

Effects of speech therapy with poetry on heart rate rhythmicity and cardiorespiratory coordination

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Abbreviated title: Speech therapy and heart rate rhythmicity

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Abstract

Our objective was to study the effects of guided rhythmic speech with poetry, referred to as Anthroposophical Therapeutic Speech (ATS), on binary differential heart rate dynamics (also called musical heart rate rhythmicity or HRR) as well as on classical spectral parameters during the 15 minutes after speech exercise has ended. A total of 105 one-hour sessions with speech or control exercises were performed in 7 healthy subjects, with 15 sessions each. Heart rate was recorded with ambulatory solid state recorders. Sessions were divided into 15 minutes baseline measurement (S1), 30 minutes of exercise, and 15 minutes effect measurement (S2). The overall binary pattern predominance (PP) as well as the frequency of predominant and cyclically recurrent cardiorespiratory phase locking patterns were calculated from HRR and their changes from S1 to S2 were compared with

the changes in low and high frequency heart rate variability. The results showed that: (1) ATS provokes alterations in heart rate dynamics which are different from those after control exercises and which persist at least for 15 minutes following exercise; (2) in comparison to spectral parameters of heart rate variability, pattern predominance discloses the effects of rhythmic speech exercises best; and (3) cardiorespiratory phase locking patterns, which contribute most to the rhythm pattern predominance, are more prominent after ATS.

Keywords

heart rate variability, symbolic dynamics, musical rhythm approach, creative arts therapy, single case study design

1. Introduction

Speech therapy with poetry is based on the anthroposophical philosophy of R. Steiner (1861-1925) and is also referred to as ‘Anthroposophical Therapeutic Speech’ (ATS) [1]. It consists of guided speaking and breathing exercises, while utilizing epic, lyric and dramatic poetry: in other words, it makes extensive use of rhythmic speech. ATS is applied in various situations, to speech impediments, psychosomatic diseases, cardiac and respiratory disorders. Although the empirical database is still limited, it is supposed that ATS also positively affects the circulatory system and adjusts heart rate control.

‘Musical heart rate rhythmicity’ (HRR) denotes a specific kind of heart rate variability (HRV) which, in a few words, corresponds to the predominance and cyclicity of (binary) patterns in series of RR interval differences. The recently developed technique [2, 3] is based on (1) symbolic dynamics, which has its origin in nonlinear dynamical system theory, (2) combinatorial theory, which helps to classify symbolic heartbeat rhythms, and (3) ethnomusicology with a main focus on some compositional principles of African Music. In other words, it expands classical heart rate analysis by a technique which explicitly takes complex musical rhythm principles into consideration. Musical heart rhythm analysis can be seen in the tradition of musical pulse diagnostics which has been common medical knowledge for more than 2000 years with its prime in the 16th century [4]. At that time a wide spectrum of techniques were adopted from musicology to communicate the cadence of heartbeat to other physicians. Unfortunately, musical pulse diagnostics fell into disuse when modern sphygmographic techniques became popular, but may be revived through the method proposed, i.e. focusing on musical patterns in symbolic (in this case binary coded) heart rate sequences.

Because of their cross-disciplinary importance, systematic and sciences-based approaches to the analysis of symbol sequences in nature also attract the attention of people working in the arts. Particularly creative arts therapists (e.g. working with music, crafts, speech, dance, drama, etc.), are naturally interested in the way the artistic creation of rhythmic patterns in time or space is related to or affects physiological time signatures in man. This is indeed important because physio-

logical components were far too often ignored in creative arts therapy research. On the other hand it has been observed by therapists (without scientific evaluation) that the creative arts greatly influence vegetative function, enforce (self-) regulatory processes, and enhance the synergetic or even salutogenetic [5] potential in man. The psychophysiological mechanisms responsible for the efficacy of creative arts therapies are certainly diverse and include improvement of physiological order in time (i.e. strengthening of flexibility, stability and coherence of regulatory processes) which may play a major role in re-establishing a healthy state. In this framework heartbeat and respiration are central, not only because they are the most vital and integrative rhythms of life, but also because they are the border posts between consciously controllable and non-controllable physiological rhythms, which corroborates their central position in the human organism. In the context of this study it is important to note that the pattern analysis of heart rate variability provides insight into the organism's ability to coordinate cardio-respiratory function [6] which has been discussed as a crucial prerequisite for health [7]. Therefore this study focused on HRR and particularly on the so-called cardiorespiratory phase locking pattern classes in differential heart rate dynamics. The method was applied to determine the immediate effects of ATS in individual subjects. Spectral analysis of HRV was also performed to compare immediate changes in HRR with those of classical HRV parameters.

