis as providing building blocks to promote and enhance further dialogue and experimentation, and it is in that spirit that the following comments are written.

I first focus on specific characteristics of the examined tasks that might help to reconcile apparent contradictions in the literature while also strengthening some primary claims of Mechsner (2004). In the first task of Mechsner, Kerzel, Knoblich, and Prinz (2001), participants were instructed to tap in symmetric or parallel fashion by producing adduction–abduction movements of the index fingers with increasing oscillation frequency to a metronome pace, for trials of 24-s duration. The palm-down versus palm-up manipulation of Mechsner and his colleagues provided the critical condition that dissociated perceptual symmetry from muscle symmetry. They interpreted the stability in the relative motion patterns of the fingers as support for the notion that perceptual rather than muscle symmetry constraints are the primary influence on movement. Riek, Carson, and Byblow (1992) conducted a very similar experiment, in which they used flexion–extension movements rather than adduction–abduction. Their findings led them to conclude that muscle symmetry (and not perceptual symmetry) provides the primary influence on performance. In my view, the apparent contradiction in findings has not been satisfactorily addressed. It seems that the adduction–abduction task of Mechsner et al. involves difficult and somewhat unnatural movements (try tapping your finger from side

to side), whereas flexion–extension tapping is quite natural. Could it be that unnatural or difficult movements are more likely to engage perceptual control?

Mechsner et al. (2001) also pointed out that producing nonharmonic movement frequencies of the two hands (i.e., 4:3) is usually impossible for healthy, unimpaired participants. Klapp and his colleagues made that point earlier on the basis of their interesting experiments with tapping tasks (Jagacinski, Marshburn, Klapp, & Jones, 1988; Klapp, et al., 1985; Klapp, Nelson, & Jagacinski, 1998). Klapp and colleagues demonstrated that severe forms of interference occur when participants use fingers of the two hands to attempt to tap in 3:2 rhythms. Similar interference occurs when participants tap one rhythm while monitoring the other (indicating that the interference must result from perception and not from motor movements). Klapp and colleagues then demonstrated that if participants repeated the mantra “not-dif-fi-cult” while tapping the syllables “not,” “dif,” and “cult” with the index finger of one hand and the syllables “not” and “fi” with the index finger of the other hand, then they were able to produce the 3:2 so-called impossible rhythm. That perceptual (or conceptual?) trick seems to have as a spatial analogue the flag-circling visual display used in Mechsner et al. (2001). In that task, participants were required to turn cranks with the purportedly impossible 4:3 frequency relation, yet the visible flags moved with a 1:1 frequency relation because of a gear system. Klapp and colleagues suggested that a perceptual gestalt might be used in shaping movement output and to create a unified perception, and similar views have been echoed by Mechsner (2004). I would add that when higher representations are available, those levels come to be the focus of attentional control (Franz, 2003; Franz, Zelaznik, Swinnen, & Walter, 2001). The availability of higher representations releases the attentional control on lower levels of the system so that they become (according to Mechsner) tuned to the perception.

In another experiment, Mechsner et al. (2001) instructed participants to tap by using two fingers of each hand in a task adapted from Kelso's (1995) earlier studies. Mechsner and colleagues cleverly constructed their experimental conditions so that perceptual symmetry would correspond to tapping movements of different fingers of the two hands, whereas perceptual parallelism would involve tapping with homologous fingers of the two hands. As in their two-finger tapping experiment, the findings revealed that perceptual symmetry, and not muscle symmetry, determined the stability of performance. Unlike their two-finger tapping task, that experiment involved finger flexion movements; so one cannot argue that the movement properties were unnatural. However, one could argue that keeping track of the four different fingers requires cognitive penetration, or the need to impose a perceptual symmetry pattern as a guide for movement.

