CHARACTERISTICS OF SILENT COUNTINGIN SYNCHRONIZED SWIMMERS

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This article describes the temporal characteristics of silent counting as used during a competition by the Russian youth team of synchronized swimmers. The athletes listened to the music that accompanied their performance at the competition. Different indices of silent counting were defined, such as the beginning and cessation of different periods of counting, counting frequency, the stability of the temporal structure of silent counting, the degree of synchronization of silent counting at different moments during the sports program. We studied the relationship of these characteristics of counting with expert estimates of the athletes' sense of tempo, coordination of movements, and choreographic abilities.

Keywords: synchronized swimming, synchronicity of movements, silent counting, regulation of motor activity.

Synchronized swimming makes high demands on the synchronicity of athletes' movements (Sysoeva, Portnova, & Ivanitsky, 2007; Bespalov & Leonov, 2008b). To synchronize the movements of athletes silent counting is often used so that the performance of certain motor elements is associated with units of counting. Synchronized swimming is accompanied by a musical composition, various parts of which are played using different tempos. Athletes can count silently by triplets (1, 2, 3, 1, 2, 3…), eights (1, 2, 3, 4, 5, 6, 7, 8 …), and so forth, in accordance with the tempo of the music and the current motor task. Some parts of the musical composition are not accompanied by silent counting. During pauses between periods of counting the team rebuilds and prepares for the next series of movements.

Perceived melody and perceived movements of other athletes are external benchmarks for the performance of synchronous movements, whereas silent counting and motor memory form a system of internal benchmarks. In the initial stages of developing a new program, the external benchmarks dominate in the regulation of movements, while after the athletes are trained to perform a program, the internal ones are dominant. As coaches note, after the development of a program athletes with well-organized silent counting can perform the program at a high level without its musical accompaniment, while it is not possible to do so without silent counting.

The structure of silent counting is determined by the moments of the beginning and cessation of counting periods at different stages of the program, as well as the count pace, or the intervals between units in different periods of counting. The structure of the athletes' silent counting in the performance of sports programs is designed by coaches at the stage of program development, and it depends on the motor elements included in the program and the pace of the musical composition. An important characteristic of silent counting is the stability of its individual structure, which is determined by how well the athlete reproduces the structure during subsequent performances of a program.

For silent counting to successfully perform the function of synchronizing the movements of different athletes, it has to have a sufficient degree of synchronicity during repeated performances. If the silent counting of different athletes is not well synchronized and its structure is not stable, the athletes cannot perform at a high level.

Because silent counting is rigidly connected with the performed movements by signaling relationships, we can assume that the degree of synchronization of the athletes' silent counting can predict the degree of synchronization of the outer movements.

In this connection the problem arises of developing quantitative indicators for the synchronicity and stability of the internal count structure in trained athletes. One of the goals of our work was to solve this problem by having the athletes count silently to the music that accompanied the sports program at the competition.

One can also assume that the ability of athletes to develop stable silent counting is dependent largely on their sense of the tempo of the musical composition. In our research, this assumption was verified by calculating the correlation between the characteristics of the athletes' stable counting and estimates of their sense of tempo that were received from the team coaches.

The specific counting structure for each program is developed in athletes during practice with the help of special exercises. In the course of practice the individual count structures of different athletes converge. At the same time their counting acquires a synchronous structure.

Absolute coincidence in time of all temporal characteristics by different athletes is impossible to achieve – in other words, absolute synchronicity of movements is impossible. It is therefore necessary to identify and assess the degree of synchronicity of different characteristics of the individual movements in a group. At practice sessions this is done by athletes and their coaches, and during competition it is also done by judges and spectators. However, their assessment is largely subjective because it is based on a holistic visual perception of movements rather than on the results of instrumental measurements of the degree of temporal coincidence of their various characteristics. In this connection the problem arises of developing diagnostic methods and quantitative indices of the synchronicity of the movements that could be used in the training process for creating specialized simulators. In our research, for assessment of synchronicity and stability of the silent-count structure, several indices and a professionally specific test method based on a musical composition that has been used in synchronized-swimming competition have been developed.

