The role of coding scheme for memorization of movements' sequences: psychological and simulation results

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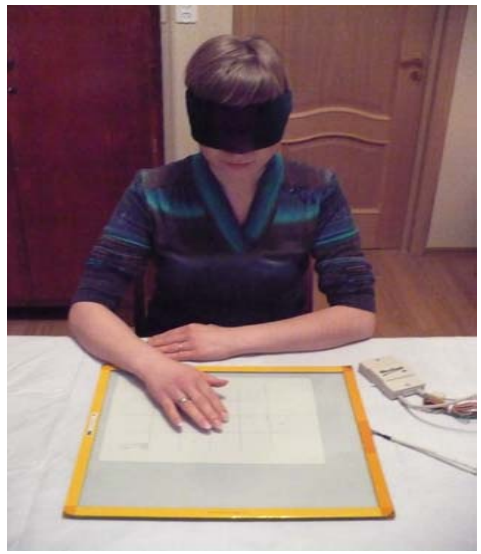
Introduction

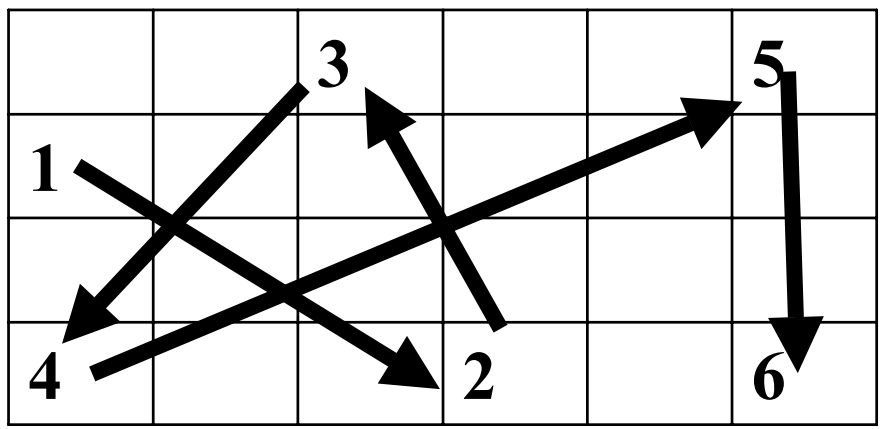
It is well known that the information in brain hemispheres is represented by different manner.

- Left hemisphere operates with the categorical information and right hemisphere operates with the precise coordinate information (Kosslyn et al., 1995).
- The control of sequence acquisition is realized by the structures of left hemisphere for the right hand, by both hemispheres for the left one (Grafton et al., 2002).
- *What happened if subject had to memorize and repeat multiple times the movement sequence by the right or the left hand?*
- *Can we simulate some features of human motor learning?*

Method: procedure

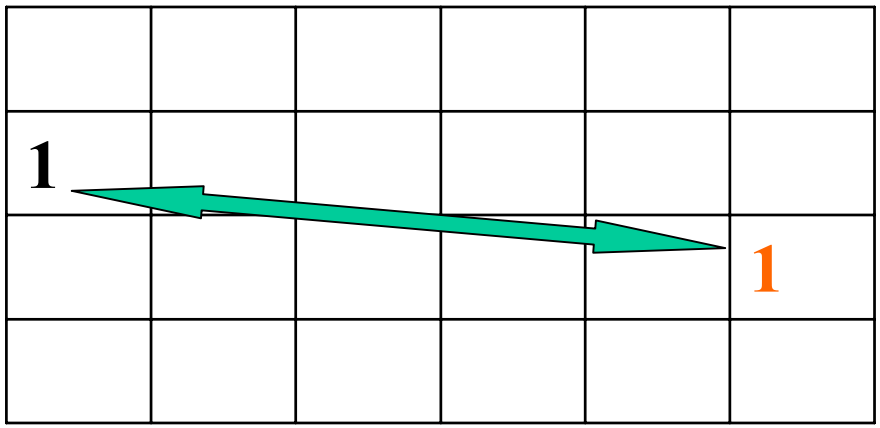
•The hand of the blindfolded volunteer was moved by experimenter from center through 6 different positions at a sheet of paper A4 located under touch screen.
•The volunteer had to remember and immediately after that to reproduce by hand the sequence of positions (three identical runs by one hand, three other identical runs by another hand).
•30 right-handed volunteers (divided onto 2 groups).
•2 groups: carried out the task by the right hand, and then by the left one (group *A*), and carried out the task by the left hand, and then by the right one (group *B*).



