

Real-Life Motor Training Modifies Spatial Performance: The Advantage of Being Drummers

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We compared the performance of skilled drummers with that of nondrummers and nonmusicians in the Simon and spatial stimulus–response compatibility (SRC) tasks to investigate whether and to what extent spatial performance can be modified by motor behaviors acquired in real life. Drummers were chosen because, compared with other musicians and the general population, their efficient performance depends mainly on the processing of spatial information. Although the Simon effect was equivalent for the three groups, the spatial SRC effect was less pronounced in drummers. The advantage was present even when feet were used as responding effectors, suggesting a central locus of the effect. These results suggest that spatial stimulus–response translations are influenced by real-life motor training, with drummers’ training speeding up the intentional stimulus–response translations when stimulus and response locations are on opposite sides.

One of the most widely studied perception and action issue concerns how the locations of objects in space are coded and how actions are organized on the basis of these representations. Spatial performance is studied primarily by means of spatial correspondence effects, namely the spatial stimulus–response compat-

ibility (SRC) proper effect (for a review see Proctor & Vu, 2006) and the Simon effect (for a review see Lu & Proctor, 1995). The typical condition in which both spatial correspondence effects are evident is a choice reaction task in which the stimulus appears in a right or left location and the response is pro-

duced manually. In the spatial SRC proper task, the response is selected on the basis of stimulus location. In compatible mappings participants are instructed to respond with the key that is located on the same side of the stimulus, whereas in incompatible mappings the instructions are reversed. In the Simon task, the task-relevant stimulus feature is nonspatial (e.g., shape or color), and participants respond with assigned right and left key presses. Thus, there are trials in which stimulus and response locations correspond (i.e., corresponding S–R pairings) and trials in which they do not (i.e., noncorresponding S–R pairings).

In both tasks, performance is usually faster and more accurate when there is spatial correspondence between stimulus and response (i.e., when the mapping is compatible for the spatial SRC task and when stimulus and response locations correspond for the Simon task) than when there is not (i.e., when the mapping is incompatible for the spatial SRC task and when stimulus and response locations do not correspond for the Simon task). Thus, the spatial correspondence effect arises irrespective of whether stimulus location is relevant or irrelevant to select the correct response. Both the spatial SRC proper effect (Vu, Proctor, & Pick, 2000) and the Simon effect (Rubichi, Nicoletti, & Umiltà, 2005; Vu, Pellicano, & Proctor, 2005) are also evident when stimuli and responses are arranged along the vertical dimension and stimulus–response (S–R) sets vary along orthogonal dimensions (for a review see Cho & Proctor, 2003) and when both the horizontal and the vertical dimensions vary simultaneously (for a review see Rubichi, Vu, Nicoletti, & Proctor, 2006).

Spatial correspondence effects belong to the family of cognitive conflict tasks, and most accounts attribute them to response selection processes that activate spatial response codes (e.g., Umiltà & Nicoletti, 1990). In particular, these accounts assume that the response selection machinery selects responses by means of two processing routes (De Jong, Liang, & Lauber, 1994; Kornblum, Hasbroucq, & Osman, 1990). By the intentional route, based on short-term, task-defined S–R links, the relevant attribute of the stimulus is translated into a response. This translation is presumed to be faster when an identity rule (e.g., respond at the corresponding response location) rather than an opposite rule or a search from a list of arbitrary S–R translations can be used. By

means of the automatic route, based on long-term S–R links, either established through training or habit or genetically determined (Tagliabue, Zorzi, Umiltà, & Bassignani, 2000), stimulus position directly activates the spatially corresponding response, irrespective of task instructions. This activation is supposed to be beneficial when it is correct and harmful when it is incorrect.