The study 'Art Therapy and Heart Rhythm' was originally designed and carried out in 1998. In a first publication [8] the heart rate data were analyzed by focusing on classical spectral and time domain heart rate variability (HRV) indices. The authors made use of a technique called 'autonomic imaging' [9]. Additionally the pulse respiration quotient (PRQ) was derived on the basis of respiratory sinus arrhythmia (RSA, algorithm described in [3, 10]). The results showed that ATS has systematic effects on HRV, both during and after exercise (simultaneous and immediate effects respectively). Reciting poems with hexameter meter, for example, modulated heart rate bimodally: two oscillations with a center-frequency ratio of 2:1 were often present in HRV spectra. Moreover, the authors stated, while speaking recitative texts, respiration may serve as a pacemaker to activate harmonics of respiratory sinus arrhythmia in HRV spectra (with a frequency ratio of $x:1$) [8]. Immediately after exercise a significant decrease in heart rate and an increase in HRV high frequency power were observed, in comparison to the pre-exercise baseline levels. These changes were more prominent after both types of speech exercises (recitative and declamatory) than after control exercises (see Methods section for further details on study design). Heart rate rhythmicity and cardiorespiratory phase locking patterns were not investigated in previous analysis and will be first addressed here.

2. Materials and Methods

2.1 Poetic background

In old European poetry we find two strong forms of poetic verse, hexameter and alliterative, the origins of which lie in different languages. Alliterative verse or alliteration, is an early verse of the Germanic languages and is characterized by

the repetition of consonant sounds at the beginning of words or stressed syllables. It is a basic structural principle rather than an occasional embellishment. Hexameter is a line of verse containing six feet, usually dactyls. The dactylic hexameter is the oldest known form of Greek poetry and is the pre-eminent meter of narrative and didactic poetry in Greek and Latin, in which its position is comparable to that of the iambic pentameter in English poetry [11]. These two principles appear both in German and English poetry but have fallen out of use (alliterative verse) or have never been adapted well (hexameter verse) to these languages. Nevertheless they seem to have a strong and specific influence on breathing rhythms, if recited in an appropriate manner. In ATS, alliteration and hexameter are regarded as examples of declamatory and recitative style, respectively, and are used from experience for 'strengthening' and 'harmonization' of the rhythmic organism, both in English and German languages.

2.2 Subjects

The study was carried out at the Medizinisch-Künstlerisches Therapeutikum, Berne from April to September 1998. Seven healthy subjects aged 26 to 59 years (mean \pm SD: 44 ± 10 years, 3 males, 1 smoker, Tab. 1) were included in the study. All subjects gave their informed consent to take part in the study. Inclusion criteria were a basic knowledge of ATS and willingness to practice the exercises during the study. Subjects with a known illness or pregnant women were excluded. The subjects did not take alcohol for 24 hours before sessions and were not under medication other than the occasional use of homeopathic remedies. Quality and duration of sleep during the night before sessions were also recorded but not taken into consideration in this study. The study protocol conforms to the ethical guidelines of the 1975 Declaration of Helsinki.

[insert Tab. 1 here]

2.3 Experimental protocol

The entire experiment consisted of 15 one-hour sessions at regular intervals of one week for each subject. Each subject came into the research laboratory at the same time in the morning. Each session was divided into three parts: 15 minutes baseline measurement (S1), 30 minutes speech or control exercise, respectively, 15 minutes effect measurement (S2) (Fig. 1). During S1 and S2 the subjects were comfortably seated on an armchair and advised not to speak, read or get up. During speech exercise either a hexameter verse (H, recitative, weeks 1, 2, 3, 7, 8, 9) or an alliterative verse (A, declamatory, weeks 4, 5, 6, 11, 12, 13) was spoken. For warming up and adaptation to the experimental situation, speech exercises were introduced with reciting of two basic exercises, which were neither specifically recitative nor declamatory character. All speech exercises were practiced upright standing or slowly walking and the subjects were instructed to support their speech with specified gestures. During control exercise (C, weeks 10, 14, 15) the subjects were requested to walk around slowly while having an everyday conversation with the therapist. This was to ensure comparability with the speech exercises, with respect to posture, strain and attention to and of the therapist.

[insert Fig. 1 here]

2.4 RR interval recording and data pre-processing

Microprocessor-based solid state recorders (HeartMan, Institute of Physiology, University of Graz, Austria) with analogous R wave detection (resolution: 0.1 ms on average) were used for RR interval registration. The beginnings of all measurement or exercise periods, respectively, were marked by pressing an event button which stores the index number of the corresponding heartbeat together with a character code to identify the respective period. The RR tachograms and the event marker data were written to binary data files which were then exported to a personal computer for further analysis.

All heart rate parameters, which are described below, were calculated with C and Matlab routines for sequences with a fixed number of heartbeats (600 RR intervals) regardless of the total time interval covered. To exclude adaptation processes 200 and 100 beats were skipped from the beginning of S1 and S2, respectively.

2.5 Heart rate rhythmicity (HRR) and cardiorespiratory phase locking patterns

[Footnote 1]

Binary coding or symbolization of RR differences enables a simple form of percussive musical interpretation of essential heart rate dynamics [2, 3]. Binary coding works as follows: RR differences smaller than zero are marked with 1 which corresponds to acceleration of the heartbeat; RR differences greater than or equal to zero are marked with 0 which corresponds to deceleration of the heartbeat [12]. If the resulting series of 1s and 0s is interpreted as a percussive pattern, e.g. as strokes and rests or as strokes on two different drums, musical impression follows instantly. Moreover, from the musical point of view, the analysis of musical rhythmicity and rhythmical complexity [13, 14] seems to be crucial.

