

**EFFECT OF RHYTHMIC AUDITORY STIMULATION ON CONTROLLING STEPPING
CADENCE OF INDIVIDUALS WITH MENTAL RETARDATION AND CEREBRAL PALSY****Panagiotis Varsamis***Aristotle University of Thessaloniki***Konstantinos Staikopoulos****Lefkothea Kartasidou***University of Macedonia*

One of the purposes of Rhythmic Auditory Stimulation (RAS) is to improve the control of dysfunctional movement patterns. This study aimed to extend the line of research by focussing on secondary students with mental retardation and cerebral palsy. According to the study's assumption, cadence can be controlled through a stable and low signal cadence to the benefit of endurance during an aerobic exercise on a stair stepper. Two conditions (Do your best and RAS) were applied in a Latin square design. Results show that in the RAS condition, as compared to the Do your best condition, students significantly decreased their cadence, increased their training duration, kept their heart rate between the bounds suggested for aerobic exercise and decreased their intra-individual standard deviations in both cadence and heart rate per minute. The researchers suggest that a variable signal cadence could have an even greater effect on exercise duration.

Rhythm is the most prominent component of music linked with individual's motor behavior, indicating the responsiveness of the sensorimotor system to auditory stimuli (e.g., Styns, van Noorden, Moelants, & Leman, 2007; Thaut, Kenyon, Schauer, & McIntosh, 1999). Rhythmic Auditory Stimulation is described as a ...*technique using the physiological effects of auditory rhythm on the motor system to improve the control of movement...* (Thaut, 2005, 139, as cited in Kwak, 2007, p. 199). More specifically, *rhythmic auditory cues synchronize motor responses into stable time relationships... via fast-acting physiological entrainment mechanisms*, while rhythm serves as an *anticipatory and continuous time reference on which movements are mapped within a stable temporal template* (Thaut, Leins, Rice, Argstatter, Kenyon, McIntosh, Bolay, & Fetter, 2007, p. 455). The present study focused on the function of musical rhythm as a parameter of motor control. The aim was to determine the effect of Rhythmic Auditory Stimulation (RAS) on cadence of individuals with Mental Retardation and Cerebral Palsy working out on a stair stepper in order to increase workout duration. Physical exercise of this kind presupposes the choice and supervision of the appropriate cadence.

Individuals with cerebral palsy and mental retardation are prone to have difficulty with rhythmic perception and rhythmic performance of movement (e.g., Grant & LeCroy, 1986; Kwak, 2007). More specifically, physical ability, cognitive function, social support and other individual characteristics may affect these individuals' response to rhythmic auditory stimuli (Kwak, 2007; McRorie & Cooper, 2004). Concerning cognitive function, the difficulty in maintaining rhythmic pattern may be attributed to a restriction of brain functions related to the perception and reproduction of a rhythmic pattern (Del Olmo & Cudeiro, 2005, p. 31), while good mental ability is related to an efficient central nervous system (McRorie & Cooper, 2004, p. 524). It is proposed, however, that individuals with cerebral palsy and mental retardation can respond to RAS through adapted forms of instruction and practice (Kwak, 2007, 211).

So far RAS has rarely been applied in cases of individuals with cerebral palsy and mental retardation, especially concerning walking. Kwak (2007) found that by setting the signal cadence at 5% to 15%

above the initial performance of individuals with cerebral palsy, stride length, gait velocity, and gait symmetry increased. However, the real cadence during exercising remained relatively stable. Research by Thaut, Hurt, Dragon, and McIntosh (1998) on individuals with cerebral palsy indicated an increase in velocity, cadence, stride length, gait, symmetry as well as an improvement of kinematic components of walking, such as increase in range of motion for, knee and hip. In a similar target group, individuals with traumatic brain injury (Hurt, Rice, McIntosh, & Thaut, 1998) increased through RAS their signal cadence by 5% and managed to improve their gait velocity, step cadence and stride length.

The domain in which RAS has been most extensively applied to is the rehabilitation of the walking ability in patients who develop neurological disorders at a relatively advanced age. For instance, in the case of stroke patients, a number of positive effects were observed, such as an improvement in alternate movement of lower limbs, symmetrical bilaterally coordinated gait, an increase in cadence, stride length, velocity and endurance in therapy, in kinematic aspects of the legs, hands and body mass center (Ford, Wagenaar, & Newell, 2007; Jeong & Kim, 2007; Prassas, Thaut, McIntosh, & Rice, 1997; Thaut, et al., 2007; Thaut, McIntosh, & Rice, 1997). Similar results were recorded with individuals suffering from Parkinson's disease. In this case the following positive effects were observed: an increase in stride length, gait velocity, cadence, as well as a reduction of suspension time and gait variability (Hausdorff, Lowenthal, Herman, Gruendlinger, Peretz, & Giladi, 2007; Howe, Lövgreen, Cody, Ashton, & Oldham, 2003; McIntosh, Brown, Rice, & Thaut, 1997; Rochester, Hetherington, Jones, Nieuwboer, Willems, Kwakkel, & Wegen, 2005; Suteerawattananon, Morris, Etnyre, Jankovic, & Protas, 2004).