Both spatial SRC proper and Simon effects depend on the automatic activation of stimulus ipsilateral responses that speeds up or slows down performance in compatible, corresponding and incompatible, noncorresponding trials, respectively. However, the two routes play a differential role in the two tasks. For instance, the Simon effect is supposed to result from the activation of the response ipsilateral to the stimulus by the automatic route. However, the size of the spatial SRC proper effect also depends on the rule implemented by the intentional route. Indeed, whereas the faster identity rule is adopted for compatible mappings (i.e., when to select the correct response it is sufficient to match the spatial value of the stimulus into the spatial value of the response), the slower opposite rule is adopted for incompatible mappings (when a left or right stimulus has to be translated into an opposite, right or left, response) (Kornblum et al., 1990).

It has been shown that although the magnitude of spatial correspondence effects decreases after extensive practice, they remain significant (e.g., Dutta & Proctor, 1992, for the spatial SRC effect; Proctor & Lu, 1999, for the Simon effect), suggesting that the way by which spatial information influences performance is a steady feature of human information processing, independently of whether S–R associations are hard-wired or learned. In spatial two-choice tasks, practice seems to produce a quantitative change in processing efficiency rather than a qualitative change. However, Proctor and Lu showed that when participants performed an SRC task using an incompatible spatial mapping for more than 900 trials and then transferred to a Simon task, the Simon effect reversed, with better performance when stimulus and response did not correspond than when they did. Similarly, Tagliabue et al. (2000) demonstrated that as few as 72 spatially incompatible trials were sufficient to eliminate the Simon effect when the Simon task was performed 5 min later (see Iani, Rubichi, Gherri, & Nicoletti, 2009, for

similar results) and to reverse it when the Simon task was performed after a week. To explain these results, it has been proposed that the spatially incompatible training leads to the acquisition of new incompatible S–R associations that counteract the effects of the automatic compatible associations. More recently, Vu (2007) suggested that with a modest spatially incompatible training, transfer effects are evident only when both stimulus and response vary along the horizontal dimension. Therefore, the new associations seem to be between specific stimulus location and response location codes. However, a more extensive training is supposed to lead to the acquisition of a more general “respond opposite procedure” being able to exert its influence irrespective of the dimension practiced during training.

The finding that short-term, task-defined associations continue to affect performance on a subsequent task even after many consecutive trials (Proctor & Lu, 1999) or after a 1-week delay (Tagliabue et al., 2000) suggests that they consolidate in long-term memory, thus modifying, for at least a week, the participant’s motor behavior. An open question is whether spatial correspondence effects can be modulated in a similar way by specific motor behaviors acquired and performed throughout life. The results of a recent study by Bialystok and DePape (2009) suggest the idea of a connection between musical experience and enhanced general cognitive performance. By comparing performance of bilinguals, monolinguals, and musical performers (vocalists and instrumentalists) on a modified version of the Simon task with arrow stimuli, they found faster overall performance for bilinguals and musicians than for monolinguals. In the present study we were interested in investigating whether a specific musical training may shape spatial performance to the point that the disadvantage for noncorresponding S–R pairings is overcome or reduced in subpopulations for which efficient motor performance is based mainly on spatial parameters. Such a finding would suggest that basic motor performance depends on or is modulated by specific life experience.

To this end, we assessed the performance of skilled drummers in two spatial tasks: the Simon and SRC tasks. Playing the drums requires both temporal processing and rhythmic precision. Nevertheless, this group was chosen because playing the drums is a

skilled motor activity in which efficient performance depends equally on spatial parameters. Practicing this musical instrument consists in performing with the upper limbs a series of reaching movements toward the components of the drum set (drums and hats), which are horizontally displaced in front of the player, to produce an effect (i.e., to produce a sound). To produce the intended effect, the player needs to select the target component, which is located on the left or right of the body midline, and the hand, which is available to reach the target (see Stins & Michaels, 1997). This implies that both ipsilateral and contralateral movements are executed. In the ipsilateral reaching movements, the starting position of the hand corresponds to the position of the target (e.g., the left hand moves from the left position to a target component located on the left side), whereas in contralateral reaching movements the starting position of the hand and the position of the target do not correspond (e.g., the right hand moves from the right position to a target component located on the left).