Methods

Participants

The participants in this test were 10 synchronized swimmers from the Russian youth national team who were practicing for international competition.

Procedure and Test Material

To study the characteristics of silent counting, the athletes listened to the musical composition that would accompany their performance at the forthcoming competition. While listening to the music sample, they had to press a key at those moments when the units of counting were pronounced silently. The instruction was the following: "While listening to a musical sample you have to keep counting silently in the same way as at the performance of your sports program. Simultaneously with the internal pronunciation of count units you must press the keyboard key." When listening to the music sample, the athletes counted silently by eights (1, 2, 3, 4, 5, 6, 7, 8; 1, 2 … 8; …), as they did during practice.

The duration of the music sample was 1.3 minutes, whereas the duration of the complete musical composition was 5 minutes. The music sample was played through headphones using a computer program that allowed the moments of the keystrokes to be recorded and marked as dots on a horizontal line that was a graphic representation of the music sample. According to the developers of the program the registration accuracy of the key stroke is 1 ms. This degree of accuracy suggests that the temporal structure of the key strokes accurately reflects the temporal structure of the silent counting.

To assess the stability of the temporal structure of individual silent counting the music sample was presented twice to each athlete. In the second test session participants were asked to count silently and to press the key as in the first session. The timing of the entire test was about 3 min.

To study the validity of the index of the instability of silent counting, this index was compared with expert estimates of the following professionally important qualities of athletes: (a) diligence and perseverance during practice, (b) a sense of tempo, (c) coordination of movements, (d) choreographic abilities. These qualities were evaluated by three athletes' coaches on a 5-point scale. Their estimates were the results of collective discussion of each athlete's qualities.

Results and Discussion

The temporal structure of the silent counting when the athletes were listening to the music sample is shown in Figure 1. The music sample was turned on at time t_0. The first pause in counting and pressing the key

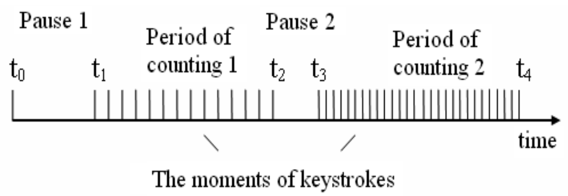

Figure 1. The temporal structure of silent counting (or keystrokes) when the athletes were listening to the music sample

lasted from t_0 to t_1. Then, from t_1 to t_2 the athletes counted by eights with a frequency of about 1 unit/s. The second pause lasted from t_2 to t_3. After that, from t_3 to t_4, the athletes counted silently by eights again and pressed the key, the frequency of which was approximately two times faster than in the first period.

Average individual beginning and cessation moments of the first and final keystrokes in different counting periods over the two sessions are presented in Table 1 and Figure 2. Figure 2 shows that the beginning and the cessation of the first period of counting occurs with high group asynchrony. The group asynchrony of time moments t_1, t_2, t_3, and t_4 (this is the beginning and cessation of two periods of silent counting) can be evaluated using two indices: the variation coefficient t_j and the range of deviation R of these moments.

Table 1

Average Individual Moments t_j of the First and Last Key Stroke in Different Periods of Silent Counting

Participants	Beginning and cessation moments of silent counting (s)			
	$j=t_1$	$j=t_2$	$j=t_3$	$j=t_4$
AV	8.098	33.205	36.395	76.390
VD	7.695	33.167	36.693	76.380
VK	9.884	24.247	36.886	76.339
MD	7.589	33.277	36.429	76.681
OA	11.772	27.489	36.493	76.534
PS	7.538	33.176	34.916	76.606
PE	9.730	22.969	36.692	76.585
SA	7.475	33.251	34.737	76.590
SM	9.806	33.090	34.785	76.382
ShV	7.655	33.306	36.457	76.512
Variation coefficient (V_t_j)	16.9%	13.5%	2.4%	0.2%
Range of deviation (R_t_j)	4.297	10.337	2.149	0.342

The variation coefficient was calculated using the following formula: $V\_t_j = (\sigma_j/t_{av\text{-}j})\cdot 100\%$, where $t_{av\text{-}j}$ is the average value t_j ($j = 1, 2, 3, 4$) for all subjects of this group and σ_j is the standard deviation t_j. The variation coefficients for each t_j are shown in the second row from the bottom of