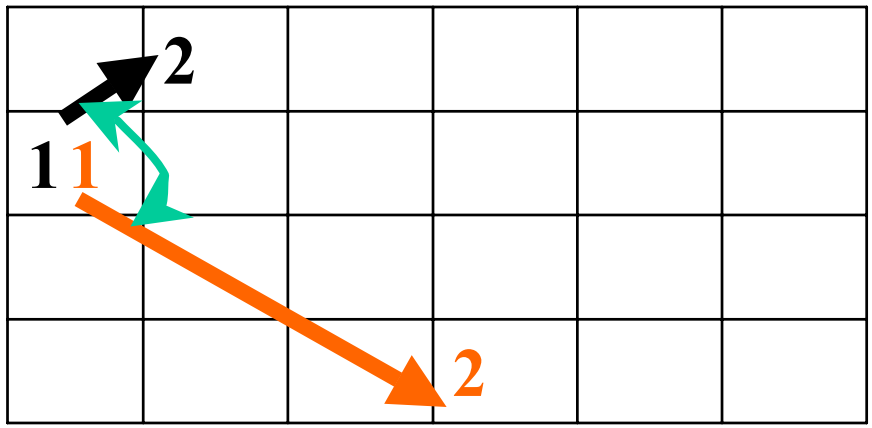


Method: data analysis

Positional errors



Movement errors



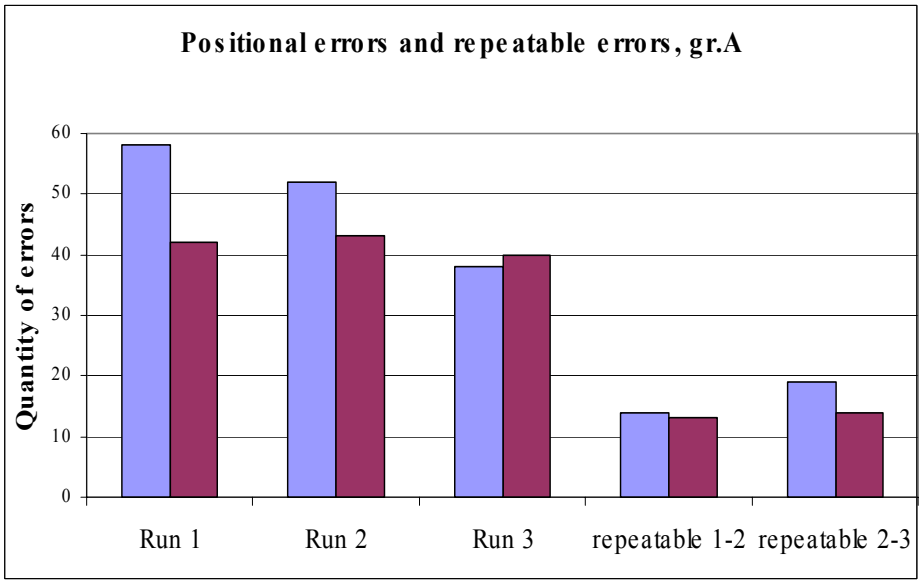
For two consecutive movements series we calculated:

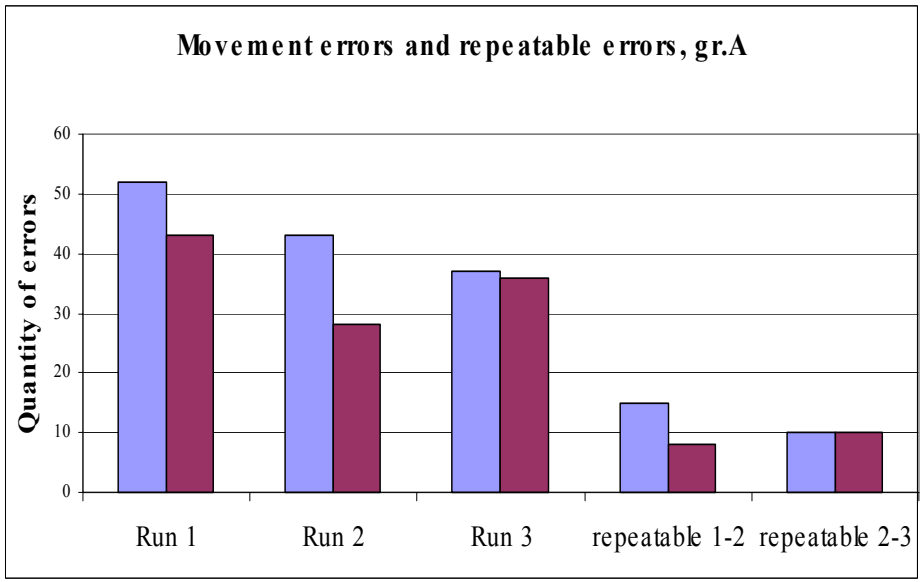
-the positional repeatable errors (the volunteer reproduced the same erroneous position twice),

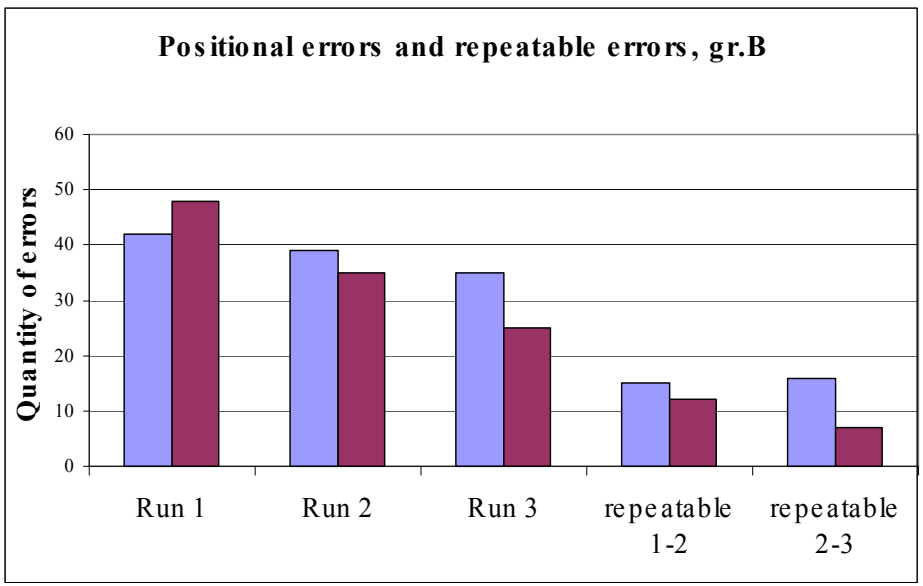
-the movement repeatable errors (the volunteer reproduced the same erroneous movement direction twice).