Chua, Carson, Goodman, and Elliott (1992) found that ipsilateral movements had shorter movement onset times than contralateral movements in pointing movements as well as in mirror movements. Furthermore, Stins and Michaels (1997) found that contralateral reaching movements toward a target took longer to initiate (response time [RT] measure) than ipsilateral reaching movements because noncorresponding hand-to-target relations needed to be processed. Similar results were obtained by Riggio, Gawryszewski, and Umiltà (1986), who used crossed and uncrossed hand-held sticks pressing left and right keys. In their study, RTs were shorter when the sticks were uncrossed (i.e., both the hand and the target button were in the same hemispace) than when they were crossed (e.g., the right hand in the right hemispace held a stick, which pressed the target button located in the left hemispace). In all these studies, the speed and accuracy of effector selection were affected by the corresponding and noncorresponding target location.

Drummers’ performance is characterized by the fact that the number of contralateral movements, in which the starting position of the hand is noncorresponding with the position of the target, is substantially comparable to the number of ipsilateral movements, in which the starting position of the hand

and the position of the target correspond. Therefore, it appears that playing the drums requires one to counteract the disadvantage normally observed in performing noncorresponding movements. Differently from upper limbs, lower limbs operate solely in the ipsilateral space.

Furthermore, within the execution of a certain rhythmic pattern, drummers actively control their motor behaviors, deciding whether a corresponding or a noncorresponding movement has to be performed at a certain point of performance. More precisely, drummers do not perform rapid reactions to a prespecified sequence of abrupt stimulus events, as in a typical experimental context. Rather, they respond to internally driven stimuli, which consist in responding to (to hit) that, and only that, stimulus (left or right drum) in that particular moment with the available hand. This situation is supposed to train the ability to control motor performance, probably more effectively than during experimental tasks in which the response depends on context-related and prespecified task instructions. Moreover, response (hand) selection in drummers is a speeded process that is crucial for a correct motor performance. For this reason, the protocols we used in the present study involved choice reaction time because it is considered the best measure of response selection processes in spatial tasks (Rubichi & Pellicano, 2004; Rubichi, Nicoletti, Umiltà, & Zorzi, 2000).

Based on the reasons outlined here, we hypothesized that playing the drums could influence performance in two different ways. First, as a consequence of the unusual increase in incompatible motor interactions with the drum set, a new automatism could be acquired so that stimuli automatically elicit spatially noncorresponding responses contrasting the “natural” corresponding ones. Second, playing the drums could increase the capability to voluntarily reduce the slowing down of performance caused by performing noncorresponding responses. More precisely, frequently switching from corresponding to noncorresponding voluntary movements could speed up the application of the opposite rule, that is, increase the speed of translation of the stimulus spatial dimension into its opposite spatial response. If the first hypothesis is true, the size of both SRC and Simon effects should be smaller in drummers than in the general population. Indeed, in both tasks

the automatic activation of noncorresponding S–R links would counteract the effects of the preexisting corresponding S–R links. Instead, if the second hypothesis is true, only the size of the SRC effect should differ, because in the Simon task the relevant stimulus feature is nonspatial.

To test these two hypotheses, the performance of skilled drummers in two spatial correspondence tasks was compared with that of two control groups: nondrummer musicians (guitar and bass players) and nonmusicians. Like drummers, guitarists and bassists were skilled musicians who underwent extensive musical and motor training, but like nonmusicians, they did not have the same motor training as drummers. Therefore, performance of drummers was expected to differ from that of both nondrummer musicians and nonmusicians, whereas the performance of the two control groups was expected to be equivalent. In Experiment 1, we compared the performance of these three groups of participants on the Simon task, whereas in Experiment 2 we compared their performance on the spatial SRC task. Because drummers often keep their hands crossed, placing the left and right hands in the contralateral side of space (a posture that is necessary to best perform certain basic rhythmic patterns), we included for both experiments a condition in which responses were executed with crossed hands. In Experiment 3, the spatial SRC task was administered to a group of drummers and a group of nonmusician, and responses were performed with the lower limbs to control for a possible upper limb advantage. Because the lower limbs act on the ipsilateral space, only the uncrossed feet condition was used.

