Rhythm and Learning

Dirk Cysarz

We might be inclined to define rhythmical phenomena as periodically oscillatory processes. A moment's thought, though, proves this statement to be incomplete. Taking the natural pattern of the course of the sun, for example, we could surely define it as a periodical feature that brings us day and night, but at the same time it is characterized by its fixed itinerary in the sky. Its position is predictable and no major deflection from physical laws is ever likely to occur. By the same token, many processes in our technical world imply a periodicity—such as clocks and turn signals on cars—but, again, they follow a standard sequence that can be correlated to physical laws. These periodical processes are fixed; no mutation is possible. And rightly so. If a clock were not accurate, it would be of little value, and if the sun were to cease following its fixed course, we would quickly recognize that the world was "out of joint."

These simple examples show that the notion of "rhythm" is not adequately defined within the inorganic or inanimate world. The organic, animate world is different; here the essential can be shown by such rhythms as heart rate and breathing rate. Careful observation of both rhythmical functions shows that these are not fixed. In a healthy being, no heartbeat ever totally replicates another. Breathing is also flexible. Both functions adapt in order to meet the numerous requirements of everyday life successfully. When climbing stairs, heart rate and breathing rate accelerate. In a subsequent moment of physical rest, heart rate and breathing slow again. This flexibility, made possible by the rhythmic nature of the process, is typical of a healthy human being.

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A steadier, less flexible heart rate is also possible. This is not common in a healthy being, but is rather a consequence of an illness such as a heart attack. It is difficult to determine the consequences of a fixed breathing rate—there would be little possibility of speech or eating; both activities influence breathing rhythm. Briefly, in animate nature, the loss of rhythm brings considerable difficulties and consequences. A fixed rhythm denotes a pathological condition, a decided restriction of possibilities.

On the other hand, it is true that rhythms do not occur completely at random. Should the heart, for instance, lose its rhythm due to partial motionlessness—arrhythmia—a pathological condition is manifest. In this case, a "pacemaker" will restore certain vital margins of rhythm.

Based on these two descriptions of the loss of rhythm—one too regular, the other too chaotic—it is now possible to define rhythm more precisely. The rhythm of a healthy heartbeat ranges between the following two extremes: the fixed rhythm, which can also be defined as a meter at fixed intervals (and which is present in the inanimate world), and motionlessness that no longer represents rhythm as such. The margin between the two extremes can be fairly wide, and rhythm thus finds ample scope.

Bearing these considerations in mind, it is readily understood why rhythm can be defined in the abstract as "a chronological repetition of similar (timed) structures." Rhythm contains aspects of the past within itself—something that has once occurred is repeated. Rhythm also allows for an aspect of the future, as the precedent feature is not stiffly repeated. Rhythm can undergo variation, offering innovation. This mutation is intended within a precise framework, however, or it would happen randomly. Rhythm unites both past and future. This combination is continually refreshed, not becoming obsolete and not running ahead of time. It takes place in the present.

Another attribute of rhythm is mediation of opposite, extreme conditions. In the heartbeat, for instance, two incompatible conditions are found: systole, during which the muscle of the heart contracts; and diastole, during which the same muscle relaxes. Rhythm is the mediating, linking element between these two conditions. In the same way, past and future are irreconcilable; only rhythm itself links one to the other successfully.