In our approach we use a classification scheme, originally developed to classify timeline rhythms in the music of Afro-American origin [15]. In short, this method has two purposes: (1) to search for statistically predominant binary (percussive) pattern classes in differential heart rate dynamics, and (2) to judge pattern classes as musically significant or predominant, if the corresponding patterns occur very often and are cyclically recurrent.

It has been shown empirically [2, 3] that most of the patterns, which occur predominantly and cyclically during resting periods or night sleep, can be assigned to the so-called phase locking pattern classes. These classes comprise patterns which inevitably occur very often if the phases of the heartbeat and a heart period modulating harmonic oscillation tend to lock frequently with the same locking ratio. Or more precisely, a single phase locking pattern necessarily occurs if any heart period modulating oscillatory cycle locks with the heartbeat itself. Fig. 2 demonstrates this by way of example for a 7:2 phase locking.

[insert Fig. 2 here]

In the range from 3:1 to 6:1 phase locking pattern predominance most likely originates from intermittent cardiorespiratory coordination as the binary constellations of these patterns correspond to high frequency HRV, i.e. RSA. These classes are therefore denoted as cardiorespiratory phase locking pattern classes without claiming a one-to-one correspondence to true cardiorespiratory synchronization. A conclusive and detailed proof of this correspondence on the basis of respiratory flow data is the subject of a following study (manuscript submitted).

In the above mentioned context, two different aspects of musical rhythmicity are furthermore considered in this study. The first one is the evaluation of the pattern predominance (*PP*). This parameter corresponds to the contrast of the normalized frequency distribution f (see definition in [2]) over all pattern classes, i.e. it quantifies to what extent some of the patterns disappear, while other patterns occur much more frequent than would be expected in equally distributed random symbol sequences (corresponding to a random walk RR tachogram). In this study *PP* has been evaluated for each of the above mentioned sequences with 600 RR intervals and is strictly defined as the mean difference between the three maximal and the three minimal f values over 46 pattern classes, i.e. 42 pattern classes comprising all binary patterns with 3 to 8 bits (Tab. 1 in [2]) plus 4 pattern classes to include the most relevant patterns with up to 12 bits. These are

class 43 (PLR: 9:2, basic pattern: 000110011, $\mu = 18$),
class 44 (PLR: 10:2, basic pattern: 0001100011, $\mu = 10$),
class 45 (PLR: 11:2, basic pattern: 00011000111, $\mu = 22$),
class 46 (PLR: 12:2, basic pattern: 000111000111, $\mu = 6$)

with phase locking ratio PLR and the total number of equivalent patterns μ within the respective class [2] [Footnote 2].

The second aspect also considers the cyclical stability of the patterns. The algorithm identifies phase locking pattern classes that are both twice as frequent as pattern classes in a random walk RR tachogram, and cyclically recurrent over two heartbeats on average. The latter condition means that, when moving a window in steps of one heartbeat over the binary sequence, the classes, which appear within the window, must be the same over two steps on average. This technique results in a histogram of the 600-beat sequences with a predominant occurrence of cyclically recurrent phase locking patterns. Only the following pattern classes with an ascribed $n:2$ locking ratio have been considered because these are the main cardio-respiratory classes (Fig. 6):

class 12 (PLR: 6:2, basic pattern: 001001, $\mu = 6$),
class 22 (PLR: 7:2, basic pattern: 0010011, $\mu = 14$),
class 41 (PLR: 8:2, basic pattern: 00110011, $\mu = 4$),
classes 43 – 46 (see above).

2.6 Heart rate variability (HRV)

A Fast Fourier Transformation (FFT) based spectral analysis of HRV was performed on all 600-heartbeat sequences. The resulting spectral power density function was integrated in the low frequency band (0.04-0.15 Hz, LF) and the high frequency band (0.15-0.40 Hz, HF). LF and HF power (*LF*, *HF*) were computed in milliseconds such that they correspond to the standard deviation of the LF and HF band-passed RR tachogram (times between R waves in milliseconds). Furthermore the balance $BAL = LF / HF$ and the mean RR interval (*RR*) were calculated. The spectral analysis was performed according to the methods of Rottman and co-workers [16] and is described in detail elsewhere [17].

2.7 Statistics

The statistical methods used in this paper are descriptive. Box plots are used for visualization, and p-values are calculated for the descriptive classification of group differences. The Wilcoxon one sample (matched pairs) signed rank test was

used to verify a change from S1 to S2 in each exercise group over all subjects and was applied to the median values of repeated measurements. A p-value near zero indicates that a parameter change from S1 to S2 is likely. The same test was also used to quantify the differences between the 3 groups of exercises (C, H and A). The resulting p-values correspond to the hypothesis that the parameter change from S1 to S2 was the same among the groups and did not depend on the type of exercise performed. For the statistical tests, the natural logarithm of PP has been taken to provide symmetrically distributed data. When interpreting p-values it has to be emphasized that the Wilcoxon test produces only p-values which are multiples of 2^{-N+1} . Thus, due to the low sample sizes ($N = 7$ median values), the possible minimal p-value is 0.016.