EXPERIMENT 1

The performance of drummers on the Simon task was compared with that of guitar and bass players and of nonmusicians. Unlike drummers, while playing their instruments guitarists and bassists do not perform contralateral and ipsilateral reaching movements. Rather, their hands move solely in ipsilateral space.

The presence of two control groups was necessary to rule out a potential confound between the specific motor skills we hypothesized for drummers and a possible general motor skill shared by musicians. Thus, if the performance of the two control groups is equivalent and equally different from that of drummers, it is

plausible to conclude that the specific motor skills of drummers are responsible for the results. Specifically, if the magnitude of the Simon effect is less pronounced in drummers than in the other two groups, this might indicate that the longtime practice enhances the automatic activation of noncorresponding responses.

METHOD

Participants

Twenty-eight skilled drummers (26 men; age range 18–35 years; 11 years of experience; 11 hours/week of practice on average), 28 skilled guitarists and bassists¹ (20 guitarists and 8 bassists; 27 men; age range 18–31 years; 8 years of experience; 11 hours/week of practice on average), and 28 nonmusicians (16 men; age range 21–32 years) participated. The nonmusicians were university students with no musical experience by self-report. Groups were equated for age (mean age was 26, 23, and 26 years for drummers, nondrummer musicians, and nonmusicians, respectively) and scores on the Edinburgh Handedness Inventory (58/100, 65/100, and 57/100 for drummers, nondrummer musicians, and nonmusicians, respectively; Oldfield, 1971). Because there are indications of a relationship between handedness and asymmetries in the Simon effect (Rubichi & Nicoletti, 2006), only right-handed participants were included in the study. All participants were naive as to the purpose of the study and had normal or corrected-to-normal vision.

Apparatus and Stimuli

A PC with a 14-in. Video Graphics Array monitor equipped with MEL 2 software was used for stimulus generation and response collection. Participants sat in front of the computer screen at a distance of 40 cm. Stimuli were red and green squares ($1^\circ \times 1^\circ$) presented 10° to the left or right of a $0.7^\circ \times 0.7^\circ$ central cross. Responses were made by pressing the “z” and “.” keys of a computer keyboard with the index fingers.

Procedure

The fixation cross remained visible across the trials. Stimuli were presented in random order for 100 ms each. Half of the participants were instructed to press the “z” key in response to the red square and the “.” key in response to the green square, whereas the other half received the opposite instructions. The experimental session consisted of two blocks of 144 experimental trials each, preceded by a practice block

and separated by a rest break. Each practice block (maximum 24 trials) terminated when the participant had entered 10 correct responses in a row. In one experimental block the hands were uncrossed, whereas in the other one they were crossed. The order of the uncrossed- and crossed-hand conditions was counterbalanced across participants. The maximum time allowed for response was 1 s. A blank frame or an error message frame (along with a 200-ms 300-Hz tone) was displayed for 1 s after a correct or incorrect response, respectively. The intertrial interval was 1 s.

RESULTS AND DISCUSSION

For each participant, responses that were more than two standard deviations greater than the participant's overall mean RT were excluded from the analyses. Correct RTs and arcsine-transformed error rates were submitted to an analysis of variance (ANOVA) with group (drummers, nondrummer musicians, and nonmusicians) as a between-participant factor and hands (uncrossed vs. crossed) and correspondence (corresponding vs. noncorresponding S–R pairings) as within-participant factors. The respective data are displayed in Table 1. The Tukey post hoc test was used to assess the main effect of group, whereas independent and paired-sample *t* tests were performed for significant between- and within-participant interactions, respectively.

The RT analysis revealed main effects of hands, $F(1, 81) = 16.12$, $p < .001$, and correspondence, $F(1, 81) = 275.16$, $p < .001$. Responses were faster with uncrossed (442 ms) than with crossed hands (455 ms) and for corresponding (433 ms) than for noncorresponding trials (464 ms). The hands $\times$ correspondence interaction was significant, $F(1, 81) = 42.79$, $p < .001$. Paired sample *t* tests showed that crossed-hand responses were slower than uncrossed-hand responses in noncorresponding trials, $t(83) = 6.83$, $p < .001$ (453 vs. 476 ms for uncrossed- and crossed-hand conditions, respectively), but did not differ in corresponding trials, $t(83) < 1$ (431 vs. 434 ms for uncrossed- and crossed-hand conditions, respectively). As a result, the Simon effect was significantly larger in the crossed-hand condition (42 ms) than in the uncrossed-hand condition (22 ms). The Simon effect was equivalent for the three groups, as indicated by the lack of a significant group $\times$ correspondence interaction ($p = .19$).