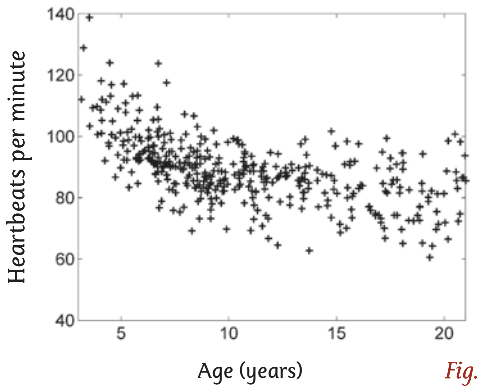

Fig. 1

Rhythms in Childhood and Adolescence

What do the foregoing statements about rhythm imply for development in childhood and adolescence? In a recent survey, we analyzed the development through childhood and adolescence of the rhythm of the heartbeat. Our research shows that the average heart rate decreases until around the age of 10 (Fig.1). We found that the heart rate in toddlers averages 110 beats per minute and only 90 beats per minute at age 10. The rhythm of the heartbeat also changes. In toddlers we find a rather fixed rhythm; rhythmical margins are narrowed by increased heart rate. From around age 10 onward, the quality of the rhythm of the heartbeat reaches features comparable to those of an adult.

Another significant human rhythm is circadian rhythm. Different studies have confirmed subjective impressions. Some people prefer to get up early in the morning (so-called "early birds" or "larks"). Conforming to their predisposition, these people are more productive early in the day, feel tired relatively early at night, and tend to go to bed early. Their MSF ("midpoint of sleep on free days") occurs earlier in the night (Fig. 2). Other people prefer to sleep in. Their productive phase occurs rather late in the evening (so-called "night owls"). There are many nuances between these two extremes and the average person's sleep need occurs between them.

Roenneberg's assessment of the distribution of different circadian rhythms in a group of approximately 25,000 subjects shows that the subjective attribution of "owls" and "larks" is not constant; it alters during the lifespan. In childhood we find a strong tendency toward the "larks." The "larks" gradually become "owls" through about age 20; that is, through childhood and adolescence, the pendulum swings from one side to the other. This result conforms to the subjective experience of parents. Children tend to prefer to get up early and they tend to have early bedtimes. The older they grow, the less sleep they need and, consequently, bedtime is generally delayed. Adolescents start to sleep longer hours and no longer want to get up early. During adolescence, nights can sometimes turn into days, postponing bedtime. Perhaps surprisingly, around age 20 the pendulum starts to swing slowly back again. Over the next decades of life, we wend our way back to the "lark."

The authors of the survey associate this change of tendency with the end of adolescence. Although initially not linked to precise biological functions, some criteria (beyond the scope of this paper) are beginning to emerge. Another remarkable feature of this turning point is the distinct difference between genders. Men tend much more to be "owls" than women. This difference subsides only at around age 40.

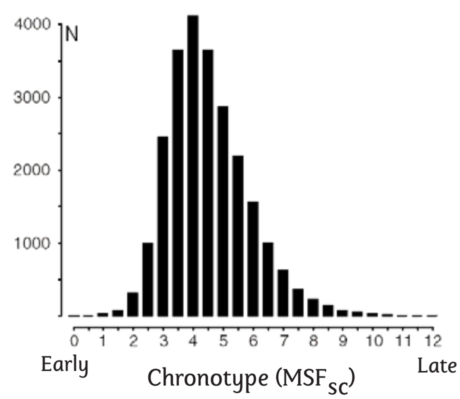

Fig. 2

If we compare the transition from "lark" to "owl" through childhood and adolescence with the development of average heart rate, it becomes clear that both functions differ in their progress. Heart rate is basically invariable from age 10 onward, whereas the circadian rhythm, including sleep habits, undergoes major changes in the years to follow. One may infer that these two functions have different implications for general development. The rhythm of the heart is fully developed around age 10, thus permitting the development of other capacities—the ability to love, for example, which is biologically manifested by puberty. Adolescents can rely on already-developed heart features and concentrate on unfolding further capabilities, which then manifest themselves in circadian rhythms.