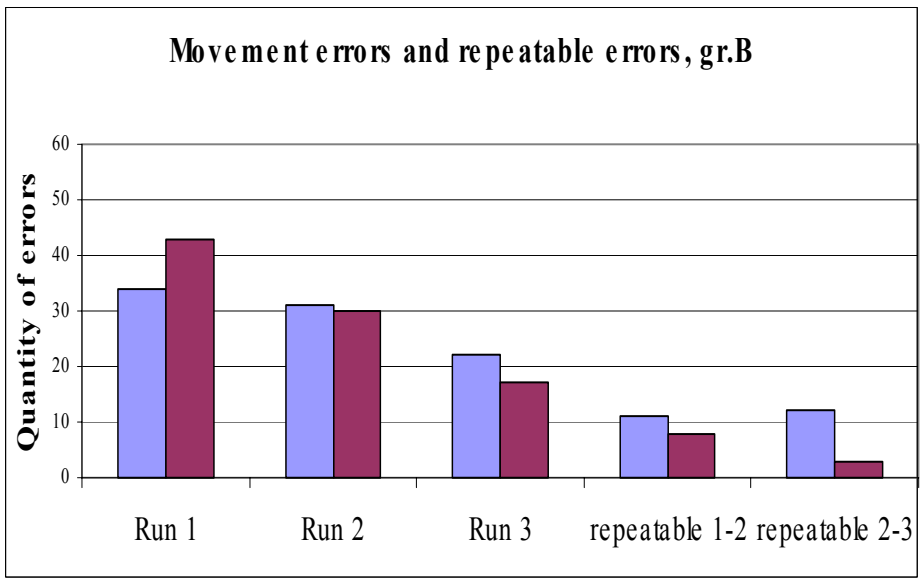
So we estimated repeatable errors in the first and second run (1-2) and in the second and third run (2-3); the ratio of repeatable errors to other errors (1-2)/1, (1-2)/2, (2-3)/2, (2-3)/3.