TABLE 1. Mean response times (RTs, in ms), standard deviations, and errors (%) for the Simon task, Experiment 1

Group	Uncrossed hands						Crossed hands						Simon effect	
	Corresponding			Noncorresponding			Corresponding			Noncorresponding				
	RT	SD	Error	RT	SD	Error	RT	SD	Error	RT	SD	Error	RT	Error
Drummers	415	46	2.6	431	46	2.9	422	52	1.9	460	60	4.8	26	1.5
Nondrummer musicians	440	82	2.3	466	75	6.8	443	65	2.0	486	66	7.2	35	4.8
Nonmusicians	438	53	2.2	462	45	3.5	438	37	1.8	483	36	5.0	34	2.2

For errors, the analysis revealed a main effect of correspondence, $F(1, 81) = 51.43, p < .001$, with fewer errors for corresponding (2.1%) than for noncorresponding (5%) trials. The hands $\times$ correspondence interaction was significant, $F(1, 81) = 8.43, p < .01$. The percentage of errors was larger in the crossed-hand condition than in the uncrossed-hand condition when S–R pairings were noncorresponding, $t(83) = 2.55, p = .013$ (4.4% vs. 5.6% for uncrossed- and crossed-hand conditions, respectively), but not when S–R pairings were corresponding, $t(83) < 1$ (2.4% vs. 1.9% for uncrossed- and crossed-hand conditions, respectively). The group $\times$ correspondence interaction was also significant, $F(2, 81) = 6.49, p < .01$, with a larger Simon effect for nondrummer musicians than for drummers, $t(54) = 3.18, p < .01$, and for nonmusicians, $t(54) = 2.45, p < .02$.

The results of Experiment 1 clearly showed that the spatial performance of drummers did not differ from that of nondrummer musicians and nonmusicians. Therefore, it seems that regular practice in playing the drums does not influence the automatic translation of stimulus location into response location operated by the response selection machinery. This result was not modified by hand position, indicating that although it causes drummers to frequently cross their hands, longtime practice did not counteract the inherent propensity for the hands to operate in the corresponding space.

EXPERIMENT 2

This experiment was designed to assess whether drummers differ from skilled guitar and bass players and from nonmusicians on the spatial SRC task. Ac-

cording to the reasoning outlined earlier, if the magnitude of the spatial SRC effect is less pronounced in drummers than in the other two groups, this would suggest that drum training exerts its effects on the intentional incompatible translations.

METHOD

Participants

The participants from Experiment 1 took part in this experiment.

Apparatus, Stimuli, and Procedure

Apparatus, stimuli, and procedure were the same as in Experiment 1 except as follows. A light gray square was the only imperative stimulus presented on the left and right of the central cross. The experiment was divided into two sessions. In one session the hands were uncrossed, whereas in the other they were crossed. Each session was divided into two blocks of 72 trials each: In one block, participants had to respond with the left key (“z”) if the stimulus was presented on the left side and with the right key (“.”) if the stimulus was presented on the right side. That is, position was the relevant stimulus feature, and the instructions were to execute responses spatially compatible with the stimuli. In the other block the S–R mapping was reversed, so that participants were required to execute spatially incompatible responses. Hand position and S–R mapping were counterbalanced across participants.

RESULTS AND DISCUSSION

Data were treated as in Experiment 1 and submitted to an ANOVA with group (drummers, nondrummer musicians, and nonmusicians) as a between-partic-

ipant factor and hands (uncrossed vs. crossed) and compatibility (compatible vs. incompatible S-R pairings) as within-participant factors. The data are reported in Table 2.