Furthermore, to demonstrate methodological interdependencies between HRV and HRR parameters, non-parametric (Spearman rank-order) correlation analysis was performed.

3. Results

The first part of this section describes the absolute changes of all parameters from baseline measurement S1 to effect measurement S2 over all subjects which may be caused by the exercises in-between. In Figs. 3 and 4 the differences from S1 to S2 (Δ) of all parameters were plotted as box and whisker plots. To support the visual impression corresponding p-values (section 2.7) were also printed. The p-values at the bottom of each plot describe the probability that the corresponding parameter change is different from zero. The p-values on top help to classify the differences in the parameter change between the groups. Seven median values of repeated measurements were considered in each group.

[insert Fig. 3 here]

[insert Fig. 4 here]

As shown in Fig. 3 RR , HF and BAL changed clearly from S1 to S2: RR and HF increased and BAL decreased on average over all subjects after all three types of exercises, including the control exercise. Remarkably, this change was qualitatively the same in all three groups as indicated by the p-values on top. The behavior of LF was different: Whereas an increase in LF could be predominantly observed after control exercise, a slight decrease was more likely after hexameter. After alliteration LF did not change in a preferred direction over all sessions.

The logarithmic binary pattern predominance ($\ln PP$) of differential heart rate dynamics behaved in a different way than classical HRV parameters. On the one hand the average change in $\ln PP$ (Fig. 4) after all types of exercises was prominent and comparable to the change of the parameters described above. On the other hand, and this seems to be the most important finding, $\ln PP$ increased on average after speech exercises but tended to decrease after control. The increase was more striking after hexameter ($p = 0.016$) than after alliteration ($p = 0.109$), whereas a decrease of PP after control exercise is supported by a p-value of 0.109. The group difference of $\Delta \ln PP$ between C and H was optimal ($p = 0.016$).

[insert Tab. 2 here]

The intra-individual behavior of *PP* is shown in Tab. 2. Median values and the quartiles (low- and high values, respectively, for the control exercises) of ΔPP are presented for each subject. Tab. 2 reveals a clear message: In all but one subject median ΔPP was positive after hexameter and negative after control exercises. Hence the increase of pattern predominance after hexameter exercise and the decrease after control exercise were highly reproducible. Alliteration exercises tended also to elevate pattern predominance but their effects were much weaker and less reproducible in individuals.

[insert Tab. 3 here]

[insert Fig. 5 here]

The Spearman rank-order correlation coefficient matrices from all parameters during S1 and S2 are presented in Tab. 3. Remarkably, the highest correlation is between *PP* and *BAL* (see also double-logarithmic plot in Fig. 5).

[insert Fig. 6 here]

Fig. 6 displays the relative frequency of S1 and S2 sequences with a predominant occurrence of cyclically recurrent $n:2$ cardiorespiratory phase locking patterns over all subjects. A remarkable augmentation of pattern stability and predominance could be noticed after speech exercises, and a reduction of rhythmicity was observed after control exercises (from S1C to S2C). Moreover, after speech exercises the profile of the distribution was sharpened, i.e. in particular the 8:2 (= 4:1) and 10:2 (= 5:1) patterns appeared much more frequently and cyclically stable. It has to be noted that the decrease after control exercises may be spurious and caused by an exceptionally high baseline rhythmicity (S1C). Nevertheless, the rhythmicity after speech exercises (S2H, S2A) was much more pronounced than even the high baseline rhythmicity before control exercises.

4. Discussion

This study has been carried out to investigate the immediate effects of speech therapy with poetry (ATS) on heart rate rhythmicity (HRR) in healthy subjects. Three issues were central:

(1) ATS has been originally conceptualized from experience to ‘harmonize’ and ‘strengthen’ rhythmic processes in man. If this experience proves to be true, long-term effects particularly on cardiovascular regulation should be expected. The first step towards proving this deduced hypothesis was to study the effects not only during but also immediately after speech exercises. Rhythmic speech, as performed in poetry recitation, modulates heart rate instantaneously via respiration. Therefore simultaneous effects both on respiration and heart rate are not surprising. But does ATS also have transitive effects which persist when poems recitation has already ended?

(2) The artistic creation of rhythmic patterns in time and/or space is a basic principle in most creative arts therapies. In analogy to a forced oscillator in physics, rhythm in creative arts may serve as an exciter while the organism reacts like a resonator. But unfortunately the nature of resonance is not known, and it is unlikely that the complex organism generally reacts like a simple harmonic oscil-

lator with ‘only’ some resonant modes in its spectrogram. But what could ‘strengthening and harmonization of rhythms’ also mean? To find a more adequate or broader approach to the phenomenon of ‘rhythmic resonance’ in physiology, the term ‘rhythm’ can be interpreted literally and regarded as what it basically is: *the cyclic repetition of similar patterns in time or space*. Consequently, rhythm approaches should be rather based on pattern concepts than on oscillator models with sinusoidal behavior. HRR takes these principles into account but its ability to unveil the effects of external rhythm exciters has still to be proven.