In the majority of the studies mentioned above, RAS was used with a signal cadence consistently higher than the cadence recorded in the initial evaluation of individuals. This indicates the general intention of researchers to maximize all variables. Only in some cases was the influence of RAS examined with a signal cadence lower than the initial one (Baker, Rochester, & Nieuwboer, 2007; Del Olmo & Cudeiro, 2005; Howe et al., 2003; Thaut, Miltner, Lange, Hurt, & Hoemberg, 1999; Willems, Nieuwboer, Chavret, Desloovere, Dom, Rochester, Jones, Kwakkel, & van Wegen, 2006). In the latter studies, the potential of RAS was tested to effectively control cadence to the benefit of other gait parameters such as stride length.

The present study constituted an attempt to extend the line of research studying the effects of low signal cadence RAS on populations of individuals with congenital disabilities, such as mental retardation and cerebral palsy (Kwak, 2007, p. 200). The aim was to control, that is, to reduce cadence on a stair stepper to the benefit of endurance during an aerobic exercise. This should keep pulse within the range appropriate for aerobic exercise (between 50% and 70% of Maximum Heart Rate) for as long as possible (e.g., Hand, Phillips, Dudgeon, Lysterly, Durstine, & Burgess, 2008) and thus should extend the duration of the exercise. We chose to study individuals with mental retardation and cerebral palsy, because these are two of the most frequent disabilities (e.g., Rapp & Torres, 2000) that coexist in the same special education schools in Greece and follow the same educational program, particularly at the secondary education level (Pedagogical Institute, 2004).

Method

Participants

The research sample consists of 18 secondary education students, 11 male and 7 female, aged 14-24 years ($M = 18.28$, $S.D. = 3.86$). Nine of the students have moderate mental retardation and the other nine have mild mental retardation. Four of the participants also have cerebral palsy in the form of mild spastic tetraplegia (see table 1). The selection of the sample was made after securing the essential permission and voluntary participation, while all students could participate, without restriction, to different forms of aerobic exercise following the medical advice of a cardiologist. Furthermore, the ability to understand simple directions and respond to rhythmic auditory stimuli was assessed through an individual task. Each student had to walk at signal cadences of 45 and 60 per minute for at least 15 seconds. The evaluation key was dichotomous (can do it - cannot do it).

According to the criteria mentioned above, 18 out of the 38 students of a Special Vocational Education and Training Secondary School in Thessaloniki (North Greece) were selected and voluntarily participated in the proposed research. In other words a purposive sampling method was used (Patton, 1990).

Testing Procedure and Conditions

The research was conducted in May and June 2008 and during this time no other form of aerobic

exercise took place. During the first week the research variables were initially evaluated. The data served as starting point for the goal setting in two research conditions (see table 2). The physical education teacher specified his goals before the beginning of these two conditions. Subsequently, student performance on the two experimental conditions was examined during the third and sixth week using a Latin square design, allowing a two-week interval to avoid the transfer from one condition to another. Students took turns participating in each of these conditions in groups of three to four. From the two meetings that took place in a week the best performance was recorded, that is the exercise that lasted the longest (duration in minutes). Students were told to step keeping their hands on the handle and to exercise on the stepper as long as possible. Stopping the exercise was up to the student and no student reached his/her maximum heart rate.

Do your best condition: the physical education teacher was asked to improve his students' performances using the methods he was familiar with. He used strategies of goal setting and self-efficacy. He thus prompted his students to step more slowly, verbalized positive outcome expectations and agreed with them on performance goals, expressed in minutes of exercising. These goals were based on the first measure and were visualized by means of shaded bars representing time. The goals were one or two minutes more than the initial performance. Intended increase rate is estimated on average at 32.98% (*S.D.* = 10.39%).

RAS condition: the physical education teacher decided on a signal cadence for every student, taking into account the individual initial means on steps per minute and on heart rate. The goal was to have students exercise as long as possible within the pulse range of aerobic exercising. In this way, a goal of a step cadence average of 44.44 (*S.D.* = 10.83) per minute was set, which means a signal cadence lower than the average initial performance by 78.67% (*S.D.* = 13.33). The signal cadence of each student was stable throughout the exercise. The instruction given to the students was to step at the rhythm they listen to. If the teacher noticed deviations from the personal goal after the first minute of the exercise, he accentuated the rhythm by clapping at the signal of the electric metronome.