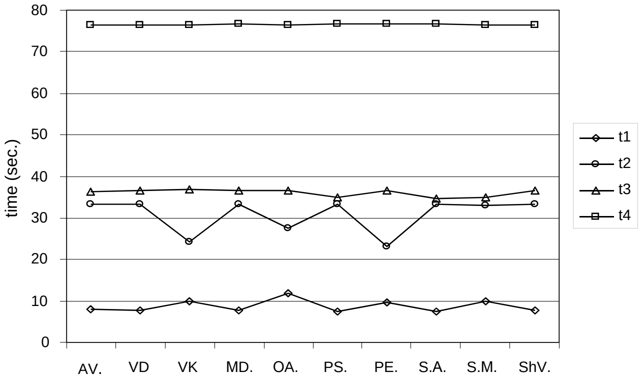

Figure 2. Average individual moments of the beginning and cessation of silent counting in the first and second periods

Table 1. The larger the variation coefficient of time t_j is, the higher is the group asynchrony at that moment. Table 1 shows that the group asynchrony of silent counting at the given index is sharply reduced from the first period of counting ($V\_t_1 = 16.9\%$, $V\_t_2 = 13.5\%$) to the second one ($V\_t_3 = 2.4\%$, $V\_t_4 = 0.2\%$), and the cessation of both periods is more synchronous than their beginning.

Another indicator of group asynchrony of silent counting at different stages of the sports program is the range of deviation of individual time moments t_1, t_2, t_3, and t_4. This index is calculated by the formula $R\_t_j = t_{j\max} - t_{j\min}$, where $t_{j\max}$ and $t_{j\min}$ are the maximum and minimum times t_j (the start and the end of counting periods) in this group of athletes. Values R_t_j are at the bottom line of Table 1. This indicator also shows that the silent counting becomes more synchronous at the end of the second period.

Another temporal characteristic of silent counting is the tempo, which is manifested in the number of keystrokes per second. Frequency (or tempo) of counting in each period is inversely proportional to the average duration between two successive strokes. Table 2 shows the durations (or time intervals Δt_j^i) between two successive keystrokes in the first and second period of silent counting; these time intervals were calculated for each athlete and were averaged over the two test sessions.

Table 2

Individual Duration (Δt^i_j in Seconds) Between Keystrokes in the First and Second Period of Silent Counting

i	Participants	Period of Counting	
		$j = 1$	$j = 2$
1	AV	1.004	0.506
2	VD	0.999	0.506
3	VK	1.026	0.503
4	MD	0.756	0.503
5	OA	0.982	0.504
6	PS	1.046	0.505
7	PE	0.802	0.505
8	SA	1.031	0.510
9	SM	0.970	0.507
10	ShV	0.789	0.507
	Variation coefficient $V\_\Delta t_j$	11.9%	0.4%
	Range of deviation $R\_\Delta t_j$	0.29	0.007

Two indicators of individual variability in the time intervals between the units of counting are shown in the lower rows of Table 2. The first index is the variation coefficient of individual intervals Δt^i_j between the keystrokes: $V\_\Delta t_j = (\sigma_j / \Delta t_{av\text{-}j}) \cdot 100\%$, where $\Delta t_{av\text{-}j}$ is the average value Δt_j ($j = 1, 2$) for all subjects (i) of this group and σ_j is the standard deviation Δt_j.

The second index is the range of deviation of time intervals between the adjacent units of counting. This index is calculated by the formula $R\_\Delta t_j = \Delta t_{j\max} - \Delta t_{j\min}$, where $\Delta t_{j\max}$ and $\Delta t_{j\min}$ are the maximum and minimum intervals between the units of counting in the first and second period in this group of athletes.

Table 2 shows that in the second period the counting tempo of different athletes is virtually identical ($R\_\Delta t2 = 0.007$ s). However, it does not mean that the count is synchronized because different athletes end the second period of counting at various moments ranging from 0.342 s (see Table 1).