Results: human errors

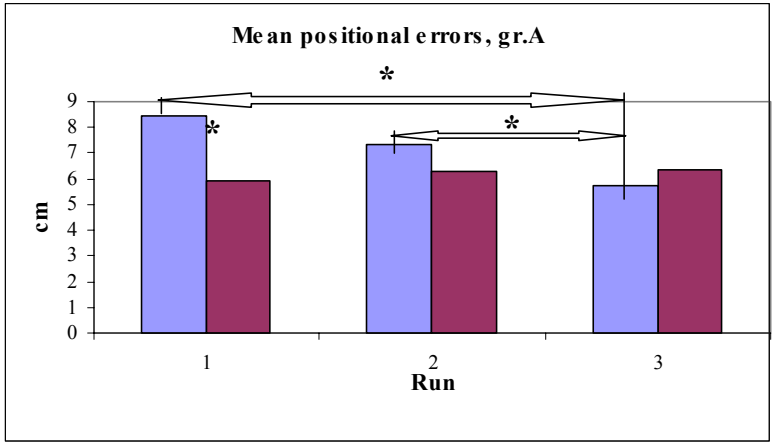


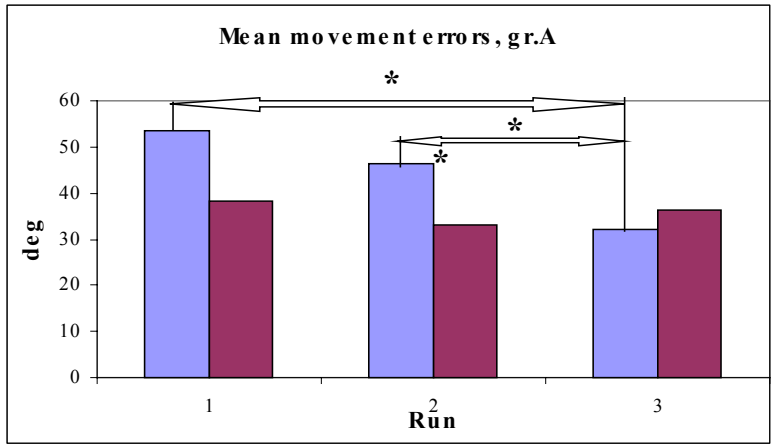


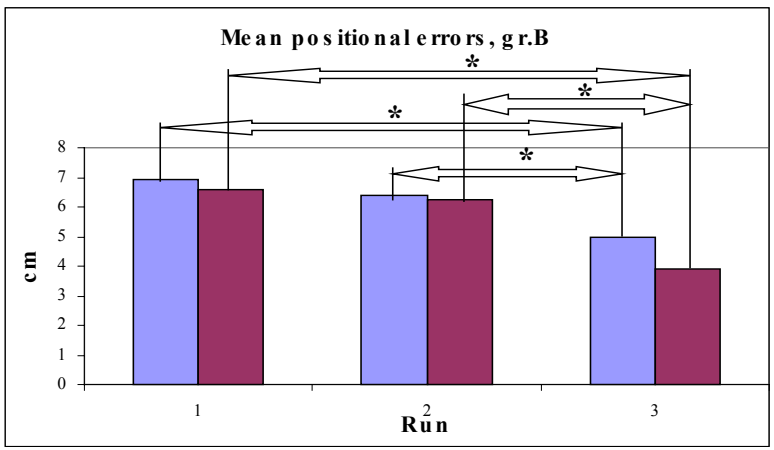


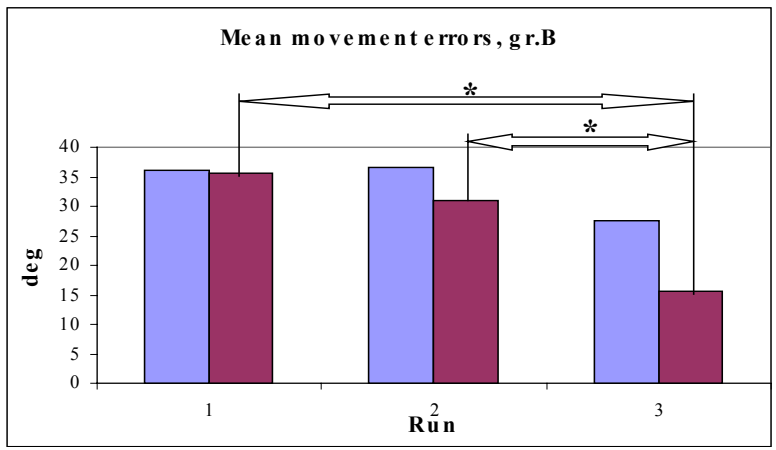


Blue bars – left hand's errors, red bars – right hand's errors









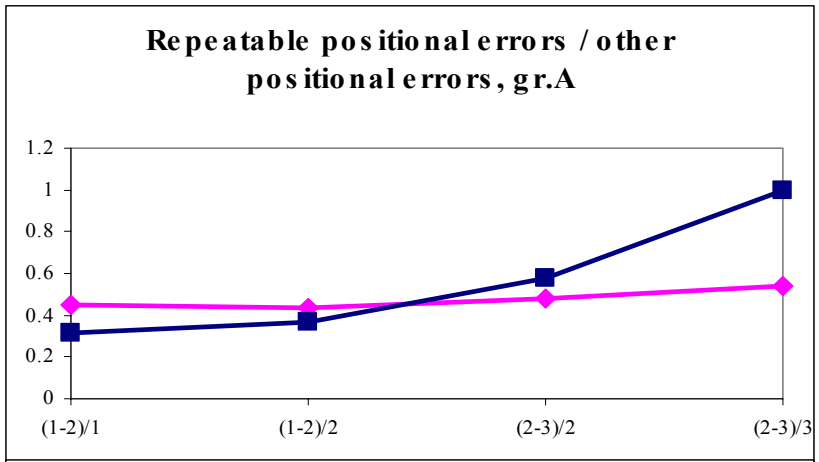
Blue bars – left hand's errors, red bars – right hand's errors

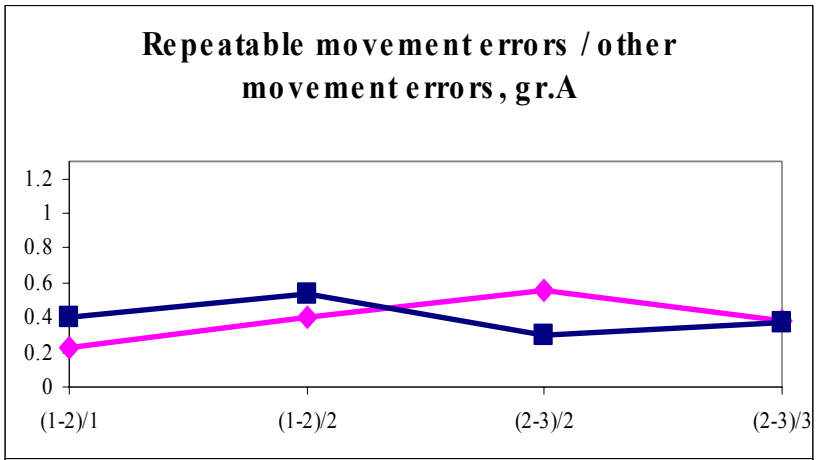
Repeatable errors exist!