Apparatus

Metronome: The electronic metronome used was *Weird Metronome* (2004) installed in a portable P/C (Acer Aspire 3630). The sound chosen was *Low Conga*. The rhythmic auditory stimuli were transmitted to the students through wired headphones (PHILIPS SBC HL140). The precision of the electric metronome was checked against a conventional metronome and no deviation was observed.

Stepper: An OEMMEBI ProFitness device was used featuring a heart rate and a step count indicator. It also featured a manually adjustable resistance knob set at the easiest level for all students and in all conditions. The physical education teacher checked the step count indicator's precision for a minute; with a pace of 60 steps a minute and the readings were found to be accurate. The heart rate indicator of the stepper was checked by means of a POLAR FS1 heart rate monitor belt and no systematic deviations were recorded.

Variables

Apart from an estimation of Maximum Heart Rate (Max HR = 220-age), for every student the researchers estimated the heart rate threshold (50-70% of MaxHR) for aerobic exercise. At the end of every minute of exercise, step count and heart rate were recorded. Of these data duration in minutes and total step count were calculated. Dividing the latter by the former yields the average step cadence for every student in steps per minute. In the same way average heart rate per minute was calculated. The last two variables are particularly useful because exercise duration varied among students and among conditions. On the measures recorded for every minute of exercise the researcher's calculated within-person, within-session variability both for the steps as well as for the heart rates, as a form of intra-individual standard deviation (IISD, e.g., Nesselroade & Salthouse, 2004).

Statistical Analysis

A statistical analysis for the normality of distribution of data using the Kolmogorov-Smirnov test indicated that the data for the majority of variables do not follow normal distribution. We thus resorted to the Wilcoxon non-parametric test on all variables in order to evaluate the differences between the two conditions in the same sample of students.

Results

Table 1. Frequencies for disability, intelligence and sex

Disability group	Mental Retardation		Cerebral Palsy		Sum
	Mild	Moderate	Mild	Moderate	
Males	5	4	1	1	11
Females	2	3	1	1	7
Sum	7	7	2	2	18

Table 1 presents the number of students on the basis of selected individual characteristics. Chi-square tests run did not yield a significantly unequal distribution of the characteristics disability, gender and mental retardation in the sample.

The average lowest bound for aerobic exercise was for the sample 100.86 (*S.D.* = 1.93) and the highest 141.21 (*S.D.* = 2.70) heartbeats per minute.

Table 2. Descriptive statistics of dependent variables and Wilcoxon tests for N=18

Condition	Assessment		Do your best		RAS		Wilcoxon
	Mean	SD	Mean	SD	Mean	SD	
Duration (min)	4.6	2.6	5.9	2.6	8.1	3.3	2.93**
Steps (Sum)	268.1	181.7	301.0	151.3	359.2	205.8	1.42
Steps per min	57.8	15.9	51.9	12.9	43.5	12.9	3.20**
Steps (IISD)	6.7	3.4	7.9	4.4	3.7	2.6	3.51**
Pulse per min	136.7	20.5	140.3	12.1	127.9	12.4	2.72**
Pulse (IISD)	14.0	8.5	11.4	4.7	8.8	5.4	2.55*

IISD = Intra Individual Standard Deviation

Table 2 shows the students' performances on the initial measure and on both conditions. According to the Wilcoxon test, the students were able to exercise significantly longer in the RAS rather than the *Do your best* condition. The total step count was greater in the RAS condition but the difference from the *Do your best* condition was not considered statistically significant. Furthermore, students produced a significantly lower step cadence and a lower intra-individual standard deviation of step cadence in the RAS condition as compared to the *Do your best* condition. It must be noted that in the RAS condition, the average deviation of steps from the personal target of students ranged from -5.9 to 7.4 steps. In absolute values, the average standard deviation was 2.69 (*S.D.* = 2.65) steps per minute, which corresponds to a 6.6% margin of error. These results were reflected in the heart rate: statistically significant decreases were observed in the average heart rate per minute as well as the intra-individual standard deviation of heart rate.

A more in-depth analysis of the data can be obtained through the examination of every minute of exercise. Such analyses were made for the first six minutes of exercise, because from the seventh minute onwards the sample of observation pairs was so small ($N \leq 5$) that not all categories of participants were represented.

As can be seen in table 4 the impact of the RAS condition lies in the significant decrease of heart rate in the first five minutes of exercise, while in the sixth minute the impact is not statistically significant. Observing the values of heart rates under the *Do your best* condition, it becomes evident that from as early as the third minute students exceed the 70% thresholds of maximum heart rate (≈ 141 heartbeats per minute). In the RAS condition, and in all minutes of the exercise, the average heart rate lies within the desirable limits for aerobic training.