The important characteristic of an athlete's silent counting is the stability of its temporal structure, which in this case is determined by the stability of the intervals between the moments t_j. If in the first test session an athlete begins and ceases the silent counting at the moments t_1, t_2, t_3, and t_4, then in the second test session these moments may differ considerably: $t_1 \neq t'_1$, $t_2 \neq t'_2$, and so forth. In this case, the structure of the silent counting for the athlete is unstable.

The index of the instability (Ind_S_t_j) of silent counting for each t_j and each athlete is calculated using the following formula: Ind_S_$t_j = |t_j - t'_j| / t_{av\text{-}j}$, where $|t_j - t'_j|$ is the absolute value of the time difference in the first (t_j) and second (t'_j) test session, and $t_{av\text{-}j}$ is the mean value of these times. The instability indices of silent counting are presented in Table 3. The higher value is the index; the temporal structure of the counting is less stable.

Table 3

Indices of the Instability of Silent Counting at the t_1, t_2, t_3, and t_4 Time Moments

Participants	Ind_S_t_1	Ind_ S_ t_2	Ind_ S_ t_3	Ind_ S_ t_4	Average over t_j index Ind_ S_ t
MD	0.001	0.0003	0.001	0.001	0.001
ShV	0.005	0.0002	0.002	0.001	0.002
VD	0.004	0.002	0.014	0.002	0.005
SA	0.047	0.003	0.002	0.001	0.013
AV	0.087	0.006	0.001	0.001	0.024
OA	0.008	0.334	0.0001	0.005	0.087
SM	0.411	0.005	0.003	0.001	0.105
VK	0.373	0.025	0.025	0.002	0.107
PS	0.433	0.103	0.009	0.005	0.138

In Table 3 the athletes are listed in ascending order according to the average value of the index of individual instability of silent counting (Ind_S_t_j). The great individual differences on this index show the high discriminative capacity of this indicator, which allows us to distinguish athletes with stable and unstable silent counting.

The reliability of this index can be estimated using correlation coefficients between the columns in Table 3. Thus, the correlation coefficient between Ind_S_t_1 and Ind_S_t_3 is $r = 0.41$ (for $p = 0.245$), and the correlation between Ind_S_t_2 and Ind_S_t_4 is $r = 0.58$ (at $p = 0.076$). Therefore, if an athlete's silent counting is unstable in the first period, it will probably also be unstable in the second period of counting.

Table 4 shows the expert estimates of the athletes' professionally important qualities on a 5-point scale. The expert estimates of sense of tempo in the athletes are correlated negatively ($r = -0.73$, with $p < 0.05$) with the average index of instability (Ind_ S_ t) of their silent counting. This result increases the validity of the index of the instability of silent counting. Correlations Ind_ S_ t with other Table 4 scales were not significant ($p > 0.05$).

Table 4

Expert Assessments of the Professional Qualities of Athletes on a 5-Point Scale

Participants	Diligence and perseverance	Sense of Tempo of tempo	Coordination of movements	Choreography abilities
MD	3	2	2	2
ShV	4	3	4	5
VD	4	3	4	4
SA	3	3	4	4
AV	3	3	4	3
OA	4	2	4	3
SM	4	2	4	3
VK	4	2	3	3
PS	3	2	2	2

Correlation analysis of the Table 4 scales revealed a significant correlation between the following scales: sense of tempo × choreography ($r = 0.78$, with $p = 0.014$) and coordination of movements × choreography ($r = 0.77$, with $p = 0.015$). Correlations between the other scales were not significant ($p > 0.05$).

The reasons for the great differences in the indices of the stability of the temporal structure of silent counting in different athletes should be considered further. Are they the result of negligence in performing the test or do they reflect weakness in the skill of silent counting or are they determined by individual characteristics of the time sense of these athletes? The first two reasons can be easily eliminated because of an increase in the interest in high test results when the instructions were more severe and the training preceding the test trials included feedback about the results. However, the characteristics of time sense are conservative and hard to improve during direct practice.

