A New Approach to Rhythm Cueing of Cognitive Functions

The Case of Ideomotor Apraxia

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Although positive effects of rhythm cueing on motor control in neurologic disorders are known, no studies have yet focused on patients suffering from impaired programming of complex actions. One patient suffering from ideomotor apraxia (a potentially ideal experimental paradigm to test the effect of rhythm on high-level motor control) underwent two rehabilitation training sets differing only for the presence or absence of rhythm cueing. Both sets of training increased the patient's proficiency, but rhythm cueing was significantly more effective, during the training as well as during the post-training uncued test. Ideomotor apraxia represents an effective model to test the effects of rhythm on high-level motor control.

Key words: **ideomotor apraxia; motor control; musical rhythm; temporal entrainment; music therapy; rehabilitation**

Introduction

The idea of optimizing cognitive processes by structuring them in a tidy, predictable, and well-oriented frame is a key goal of many training procedures, both educational and rehabilitation oriented. Music, and particularly rhythm, thanks to a favorable array of perceptive, cognitive, and motivational properties, appears as an optimal candidate to drive the facilitation of this frame.[1]

Up to now, scientific research devoted only little attention to the bind between rhythm cueing and cognitive operations.

Nevertheless, rhythm cueing has been shown to improve not only low-level motor control (upper-limb motor control of hemiparetic patients, gait in Parkinson's disease),[1] but also word articulation in patients with apraxia of speech.[2] Moreover, EEG studies have shown that musical mnemonics induce oscillatory synchrony in neural networks underlying memory.[3]

The aim of this study was to test an experimental model to investigate the interaction between rhythm cueing and cognitive programming of complex actions.

Several elements point out ideomotor apraxia (IA) as a potentially effective one. IA is a selective impairment of high-level voluntary motor control attibutable to focal brain damage, in which a patient is unable to translate the abstract representation of a complex action in a correct sequence of motor commands (*conduites d'approche*, omissions, substitutions, perseverations, transpositions).[4] IA is not caused by hemiparesis, ataxia, dyskinesia, or dystonia since a movement that cannot be produced in an artificial situation can easily be produced if triggered by proper contextual information (automatic-voluntary dissociation). Moreover, according to

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Roy's model,[5] errors arise particularly at the key checkpoint for the movement, whenever the subject has to choose between two or more alternative motor programs. Key checkpoints require a highly controlled modality of execution and the focalization of attention, while the parts of the movement that do not require online control benefit from an automatic modality of execution. IA patients, on account of lack of resources and damaged connections between motor control centers in the brain, are unable to switch flexibly between these two modalities.[5]

Altogether, these features of IA allow us to predict that rhythm cueing may improve the performance of a patient with IA because:

1. Synchronizing with rhythm would help to structure the motor sequence in a regular way.
2. When the movement is synchronized with rhythm, IA patients would get information on the key checkpoint sequence from the sound pattern, thereby being able to foresee with minimal cognitive load the moment in which focalization of attention is required, and thus facilitating the modality switch.
3. Because of automatic-voluntary dissociation, IA patients might be particularly influenced by external triggers and templates, as the one mediated by a musical rhythm.

An improvement of rhythm-cued motor performance, compared to an uncued one, in an IA patient would point out IA as an effective neuropsychological model to test the effects of rhythm on high-level motor control.

Clinical Case

The subject, R.G., is a 32-year-old woman. Five months before entering the study, she suffered from the rupture of a cerebral aneurysm, causing a left frontoparietal lesion.

Neuropsychological evaluation[4] revealed IA (44/72; cutoff 54/72) and a severe nonfluent language impairment. R.G. was not affected by attentional deficits, unilateral neglect, or visual agnosia.

Because of the right hemiparesis, the evaluation and the training were done on the left upper limb.

Materials and Methods

R.G. was asked to learn complex novel motor sequences.

Each motor sequence was preliminarily evaluated without rhythm (pretraining test), then treated for approximately 15 min and finally re-evaluated (without rhythm) (post-training test). Video recordings were made for each phase.