Table 3. Descriptive statistics of steps in each minute and Wilcoxon tests

	Do your best		RAS		N	Wilcoxon
	Mean	SD	Mean	SD		
1 st min	56.5	19.4	46.5	14.8	18	2.55*
2 nd min	51.4	16.5	42.6	12.7	18	2.77**
3 rd min	50.3	14.0	42.2	13.3	18	2.47*
4 th min	49.5	14.6	42.7	12.2	13	1.86
5 th min	52.6	16.3	40.0	10.8	11	2.85**
6 th min	44.1	14.7	40.6	10.0	8	1.15

Additional information about sample characteristics for N < 18

N	Sex		Disability		Intelligence group	
	Males	Females	ID	CP	Mild	Moderate
13	9	4	9	4	7	6
11	9	2	8	3	6	5
8	6	2	6	2	4	4

Regarding steps (see table 3), we observed a significantly decreased step count in the RAS condition as opposed to the *Do your best* one in the first three minutes as well as the fifth.

Table 4. Descriptive statistics of Heart Rate in each minute and Wilcoxon tests

	Do your best		RAS		N	Wilcoxon
	Mean	SD	Mean	SD		
1 st min	122.6	14.0	114.7	14.0	18	2.35*
2 nd min	136.5	14.4	122.3	16.2	18	2.66**
3 rd min	145.5	13.3	124.1	16.9	18	3.42**
4 th min	148.9	15.8	126.7	11.9	13	3.04**
5 th min	148.5	14.5	131.9	8.9	11	2.67**
6 th min	145.1	17.2	133.6	10.1	8	1.35

Discussion

In the present research the point of reducing step cadence through Rhythmic Auditory Stimulation (RAS) was to increase the duration of the exercise on the stepper within the proposed limits for aerobic training. This pilot study testing students from a Special Vocational Education and Training Secondary School with mental retardation and cerebral palsy that was not free of limitations. The sample was relatively small and non-homogeneous as to the disability involved. In addition, given the chosen research plan, one cannot detect all aspects of long-term exercising to RAS.

What we did find was that RAS helped young students with mental retardation and cerebral palsy to reduce their stepping cadence, that is, to gain control over their exercise tempo. Of course, the margin of error for the reproduction of the rhythmic pattern was greater than those of other studies (Thaut

McIntosh, Rice, Miller, Rathbun, & Brault, 1996) and this was probably due to the cognitive and psychomotor disorders of the students in our sample. While acknowledging these limitations, one cannot question the potential of RAS to quickly affect the periodicity of motor patterns (Thaut, Kenyon, Hurt, McIntosh, & Hoemberg, 2002). To this conclusion also points the fact that the students of the sample decreased step variability within the RAS condition and worked out at a relatively more stable cadence. In RAS the total step count did not increase significantly but the overall step count was distributed along more minutes of exercise.

The dominant result was the decrease of step frequency per minute, which led to the increase of overall exercise duration and the decrease of heart rate per minute. Apart from RAS, this can be attributed to two more reasons. First, because the low intra-individual variability was considered a component of psychomotor maturity (cf. Hausdorff, Zemani, Peng, & Goldberger, 1999) and second, maintaining a relatively stable rhythm was a significant endurance factor (cf. Tenenbaum, Lidor, Lavyan, Morrow, Tonnel, Gershgoren, Meis, & Johnson, 2004). The results produced by the RAS condition are particularly significant because heart rate was maintained within desirable limits for enhancing aerobic capacity.

The difference between RAS condition and *Do your best* condition was not statistically significant in the last minute of the exercise as far as heart rate was concerned. This happened, because in both conditions heart rate tended to rise as students reached the limits of their aerobic endurance. The same effect occurred in the step frequency per minute. Concretely, students tended to reduce their step frequency in the *Do your best* condition, as they became tired. Both of these phenomena stemmed from a cause irrelevant to RAS and have no bearing on its established effectiveness.

Conclusion

In the present study, RAS was used to control (i.e., to decelerate) the stepping cadence of the students with mild mental retardation and of the students with cerebral palsy, aiming at the increase of the exercise duration. Furthermore, the signal cadence used was constant for all minutes of the exercise. We believe that a variable signal cadence based on the actual heart rate can be even more effective, as long as students with congenital disabilities have been trained in the reproduction and change of rhythms.

In conclusion, the use of RAS seemed to have a significant effect on the step frequency and on the heart rate of the students with mild mental retardation and of the students with cerebral palsy. Thus, the students can profit from RAS in an effort to enhance the efficiency of physical activity and exercise in the context of Special Education. We suppose that a prolonged exercise program with RAS can have positive long term effects on students' rhythmic ability and aerobic capacity.

More research in Special Education is needed in order to explore the influence of RAS on more physical activities that involve circular movements such as stepping, running and cycling. Moreover the possibility should be considered of examining the influence of long-term exercise on RAS as well as the possibility of complementing it with other techniques (e.g., goal setting). Specifically in educational settings, it is important to study how RAS can best be implemented and also to determine its significant impact on the motivation of students with disabilities.

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