The RT analysis revealed main effects of hands, $F(1, 81) = 136.79, p < .001$, and correspondence, $F(1, 81) = 287.71, p < .001$. Responses were faster with uncrossed (347 ms) than with crossed hands (373 ms) and in compatible (336 ms) than in incompatible trials (384 ms). The group $\times$ compatibility interaction was significant, $F(2, 81) = 4.86, p < .02$. Independent sample t tests indicated that drummers were faster than nondrummer musicians, $t(54) = 2.15, p < .04$, and nonmusicians, $t(54) = 2.92, p < .01$, when performing the incompatible trials, whereas performance was equivalent to that of nondrummer musicians and nonmusicians in the compatible trials, $t(54) < 2$. Furthermore, performance of nondrummer musicians and nonmusicians did not differ in incompatible and compatible mapping conditions, $t(54) < 1$. Therefore, the spatial SRC effect was smaller for drummers (35 ms) than for nondrummer musicians (54 ms) and nonmusicians (54 ms).

For errors, the main effect of group was significant, $F(2, 81) = 7.87, p < .01$. Tukey post hoc test showed that the percentage of errors was higher for the nondrummer musicians (3.3%) than for drummers (1.6%, $p < .01$) and nonmusicians (1.4%, $p < .01$). The effect of hands was significant, $F(1, 81) = 33.76, p < .001$, with fewer errors in the uncrossed-hand condition (1.3%) than in the crossed-hand condition (2.9%). The effect of compatibility was significant, $F(1, 81) = 52.40, p < .001$, with fewer errors for compatible (0.9%) than

for incompatible (3.3%) trials. The group $\times$ compatibility interaction was significant, $F(2, 81) = 3.96, p < .03$. Independent sample comparisons indicated that the SRC effect was larger for nondrummer musicians than for nonmusicians, $t(54) = 2.35, p = .023$. No difference was evident between nondrummer musicians and drummers, $t(54) < 2$.

These results showed that when stimulus location was relevant for response selection, the spatial performance of drummers differed from that of nondrummer musicians and nonmusicians. The spatial SRC effect was smaller in drummers than in both nondrummer musicians and nonmusicians because the execution of incompatible responses was faster. Therefore, it seems that regular practice in playing the drums improves response selection in spatial tasks when there is the voluntary translation of stimulus location into response location, to the point that in the incompatible mapping condition, the implementation of the opposite rule along the intentional route is faster in drummers than in nondrummer musicians and nonmusicians.

Similarly to Experiment 1, performance for the three groups did not differ as a function of hand position, thus strengthening the conclusion that the longtime practice did not counteract the inherent propensity for the hands to operate in the corresponding space.

EXPERIMENT 3

The speed-up of incompatible responses in the spatial SRC task observed for drummers could be related to central response selection efficiency. Alter-

TABLE 2. Mean response times (RTs, in ms), standard deviations, and errors (%) for the spatial stimulus–response compatibility (SRC) task, Experiment 2

Group	Uncrossed hands						Crossed hands						Spatial SRC effect	
	Compatible			Incompatible			Compatible			Incompatible			RT	Error
	RT	SD	Error	RT	SD	Error	RT	SD	Error	RT	SD	Error		
Drummers	320	37	0.3	348	36	1.5	338	36	1.0	380	42	3.7	35	2
Nondrummer musicians	322	52	0.4	381	56	4.2	352	61	2.6	401	58	6.1	54	3.6
Nonmusicians	331	40	0.2	382	44	1.5	356	38	1.0	411	51	2.8	54	1.6

natively, it could result from an upper limb advantage that might be evident after regular practice. Given that performance of nonmusicians and nondrummer musicians was equivalent in Experiment 2, in the present experiment we used nonmusicians as the only control group.

To assess whether the advantage observed in Experiment 2 was related to response selection efficiency, in the present experiment we asked drummers and nonmusicians to respond with their lower limbs in a spatial SRC task that was identical to that of Experiment 2. The activity of playing the drums requires the feet to press pedals in the ipsilateral hemispace only. If the advantage observed for drummers in incompatible mappings is effector dependent, it should disappear when participants respond with the lower limbs. On the contrary, if it depends on response selection efficiency, then it should be present even when feet are used as effectors.