The evaluation of motor sequences was made by counting both the number of correct limb positions ($n = 9$) and the number of trajectories ($n = 9$) along the path (total score $= x/18$).

Ten healthy subjects (mean age of 30 ± 3 years) were evaluated with the pretraining test. Their mean score was 15 ± 2; a score of 10 was considered the cutoff for pathology in the pretraining test.

In each experimental session, two motor sequences were considered: one to be trained with rhythm cueing and another without. R.G. underwent four experimental sessions on different days; she therefore practiced eight different motor sequences, four with the aid of rhythm cueing and four without. In each session, the order between the cued and the uncued sequences has been counterbalanced.

Rhythm cueing consisted of an isochronous metronome-like square wave tone. In the rhythm-cued motor sequences, rhythm was introduced after approximately 2 min of training (initial base line) followed by the specific exercise, and was employed for about 7 ± 1 min. Rhythm-cued exercises were flexibly alternated with uncued exercises and with rest time to prevent fatigue and

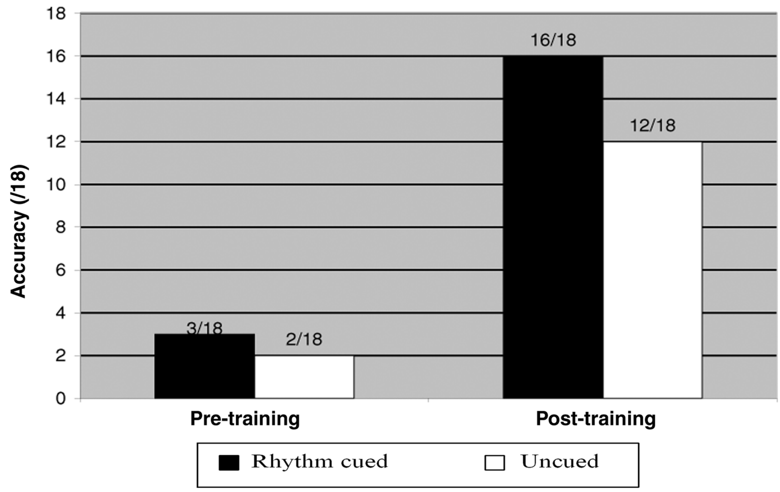


Figure 1. Rhythm-cued versus uncued training.

discomfort from the continuous sound. When rhythm was introduced, the patient was asked to focus on the acoustic template and let the movement to be synchronized with the impulses, without exerting too much cognitive control on the movement itself. The initial speed of rhythm cueing was approximately matched to the spontaneous frequency of motion exhibited by the patient for the target motor sequence; the speed of rhythm was then changed flexibly within the training, in order to suggest either slower or faster/smoother approaches to the target motor sequence, depending on the specific difficulties of the patient R.G.

Apart from the presence or absence of rhythm cueing, the treatment was characterized by: (i) demonstration of the motor sequence by the trainer; (ii) demonstration of the motor sequence by the trainer and simultaneous imitations by R.G.; (iii) feedback about correctness; and (iv) relational support.

Results

Apart from the presence/absence of the rhythm cueing, the two sets of training were actually identical with respect to number of demonstrations (dependent t-test: $t = 0.72$, $P = 0.52$), number of demonstrations + imitations ($t = -1.85$, $P = 0.16$), number of R.G.'s movements ($t = 1.26$, $P = 0.29$), working time ($t = -0.78$, $P = 0.49$), and resting time ($t = 0.91$, $P = 0.43$).

In the pretraining evaluation there was no difference in accuracy between the motor sequences to be treated with and without rhythm cueing ($3 \pm 2/18$ versus $2 \pm 3/18$, dependent t-test: $t = 0.48$; $P = 0.664$, n.s.) (Fig. 1).