(3) As could be shown in the past, adjustment of heart rate control is not only a question of improving heart rate variability but also of reinforcing the interaction and coordination with other oscillators such as blood pressure and respiration. Cardiorespiratory coordination or synchronization seems to be a particularly important prerequisite for health [7]. HRR focuses indirectly on cardiorespiratory coordination solely on the basis of heart rate recordings and is therefore appropriate to quantify both rhythmization and coordination which are mutually conditional (with the reservation noted in 2.5 regarding the role of cardiorespiratory phase locking patterns). But it remains unanswered if these well-defined terms are really suited to substitute for the ambiguous terms ‘strengthening and harmonization’.

All three issues have been addressed in this study and the results provide answers to the above questions. The most important result is that the pattern predominance (*PP*) was clearly increased after speech exercises and decreased after control exercises, both inter- and intra-individually. These opposing effects show that speech exercises cause rhythm alterations which cannot be explained by simple adaptation processes to the experimental situation. Moreover, the apparent divergence of *PP* after different types of exercises demonstrates that *PP* contains information which cannot be derived from spectral indices of HRV alone. The latter did show clear alterations after exercises, but direction and extent after rhythmic speech were similar to those after control exercise. Only the low frequency component *LF* revealed different effects after control and hexameter exercises. But the separation between the groups was less and ΔLF was indifferent after alliteration. This result is partly in contrast to the findings from the first analysis [8]. The authors found that the changes of *HF* were more prominent after hexameter exercise than after control or alliteration exercises. The main reason for this discrepancy is that the RR tachograms analyzed were not identical: The time length of all tachograms was fixed for the first evaluation and the number of heartbeats in each tachogram was fixed for the second.

From the methodological point of view *PP* does not relate per se to a specific frequency range of HRV. For example, alteration of both types of variability, *LF* and *HF*, may only indicate an adjustment of amplitude but not of dynamical structure and, therefore, need not necessarily affect *PP*. On the other hand we expected that a change of *BAL*, i.e. a shift from low- to high-frequent heart rate variations or vice versa, would be accompanied by a shift in the distribution of predominant pattern classes. An increase of *BAL*, for example, was supposed to be related to a *lower* predominance of cardiorespiratory phase locking patterns and/or a *higher* predominance of pattern classes with longer runs of ones and zeros. The results corroborate only the first assumption. The negative correlation between $\ln PP$ and $\ln BAL$ (Fig. 5) can be interpreted in the way that mainly the relative degree of (high-frequent) beat-to-beat fluctuations relates to the predominance of binary patterns. The relative degree of low frequency HRV seems to have less positive

effect on *PP*. On the other hand, the simple law ‘increase of *BAL* \leftrightarrow decrease of *PP*’ and vice versa cannot be generalized: After control exercises both *BAL* and *PP* decreased on average. This discrepancy discloses the complex relationship between HRV and HRR and further studies are needed to gain deeper insight into physiological background of HRR.

The distribution of sequences with a predominant cardiorespiratory phase locking pattern recurrence (Fig. 6) specifies the responsibility for the increase of *PP* after speech exercises. Particularly the 4:1 and the 5:1 pattern classes appear more often and are cyclically recurrent.

It can be summarized that (1) ATS provokes alterations in heart rate dynamics which are different from those after control exercises and which persist for at least 15 minutes following exercise, (2) the rhythm pattern predominance discloses the effects of rhythmic speech exercises best, and (3) cardiorespiratory phase locking patterns, which contribute most to the rhythm pattern predominance, are more prominent after ATS.

5. Limitations

Although these conclusions have been drawn confidently, some crucial limitations must be admitted.

(1) A basic problem which arises when studying the effects of poems recitation on heart rhythm is whether these effects are caused by artistic verbalization or are mainly due to speech-adjusted breathing rate. As has been shown recently by Bernardi et al. [18] ‘simple mental and verbal activities markedly affect HRV through changes in respiratory frequency’. Thus the effects of speech therapy on cardiac control may be strongly connected with the effects of slow breathing (see also literature on meditation breathing below), and there seems to be no excuse for disregarding this context by neglecting the control of respiratory frequency or the reproduction of speech-like breathing patterns during control sessions. On the other hand it has to be said that during speech exercises the tempo of speech and respiration are controlled autonomously, whereas in control sessions only external (metronome) controlled respiration would have been practicable. These two types of respiration are incompatible and would probably result in different effects on heart rate control. Thus the study design chosen holds a substantial drawback, but it seemed the best for lack of alternatives. Nevertheless, focusing on the differences between controlled breathing effects, speech induced breathing effects, and mental speech effects on heart rate control will be a challenging objective in future studies. In this respect it will be helpful to turn the attention also to the stimulating results of Yoga and meditation research [19-25]. Furthermore, if focusing particularly on breathing effects of rhythmic speech, respiratory flow measurements are mandatory and will also help to clarify the role of cardiorespiratory synchronization.

(2) A second limitation has to be mentioned regarding the succession and number of control sessions (see Fig. 1). The first control sessions was performed after 2/3 of the speech sessions, while the second and third were performed at the end of the 15-week experiment. Moreover, due to compliance problems, only three con-

trol sessions could be totally performed in each subject compared with six hexameter or alliteration sessions.