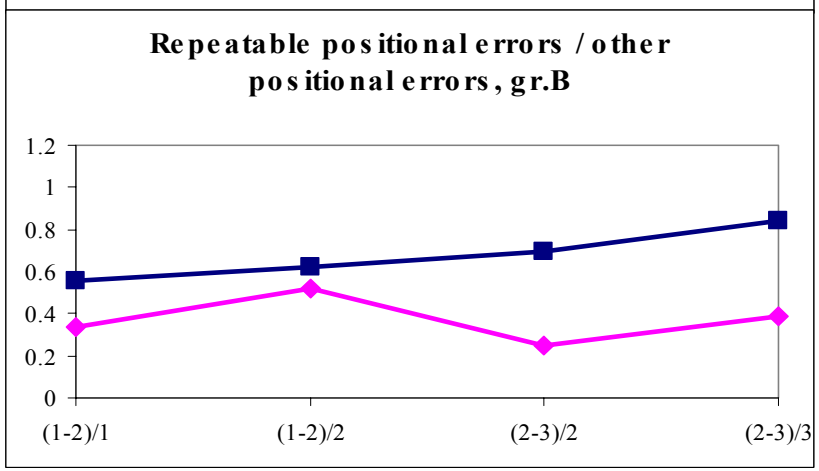
Gr.A – no learning for right hand, no skill transfer, moreover left hand works worst of all immediately after the right one.

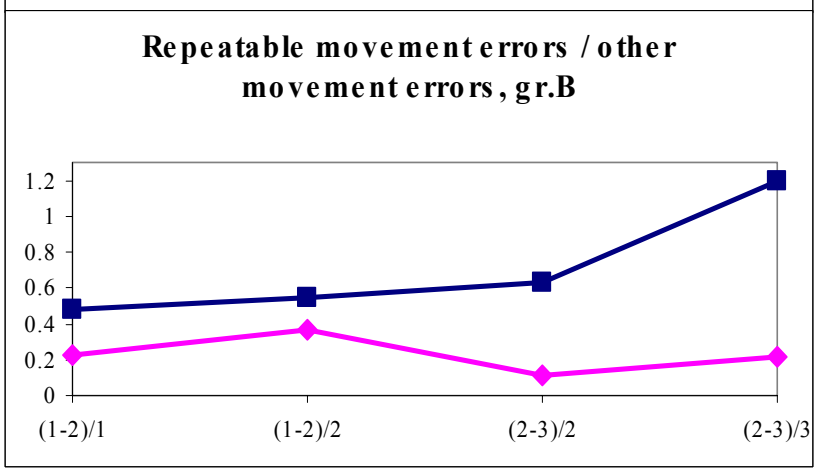
Gr.B – positional learning for left hand, skill transfer to right hand.

Human repeatable errors









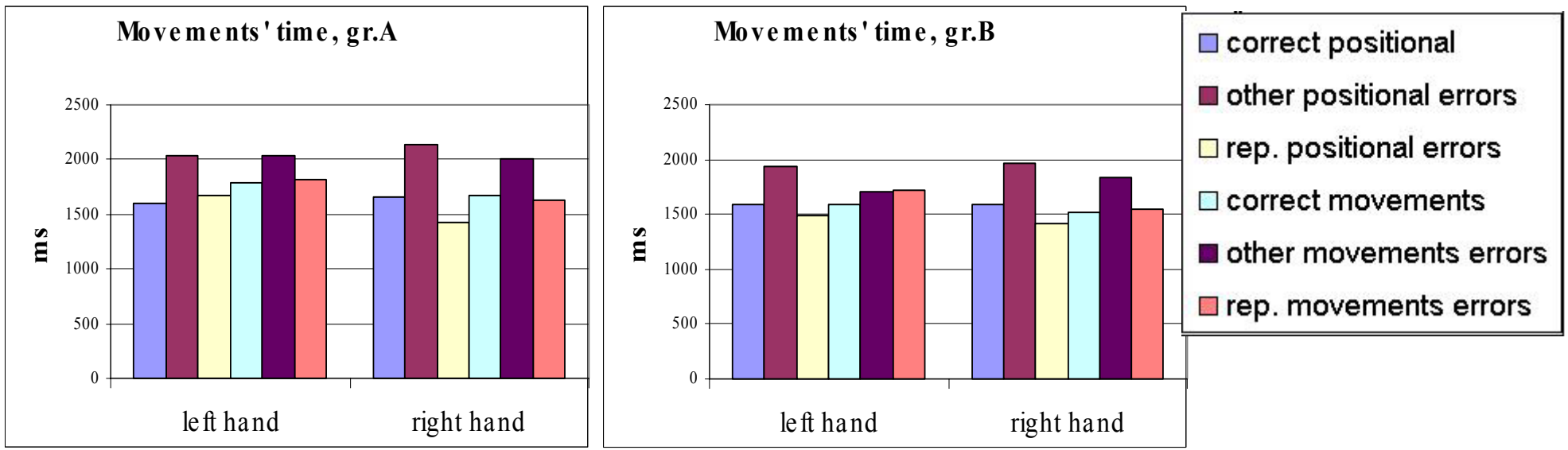
Blue lines – left hand's errors, red lines – right hand's errors

The repeatable / other errors ratio doesn't fall at learning. It remains constant or grows because subjects try to correct mainly their non-repeatable (other) errors.