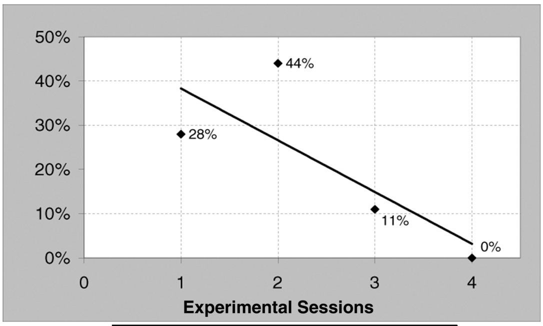
Both sets of training increased the patient's accuracy, but rhythm cueing was significantly more effective (post-training accuracy for rhythm-cued training $= 16 \pm 2/18$, for uncued training $= 12 \pm 3/18$, dependent t-test: $t = 3.83$; $P = 0.031$) (Fig. 1).

Furthermore, during the rhythm-cued training, R.G. produced significantly more correct motor sequences (26/237, 11%) than during the uncued training (10/180, 6%) ($\chi^2 = 4.26$; monodirectional $P = 0.019$).

Finally, the advantage of rhythm-cued training decreases linearly during the four experimental sessions ($Y = 0.5 - 0.117^*x$; $R = 0.77$; $R^2 = 0.6$) (Fig. 2).

Conclusions

The aim of this study was to identify an experimental model to investigate the interaction



Line equation: Y = 0.5 – 0.117 * x; R^2 = .6

Figure 2. Trend of superiority of rhythm-cued training defined as % accuracy "cued" minus % accuracy "uncued."

between rhythmic cueing and cognitive programming of complex actions.

Although preliminary, results point out IA as a powerful neuropsychological model to test the effects of rhythm on high-level motor control, in fact, rhythm-cued training has been shown to be more effective than uncued training in the patient R.G. The two sets of training differed only with respect to the presence or absence of rhythm cueing. The rhythm template seems to have successfully reorganized R.G.'s motor control, leading to optimal motor performance.

The superiority of rhythm-cued training can be explained within the frame of our hypotheses: (i) synchronizing with rhythm helped to structure the motor sequence in a regular way; and (ii) thanks to rhythm synchronization, R.G. got information on the key checkpoint sequence from the sound pattern.

Our results are consistent with Roy's account of motor control[5] and with the data of Thaut *et al*. and Wambaugh and Martinez regarding the effect of rhythm on motor control.[1,2] Moreover, learning in the context of a musical template (rhythmical in this case) might have strengthened coherent oscillations in cortical networks underlying motor planning and learning in a manner similar to those of previous observations[3]; a direct test of this hypothesis would require EEG recordings during pre- and post-training evaluation, and could be a future development of this study.

Of particular interest is the fact that R.G.'s performance improved during the post-training (uncued) test, and that the superiority of rhythm-cued training decreased along the four experimental sessions. This may happen because of a progressive structuring of motor control around a regular pulse; at the beginning this depends on the sound, but in the course of time it becomes a self-triggered and endogenous strategy of directing and regulating motor control; data suggest a positive generalization effect.

Further investigation may be directed to the specific role of factors, such as automatic-voluntary dissociation, different kind of sounds (e.g., artificial versus action-related sounds) and movements (e.g., familiar versus unfamiliar), severity and type of apraxia, lesion localization, influence of other concomitant disorders, and self-paced administration of rhythm cueing by the patient. The patient R.G. shall also be tested in a follow-up design with a retraining paradigm. Finally, the interaction between rhythm and high-level motor control could be investigated in healthy subjects and highly skilled individuals (e.g., musicians, sportsmen), using modified experimental situations (e.g., the time pressure paradigm).

Even if not directly addressed by our work, these data potentially have implications for rehabilitation. Issues such as optimal length of treatment and functional outcomes of treatment should be examined in future investigations before this treatment is advocated for clinical use, and replications of this investigation in wider patient populations are obviously necessary for the purposes of generalization. However, this type of treatment does appear to have promise for the treatment of IA and certainly warrants further study.

Conflicts of Interest

The authors declare no conflicts of interest.

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