6. Implications and Outlook

(1) In subsidiary areas of sciences or in interdisciplinary research, concepts are sometimes formed by adopting terms from natural sciences, accepting that well-defined terms inevitably lose their unequivocal meaning. Another reason for misunderstanding and misinterpretation may be an ambiguous nomenclature to elude any form of commitment. In our case the terms ‘strengthening and harmonization of rhythms in man’ are liable to irritate the scientific community. Both terms are rarely used in scientific contributions, and like for the term ‘rhythm’ itself, definitions are lacking. In cardiovascular time series analysis the term ‘harmonization’ is sometimes used to illustrate the activation of harmonics in Fourier spectra, or to denote frequency coordination between different (harmonic) oscillators, i.e. an adjustment of constant integer frequency ratios on average [26-28]. This study has shown that both terms can be interpreted in a more general way. ‘Strengthening of rhythms’ could simply mean enhancing the predominance of rhythmic patterns in the dynamics under consideration; and ‘harmonization of rhythms’ can be interpreted as requiring the cyclical stability of typical phase locking patterns and thus indicating an improvement of coordination processes. Both interpretations are straightforward and can be easily put into practice.

(2) The study design chosen is a compromise between a cross-sectional survey and a classical single case study. Due to the high number of similar exercises together with their controls in each subject, the results provide evidence of the efficacy of ATS in some individuals (with the reservation that in the present study the number and the order of control sessions are critical; see limitations above). Furthermore, by combining the results from seven individuals more general statements could be made on a broad data basis. We therefore conclude that similar (improved) study designs, with a carefully balanced number of longitudinal and cross-sectional measurements, in general, are well suited in the field of creative arts therapy research.

(3) Aldridge [29] reviewed the work on the role of verbal and (improvised) musical communication in therapy and medicine ten years ago. The author emphasized that speech and musical improvisation on the one hand and cardiovascular control on the other hand are mutually dependent and do influence each other. In his conclusions he therefore reminded his readers of the necessity to also include physiological parameters such as heart rate and heart rate variability in music therapy research. The results of the present study have shown that this may also be essential for research on guided speech therapy to provide a more holistic view of the complex interplay between (exciting) external and (resonating) internal rhythms of man. Furthermore, physiological parameters in general also help to improve objectivity in creative arts therapy research since they have the potential to demonstrate the stimulation of self-regulatory processes or the subtle redressing of psychophysiological balance due to therapeutic intervention.

Acknowledgements

H.B. and D.C. acknowledge financial support from Weleda AG, Schwäbisch Gmünd, Germany. M.M. acknowledges support from the special research project 'Optimization and Control' (part 312) of the Austrian Research Fund.

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Footnotes

Footnote 1

A detailed description of the HRR method can be found in [2] which can be downloaded from the website:

<http://ajpheart.physiology.org/cgi/content/abstract/277/5/H1762>

Footnote 2

A binary musical pattern class is defined as a set consisting of all binary patterns with constant pattern length which can be transformed into each other by rotation (shifts in origin) or by permutation (exchange) of 1s and 0s. One can also think of a necklace with white and black beads. Moving beads from one side to the other (rotation) or exchanging white and black beads (permutation) does not affect the symmetry type of the necklace.

Table 1

Study population

Subject	Gender	Age	Height (cm)	Weight (kg)
1	f	43	170	56
2	m	41	173	64
3	f	53	168	65
4	f	43	178	56
5 (smoker)	m	43	172	79
6	f	59	170	54
7	m	26	179	81
mean		44.0	172.9	65.0
SD		10.3	4.2	11.1

Table 2

Lower and upper quartile and median values (low, mid and high values in C) of ΔPP in individual subjects

Subject	Control ($N = 3$)			Hexameter ($N = 6$)			Alliteration ($N = 6$)		
	low	mid	high	lq	med	uq	lq	med	uq
1	-6.4	-5.2	2.8	10.2	11.1	14.5	4.7	8.5	13.2
2	-4.2	-2.8	-0.8	4.2	5.1	8.8	1.7	7.0	8.8
3	-1.3	-0.4	0.7	-0.1	1.7	2.4	-4.0	-1.8	0.3
4	-2.4	-2.0	-0.8	0.3	0.8	1.4	0.2	0.8	1.0
5	-0.0	0.7	1.6	2.1	4.2	6.9	-0.7	1.0	3.2
6	-4.2	-1.4	1.2	2.1	2.2	2.7	0.3	0.7	2.1
7	-0.4	-0.2	0.0	0.2	0.7	1.4	-0.4	0.0	0.3

Table 3

Spearman rank-order correlation coefficient matrix from all heart rate parameters during S1 and S2 (210 values)

	<i>LF</i>	<i>HF</i>	<i>BAL</i>	<i>RR</i>	<i>PP</i>
<i>LF</i>	1.00				
<i>HF</i>	0.30	1.00			
<i>BAL</i>	0.45	-0.66	1.00		
<i>RR</i>	0.56	0.58	-0.11	1.00	
<i>PP</i>	-0.35	0.51	-0.73	0.11	1.00