METHOD

Participants

Twenty new skilled drummers (17 men; age range 19–44 years; 11 years of experience; 11 hours/week of practice on average) and 20 new nonmusicians (10 men; age range 19–43 years) participated. Participants were selected as before.

Apparatus, Stimuli, and Procedure

Apparatus, stimuli, and procedure were the same as those used for the spatial SRC task in Experiment 2, except that participants responded with their lower limbs, and feet were always uncrossed. Two foot pedals were positioned on the floor on the left and right side of the body midline, 40 cm away from each other, and participants pressed the left pedal with the left foot and the right pedal with the right foot.

RESULTS AND DISCUSSION

Data were filtered as in the previous experiments. Errors were less than 1% and were not analyzed. Correct RTs were entered into a repeated-measures ANOVA with group (drummers vs. nonmusicians) as a between-participant factor and compatibility (compatible vs. incompatible pairings) as a within-participant factor. The data are reported in Table 3.

The main effect of compatibility was significant,

TABLE 3. Mean response times (RTs, in ms) and standard deviations for the spatial stimulus–response compatibility (SRC) task, Experiment 3

Group	Compatible		Incompatible		SRC effect
	RT	SD	RT	SD	RT
Drummers	337	31	375	35	38
Nonmusicians	343	39	413	64	70

$F(1, 38) = 108.83, p < .001$, showing that responses were faster for compatible (340 ms) than incompatible (394 ms) mappings. Although drummers were faster (356 ms) than nonmusicians (378 ms), this difference did not reach significance, as indicated by the nonsignificant effect of group, $F(1, 38) = 2.87, p = .098$. The group $\times$ compatibility interaction was significant, $F(1, 38) = 9.78, p < .01$. Independent sample comparisons showed that drummers were faster than nonmusicians in incompatible trials, $t(38) = 2.34, p < .03$, whereas performance was equivalent in compatible trials, $t(38) < 1$. Therefore, the spatial SRC effect was smaller for drummers (38 ms) than for nonmusicians (70 ms).

Results clearly showed that the advantage of drummers found in Experiment 2 was present also when the lower limbs were used. This result ruled out the possibility that drummers' advantage could be ascribed to postselection execution efficiency of the upper limbs.

GENERAL DISCUSSION

Spatial correspondence effects consist mainly of a performance disadvantage for noncorresponding S–R pairings when stimulus position is either relevant (SRC effect) or irrelevant (Simon effect). Recent studies provided evidence that practicing with an incompatible spatial mapping (e.g., respond to the left stimulus with the right key and vice versa) before performing a Simon task can eliminate (Tagliabue et al., 2000) or even reverse the Simon effect (Proctor & Lu, 1999). In these studies, corresponding S–R associations were neither improved by compatible mapping training nor directly weakened by incompatible mapping training. Therefore, the tendency to

respond toward the source of stimulation, whether it is hardwired or learned, is substantially unaffected by further training. However, the incompatible mapping training led to the acquisition of new noncorresponding S–R associations that counteracted the effects of the original corresponding ones. Thus, the tendency to execute the response that does not correspond to the location of the stimulus can be acquired through experimental training.

An open question is whether spatial correspondence effects can be modulated in a similar way by specific motor behaviors acquired and performed outside the laboratory, throughout life. More precisely, we were interested in assessing whether the frequent use of noncorresponding actions could eliminate the disadvantage for noncorresponding responses generally observed in the general population. To address this question, we assessed spatial correspondence effects in a group of drummers compared with two control groups: guitarists and bassists (the nondrummer musicians group) and nonmusicians. Because for drummers efficient performance is based equally on spatial corresponding and noncorresponding actions, they perform noncorresponding responses more frequently than other musicians and nonmusicians.