Taking the multiple-finger-tapping example further, one might consider an interesting experiment performed earlier by MacKay and Soderberg (1971). They instructed participants

to produce four-key sequences with each hand by hitting keys in a sequence from left to right with fingers of the two hands concurrently. Note that with that arrangement, the small finger of one hand hits its respective key at the same time as the index finger of the other hand hits its key, and so on. The researchers manipulated attention to one hand or the other and found that intrusion errors often occurred in which homologous fingers of the two hands responded together even though that was inappropriate for the task. Those errors were increased when additional emphasis or stress was placed on particular fingers. It is therefore possible that with a low level of representation (attention to the hands), interference at that level is likely to occur. To further support that point, recall that Mechsner et al. (2001, p. 72, bottom) reported anecdotally that attention to the hands disrupted control of the flags in their bimanual circling task. Thus, although the results of Mechsner et al. and MacKay and Soderberg might at first glance appear contradictory, that picture changes somewhat if one considers the mediating role of attention and the notion that different levels of representation might coincide with different attentional foci (Franz, 2003, 2004).

For both the two-finger and four-finger tapping tasks, Mechsner et al. (2001) claimed that conditions with no vision resulted in the same effects as did conditions with vision. I would have liked to see those data (and also to know that condition order was properly controlled). A recent study that directly compared visual and nonvisual attention (proprioception) revealed differences in the phase relations of bimanual circling in those two conditions, indicating that visual and proprioceptive perception do not always produce identical results (Franz, 2004). Other findings have suggested that the subjective experience of movement can influence abstract forms of coupling between the limbs even when one limb is amputated, but visual imagery without subjective experience of movement might not produce the same effects (Franz & Ramachandran, 1998). Those findings may suggest a need to revisit issues related to visual versus nonvisual effects, although, in general, those studies provide strong support for Mechsner's primary thesis.

I now turn to the anecdote described in the opening paragraph of Mechsner (2004). He opened the cabinet and reached for a glass with his left hand. Another glass fell from the shelf, and his right hand caught it faithfully and with split-second timing and spatial accuracy. That example seems very different from the type of task used in Mechsner's experiments. In some cases, 15–20 min of practice was provided before the test, suggesting that perceptual-motor learning was involved. The anecdotal example seems much more similar to the type of task examined in an intriguing set of studies by Flanagan and Wing (1997). Those researchers demonstrated that very rapid adjustments occur in grip force with manipulated changes in load, and they concluded that those effects were likely to be mediated by an internal model. If that analogy is plausible, then it also seems possible that Mechsner's anecdote illustrates predictive properties of perception that rely on internal

models, whereas the experimental tasks of Mechsner et al. (2001) illustrate the way online visual guidance comes to dominate perceptual-motor learning. But, contrary to that argument, Mechsner et al. concluded that there is no need for the motor system to translate by using internal models. That conclusion leads one to ask the following questions: What are the mysterious processes that guide the hand to catch the falling glass? Do they rely on a body representation? If so, can they be considered as purely perceptual?

I am left pondering the example from Mechsner's (2004) opening paragraph. At first, it seems a puzzling question: Why did Franz Mechsner knock over the glass to begin with, if his actions are guided by perception? Surely he would have perceived that another glass is located nearby the one he was reaching for. Or did he fail to correctly grasp the glass he was reaching for, causing it to fall from the shelf? The former case would suggest a faulty perception that was saved by a finely calibrated motor system. The latter would suggest a faulty calibrated motor system of one hand that was compensated by a finely calibrated motor system of the other hand. Is a finely calibrated motor system the result of perception? In sum: Can we ever really know whether control is purely perceptual?

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Postintentional Neglect

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ABSTRACT. F. Mechsner (2004) seems to deny a functional importance of postintentional processes, except that their characteristics can be taken into account at the perceptual-cognitive level of control. In that perspective, processes that are critical for the understanding of motor control and its limitations are neglected. On the other hand, the functional importance of task conceptions or task sets, which can vary and affect performance even for tasks that appear identical to an observer, is emphasized.

Key words: arm-head coordination, intention, task set

Mechsner (2004) claims that the control of voluntary human movement is purely and directly perceptual-cognitive in nature and that there is no need for an additional process that organizes motor commands. The claim seems to deny any functional importance at least to some postintentional processes that serve to implement a particular movement intention. Postintentional processes serve not only to select a unique movement among the typically many movements that would satisfy the intention but also to generate the appropriate motor commands, provide the necessary postural adjustments, and tune relevant reflexes appropriately (cf. Spijkers