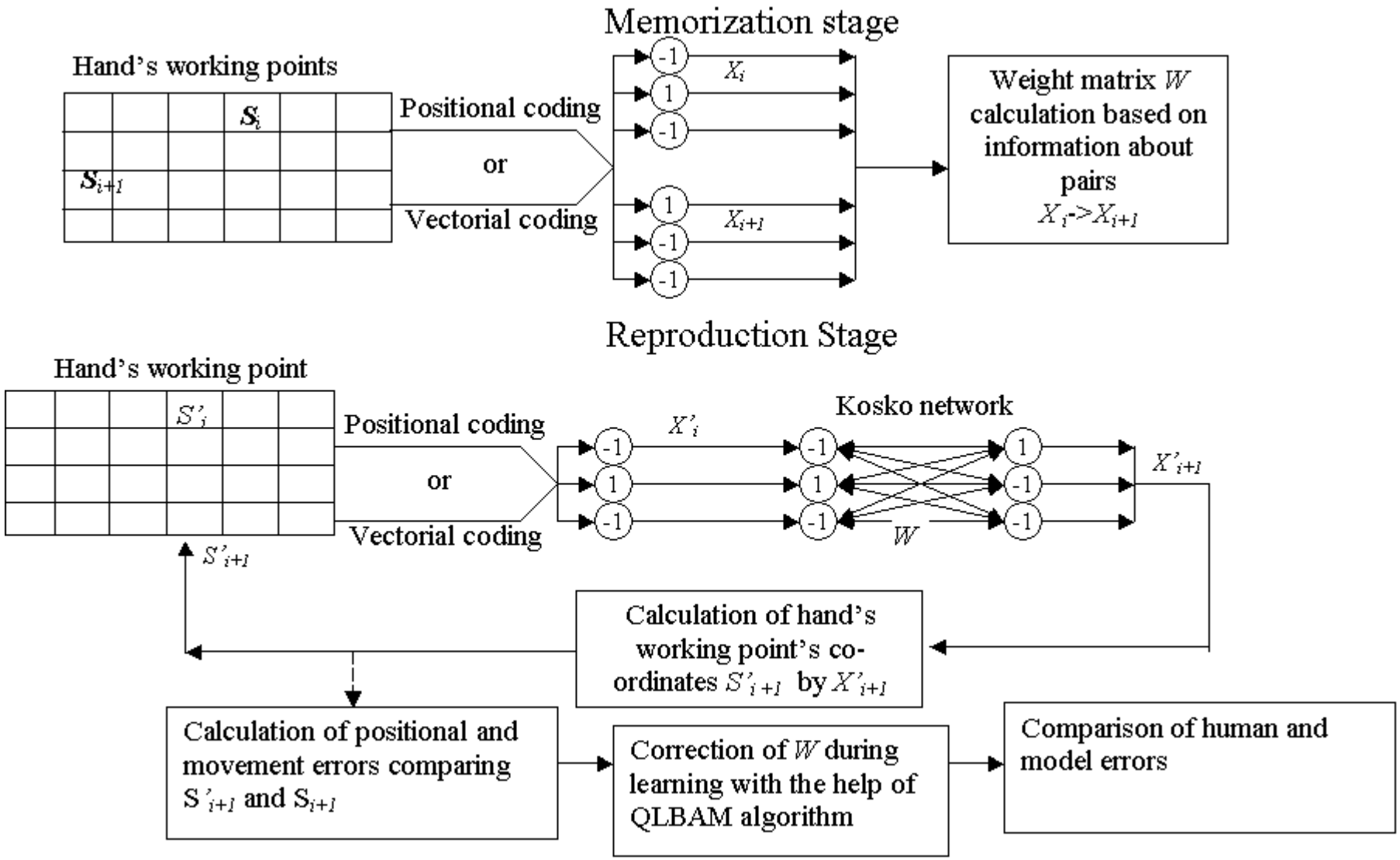
Time of correct and erroneous movements

Mean time of movements connected with repeatable errors is significantly lower than mean time of movements connected with other errors and doesn't differ from time of correct movements (except time of repeatable movement errors for left hand, gr.B).

We propose that at learning the volunteers are sure for correctness of movements connected with repeatable errors, so they can not distinguish them from correct movements and try to correct only their non-repeatable (other) errors.



Model scheme



The number of network's iterations

Error, bit	0	1	2	3	4	5	6	7	8
Posit. coding	1.35	1.6	1.62	1.69	1.75	1.74	1.69	1.72	1.8
Vector. coding	1.4	1.6	1.7	1.8	1.8	1.7	-	-	-

For both coding schemes the artificial neural network comes to steady state significantly faster for correct answers (0 error bits). That is, although the information about self-correctness is not accessible for model, the neural network can estimate self-correctness by the number of iteration.
The number of iteration is the network's analogue of human decision time.

We will correct weight matrix *W* with the help of QLBAM algorithm only for objects "slowly" (I.e. potentially erroneously) reproduced by neural network.
Will we see learning for both coding schemes? Will we see the model repeatable errors similar to human repeatable errors?