Being a drummer could influence performance in spatial tasks in two different ways. First, as a consequence of the increase in incompatible motor interactions with the drum set, new S–R links would be acquired so that spatial stimuli automatically elicit spatially noncorresponding responses, which counteract the effects of the preexisting and “natural” S–R corresponding links. Second, because drummers implement the opposite rule more frequently than nondrummers, this training would speed up the implementation of the rule and eliminate or reduce the differences in performance between the identity and the opposite rules.

If the first hypothesis is true, both SRC and Simon effects should be smaller for drummers than for nondrummer musicians and nonmusicians. Indeed, in both tasks the automatic activation of noncorresponding S–R links would counteract the effects of the preexisting corresponding S–R links. Instead, if the second hypothesis is true, only the SRC effect should be smaller for drummers than for the control groups because the spatial SRC task alone implies a

controlled translation of the spatial value of the stimulus into its assigned spatial response.

We found evidence that the spatial SRC effect was smaller in drummers than in the two control groups, because of a performance advantage in the incompatible condition (Experiments 2 and 3), whereas the three groups did not differ in Simon task performance (Experiment 1). Thus, the tendency to respond toward the source of stimulation appeared to be unaffected by long-term real-life training. Indeed, even though the Simon effect tended to be smaller for drummers in both RTs and errors, this difference was far from significant. These results differ from what is found in the laboratory, probably because drummers’ training is not completely comparable to the pure spatially incompatible training administered in the laboratory. Indeed, whereas in this latter condition participants focus their practice on a single incompatible spatial mapping, in real life drummers experience both compatible and incompatible mappings. For this reason, it is plausible that incompatible S–R memory links are not created in drummers in the same way as would be expected if their training consisted of incompatible S–R mappings, exclusively. Thus, results are to be seen as the product of different proportions of incompatible and compatible mappings, which are more balanced in drummers than in the general population.

Results support the second hypothesis, suggesting that the positive influence of drummers’ motor training exerts its effects on the intentional incompatible S–R translations rather than affecting the automatic associations between stimulus and response locations. Longtime practice of drums appeared to speed up the intentional route when the opposite rule was called for by task instructions.

Although our results provide clear evidence of the effects of playing drums on performance in the SRC task, we cannot disregard the opposite possibility, that our participants became drummers in part because they had innate talent, that is, they were already able to make incompatible S–R translations faster than most other people. However, we believe that even though this possibility is theoretically plausible, it is less likely and that even if they had some initial predisposition, it would be difficult to claim that lifelong training had no effect. This conclusion is in line with studies on deliberate practice in the ac-

quisition of expert performance (Ericsson, Krampe, & Tesch-Römer, 1993; Ericsson & Williams, 2007), which claim that the differences between expert performers and normal adults critically reflect a lifelong period of deliberate effort to improve performance in a specific domain. Of course, only a within-participant, longitudinal study would allow a more powerful demonstration of the relationship between the effects of deliberate practice in drumming and performance on SRC tasks.

Our assumption that the advantage of being drummers is a response selection effect gathered empirical support in Experiment 3, where the drummers' advantage in incompatible S-R pairings was evident even with the lower limbs. This result rules out the possibility that the drummers' advantage was effector dependent, which would suggest a response execution locus of the drums' training effect. The finding that the drummers' advantage is effector independent is in line with the view that actions are coded in terms of their distal features rather than of their proximal ones (Hommel, Müsseler, Aschersleben, & Prinz, 2001) and suggests that actions are represented in terms of their goals, not in terms of specific muscle innervation patterns. Further support comes from the finding that the effect of drummers' training was evident in a discrete motor task that differs from the motor activity drummers perform in real-life settings.

The effects of real-life training found in the present study are in line with proposals that combine nativist and empiricist claims. According to these proposals, innate predispositions would be coded at the subcortical level, whereas at the cortical level representations would not be hardwired but rather would emerge through experience (Elman et al., 1997). The strong effects of real-life training that we found are consistent with the view that representations emerge through experience, from the interaction between organisms and the environment.

NOTES

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1. We originally tested 30 skilled guitarists and bassists. However, 2 guitarists were excluded from the analyses because they played the drums too and had more experience as drummers than as guitarists.

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