Some characteristics of time sense in these athletes were measured previously using the techniques of 2–5 s reproduction intervals filled with metronome beats, continuous sound, physical effort, and "empty intervals" (Tzukanov, 2000; Bespalov, Leonov, & Strelkov, 2006), as well as using methods of estimating the latent time of motor reactions to sound (Gellerstein, 1958; Bespalov & Leonov, 2008a). The index of the stability of the counting structure was compared with an average relative error ε_{ave} of reproducing the 1.5 s and 1.67 s intervals, which were determined by 4 and 6 metronome beats, respectively (the metronome rhythm was 2 and 3 beat/s, respectively). The average relative error of reproduction was calculated using the following formula: $\varepsilon_{ave} = (t_{repr} - t_{preset}) / t_{preset}$, where t_{preset} is the duration of a given interval, and t_{repr} is the average over 10 trials of the reproduced interval.

The correlation coefficients between Ind_S_t and $\varepsilon_{ave\text{-}4\text{-}blows}$ or $\varepsilon_{ave\text{-}6\text{-}blows}$ were negative and equal to $r = -0.5$ ($p = 0.1$) and $r = -0.4$ ($p = 0.12$), respectively. Thus, athletes with an unstable structure of silent counting tend to have negative values ($\varepsilon_{ave} < 0$) – that is, they do not achieve complete reproduction of the intervals – whereas athletes with low Ind_S_t values more often "overreproduce" intervals – that is, they reproduce these intervals with more duration than required ($\varepsilon_{ave} > 0$). Why in the athletes who "hurry" (do not achieve complete reproduction of the intervals) is the structure of the silent counting less stable? This question should be studied further.

Conclusions

Silent counting in synchronized swimmers serves as a time regulator for the subsequent motor performance and is a psychological means of synchronization of the movements that are associated with it. We studied the temporal characteristics of silent counting used by athletes during synchronized swimming, which is accompanied by a musical composition. The athletes listened to the music for their performance at a forthcoming competition. While listening to the music they had to press a key at those moments when the units of counting were pronounced silently. The moments of the keystrokes, which reflect the moments of uttering the units of counting during the sports program, were recorded.

Individual and group characteristics of silent counting were defined. Individual characteristics of silent counting were specific in each athlete and included the following:

1) time moments of beginning (t_1 and t_3) and time moments of cessation (t_2 and t_4) of silent counting in the first and second test sessions;
2) count rate, which was measured by the frequency of counting and by the average duration between two consecutive units of count;
3) stability of the temporal structure of silent counting or reproducibility of its structure in repeated test sessions.

Great differences were observed (from 0.001 to 0.138) in the value of the index of the instability of silent counting in different athletes. The great individual differences in this index show the high discriminative capacity of this indicator, which allows us to distinguish the athletes with stable and unstable silent counting. It can be assumed that athletes with unstable silent counting produce movements associated with the counting that are hard for other team members to predict; this problem makes group synchronization difficult.

The indices of individual instability of silent counting also are significantly and negatively correlated (r = -0.73) with expert (coach) estimates of the sense of tempo in athletes. Estimates of the sense of tempo significantly correlated with expert estimates of the choreographic abilities of athletes (r = 0.78). These correlations increase the diagnostic value of the index of the instability of silent counting in athletes.

Group temporal characteristics of silent counting reflect the group asynchrony of time moments t_1, t_2, t_3, and t_4 (this is the beginning and the cessation of two periods of silent counting) and can be evaluated using two indices–the variation coefficient t_j and the range of deviation of these moments.

These indices allow us to estimate the synchronicity of silent counting at different moments of sports programs. Based on these assessments of silent-count synchronicity coaches and athletes can use extra practice and exercises for improving the synchronization of counting.

Based on the introduced indices of silent counting, certain predictions about the synchronicity associated with counting and athletic movements can be made. Thus, Table 1 shows that $R\_t4 = 0.342$ s–that is, athlete VK ceases counting in the second period 0.342 s before athlete MD. This difference could mean that at the 76th-77th second of the program the movements of these athletes are asynchronous, providing that at this moment the speed of their movements exceeds 1.5-2 ms.

The introduced characteristics and indices of silent counting can also be used in evaluating the effectiveness of exercises aimed at the development of this skill. Athletes can be informed about their indices as psychological feedback when using training simulators.

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