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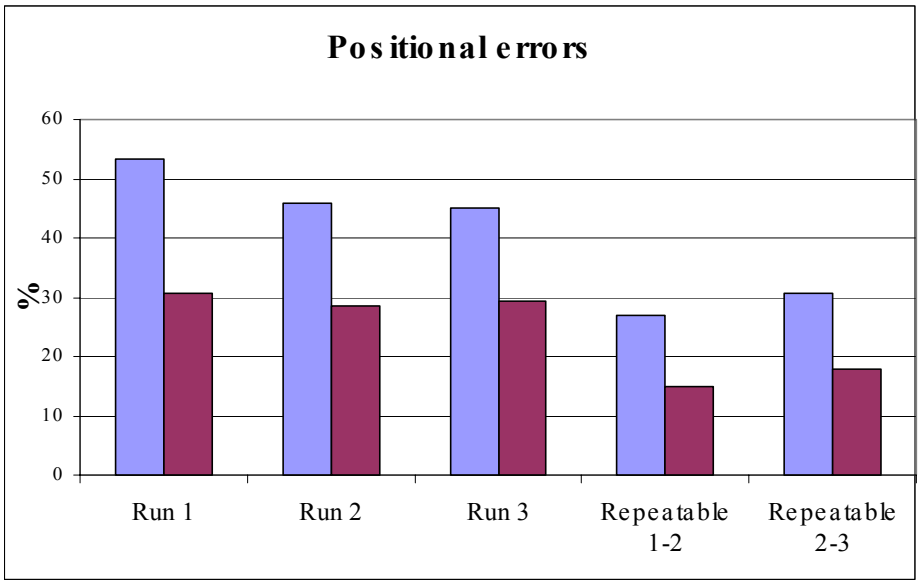
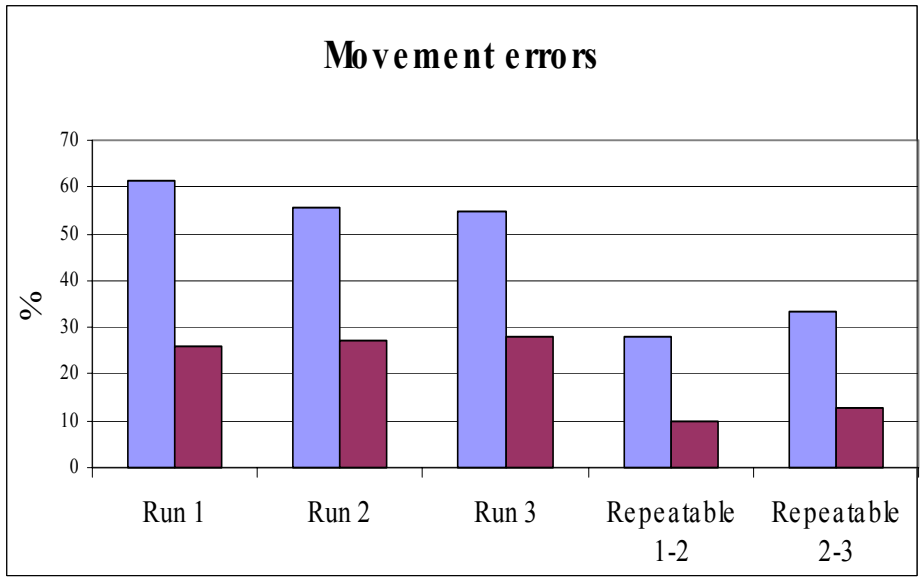
Results: the model errors