Figure legends

- Fig. 1 Experimental protocol: 15 one-hour sessions were performed in each subject at regular time intervals of one week, and sessions were divided into three different periods of measurement (see text).
- Fig. 2 Illustration of a 7:2 phase locking of heartbeat (the vertical bars mark the R time) and a heart period modulating harmonic oscillation (e.g. respiration). The effects on the heartbeat period and its symbolic dynamic are shown; the two possible binary patterns are complementary and belong to the same pattern class 22.
- Fig. 3 & 4 Box and whisker plots of all subjects' median differences from S1 to S2 for three groups of exercises (C, control exercises; H, hexameter exercises; A, alliteration exercises); the p-values at the bottom of each plot describe the probability that the median of median differences is zero; the p-values on top classify the similarity of parameter change between the groups; the box plots display median and quartiles (horizontal lines), mean value (star), and maximum and minimum values (whiskers).
- Fig. 5 Correlation diagram and Spearman rank-order correlation coefficient (r) between $\ln PP$ and $\ln BAL$ (ln: natural logarithm)
- Fig. 6 Relative frequency of S1 and S2 sequences with a predominant occurrence of cyclically recurrent $n:2$ cardiorespiratory phase locking patterns over all subjects.

Figure 1

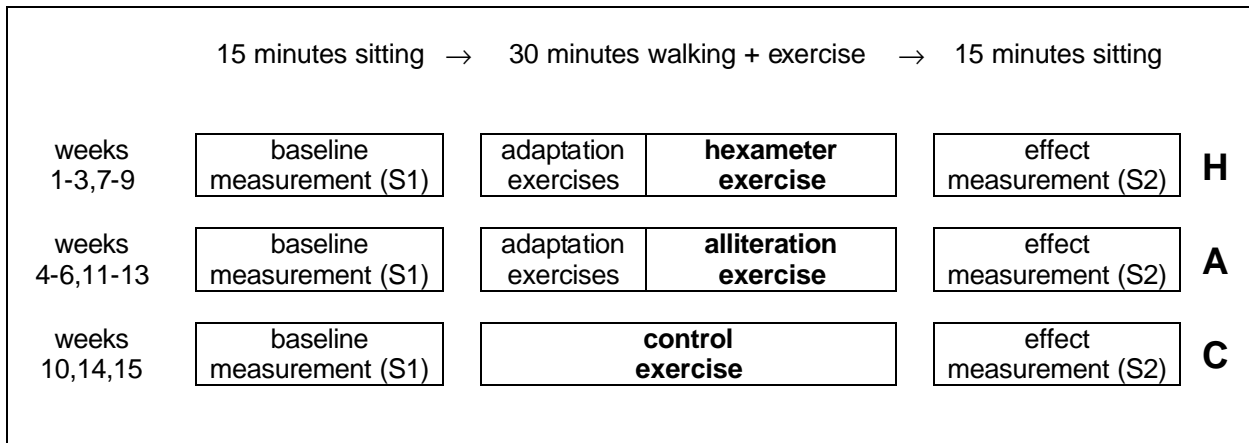


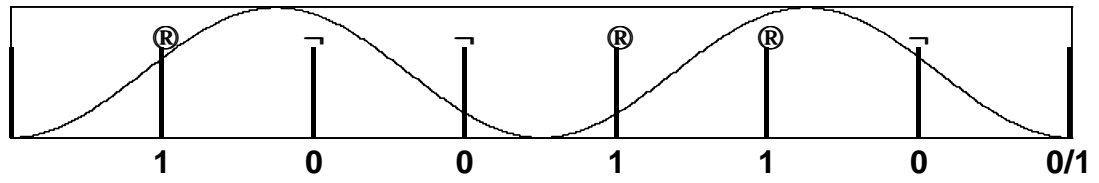
Figure 2

Figure 3

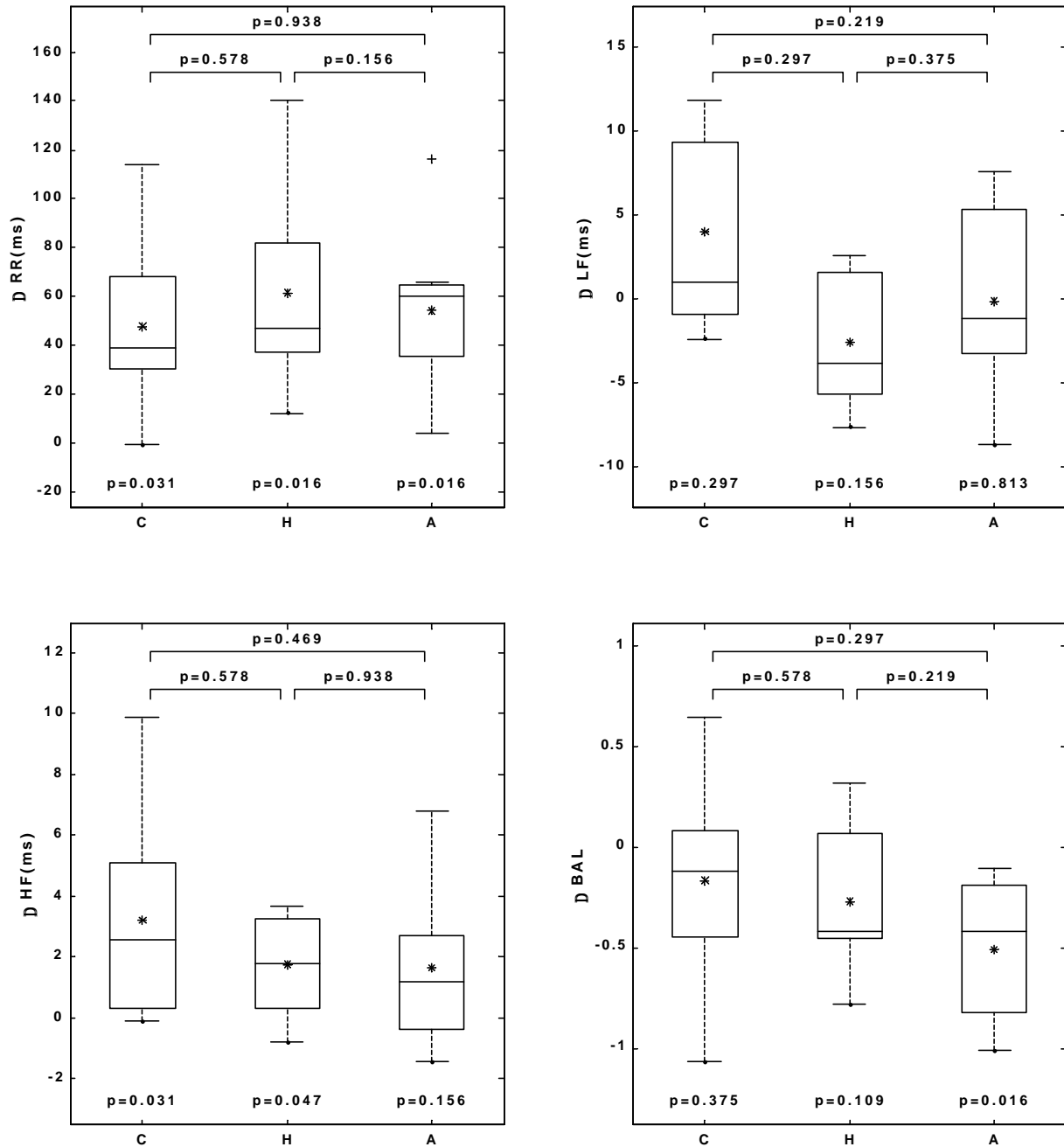


Figure 4

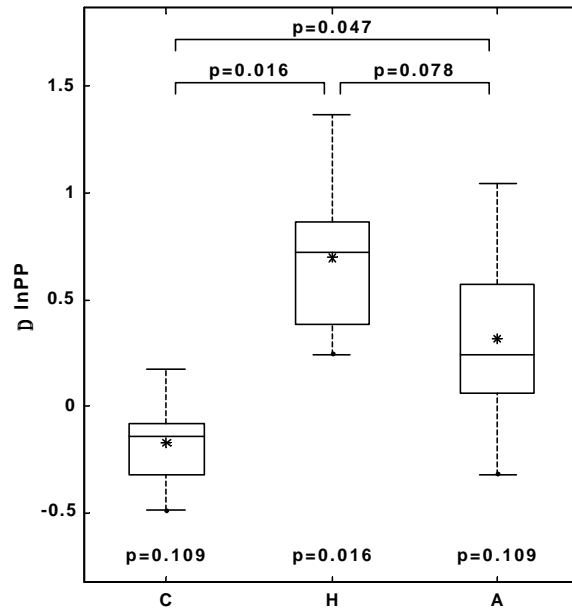


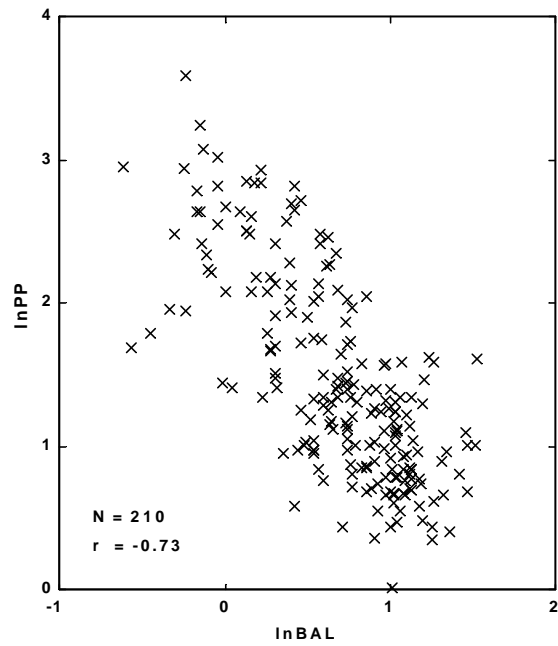
Figure 5

Figure 6