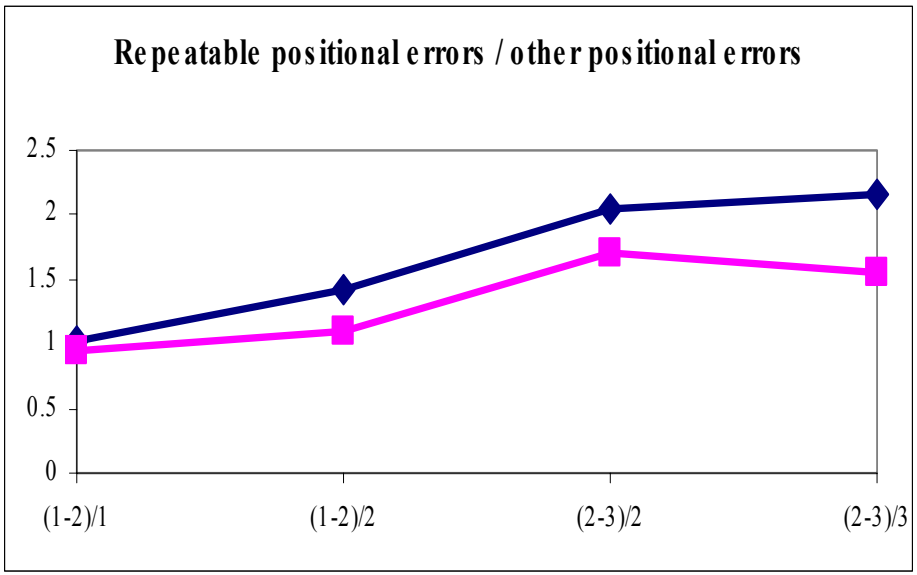


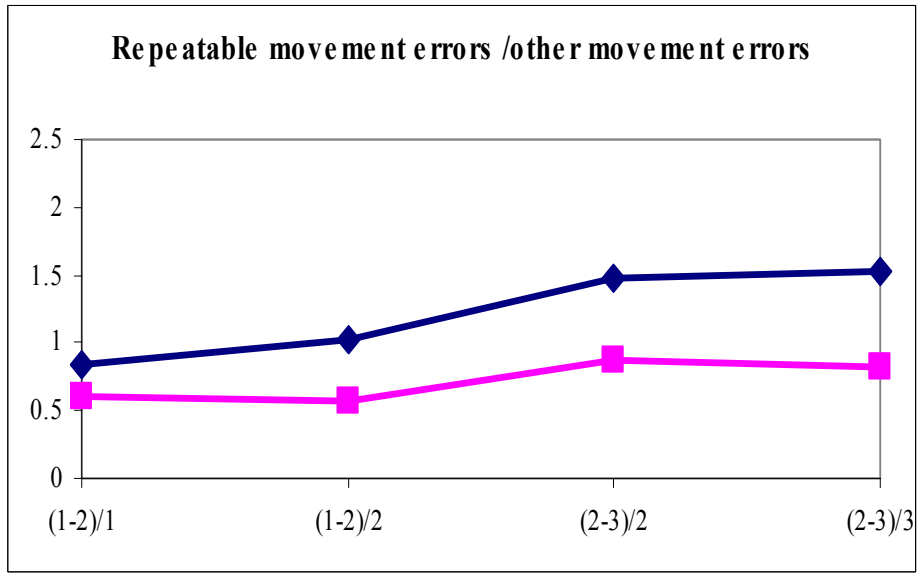
Blue bars – positional coding, red bars – vector coding

Repeatable errors exist!

The learning exists only for positional coding scheme.

Model repeatable errors

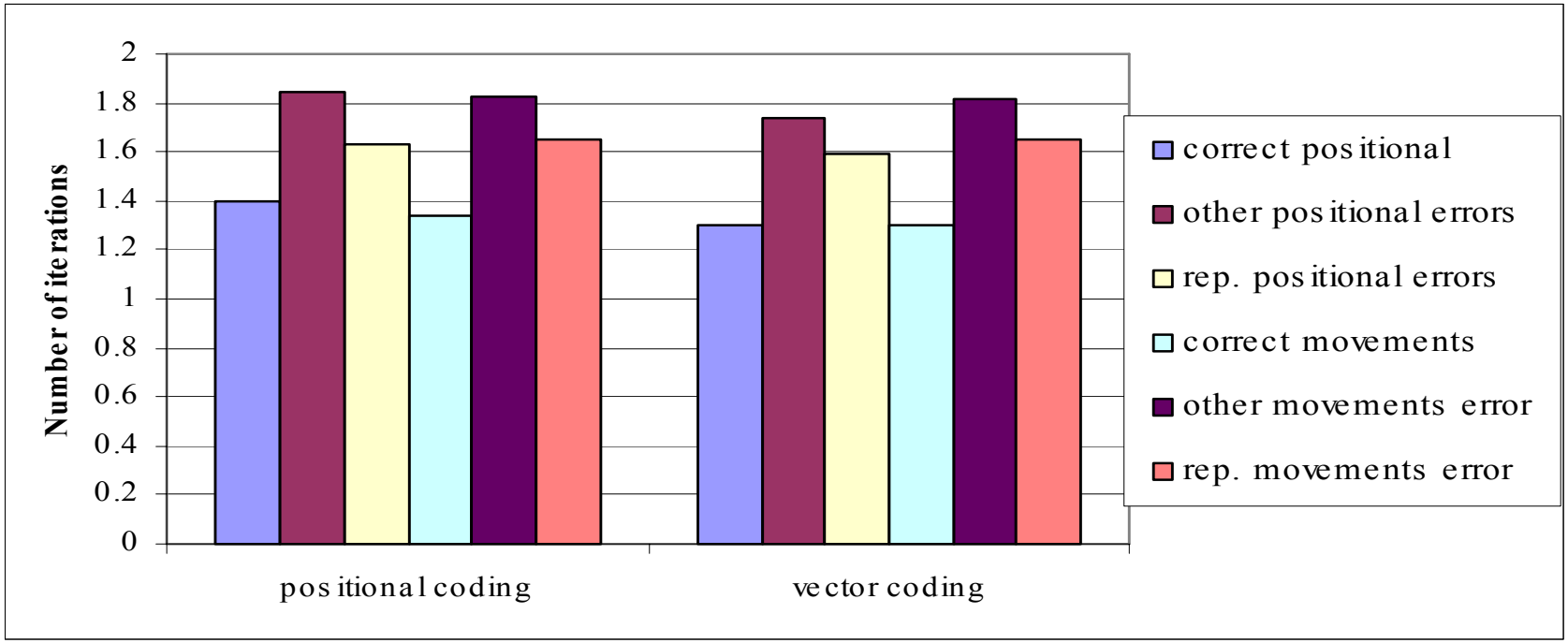




Blue lines – positional coding, red lines – vector coding

The repeatable / other errors ratio doesn't fall at learning. It remains constant or grows because the repeatable error states are stable attractors of the artificial neural network.

“Time” of correct and erroneous “movements”



Mean number of iterations connected with repeatable errors is lower than mean number of iterations connected with other errors.

Conclusion

- The mean error values and the values of repeatable errors suggest fast improvement of positional coding scheme for left hand control.
- The mean error values show the skill transfer only from the left hand movements to right hand movements.
- The learning curves of developed neural network model trained by QLBAM algorithm also show the performance improvement for positional coding scheme.
- The phenomenon of repeatable errors is well simulated by model.