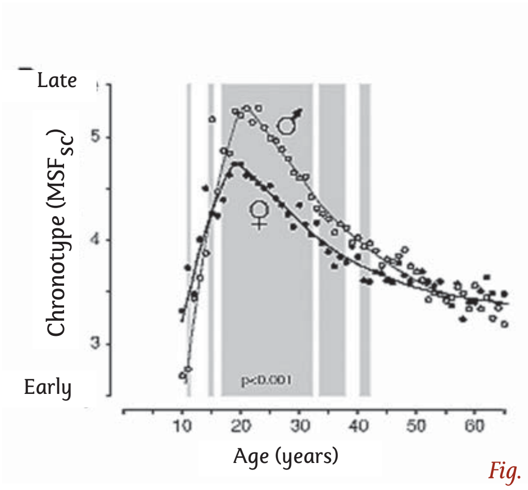

Fig. 3

The Circadian Rhythm and the Learning Process

In the past decades we have seen a remarkable number of studies regarding the relationship between learning and sleep. Many of these studies establish the relevance of sleep for the learning process. A significant number of these studies has been carried out at Harvard Medical School and at Lübeck University.

The American authors Stickgold, Walker, and their colleagues primarily study the performance of motor skills during wakefulness and sleep. In one study, subjects were asked to complete short finger-tapping tasks on a computer keyboard. The number of completed sequences and the errors were timed. The use of the computer allowed for the measurement of intervals between the tapping of keys. This experiment was repeated a few times during one day, at the end of which the subjects were allowed to have a night's sleep before being asked to perform the finger-tapping task again the next morning. The fact that the keystroke transition speed moderately increased during the day caused little surprise (see Fig. 4a). The number of sequences per training session rose slightly. The distinct, large augmentation of sequences after a night's rest, however, was astounding. Further practice following sleep showed only a "normal" increase, that is, the normally expected improvement in performance during the day (see Fig. 4b). Another surprising finding was that those keystroke transitions that had been difficult on the first day became clearly easier to perform following sleep. By contrast, these same transitions could not be improved during one day (see Fig. 5). Sleep, therefore, manifestly enhances those motor skills that affect both speed and fluency of movement. Although this study was carried out on a computer keyboard, it is evident that other motor tasks, like practicing a musical instrument, for example, follow the same principle.

An obvious next step was to ascertain to what extent a daytime nap influenced the learning of motor skills. Here again extraordinary results came to light. A midday nap also yields enhanced motor performance, albeit less than a night's rest (see Fig. 6). When both groups (subjects who did and did not nap) were tested again

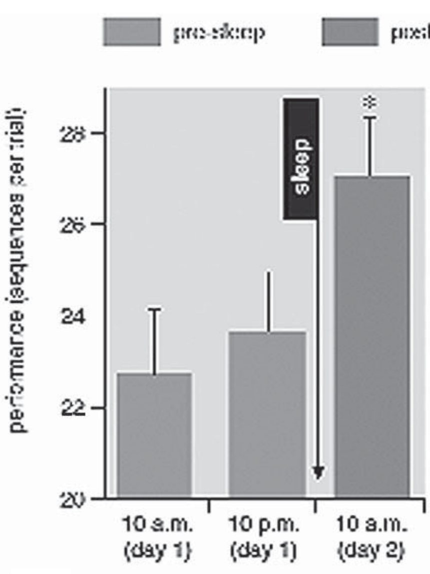

Fig. 4a

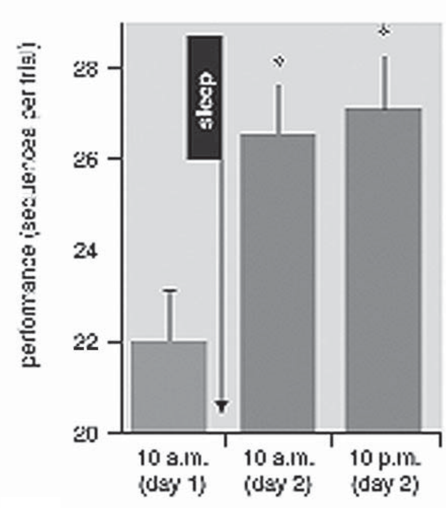

Fig. 4b

the next day, following a full night of sleep, those subjects who had napped showed only a slight additional increase in performance speed. Those who had not napped (who had only a night's sleep), however, showed a more significant increase in performance speed. Total daily improvement for both groups (nap and sleep and sleep only) was approximately the same.

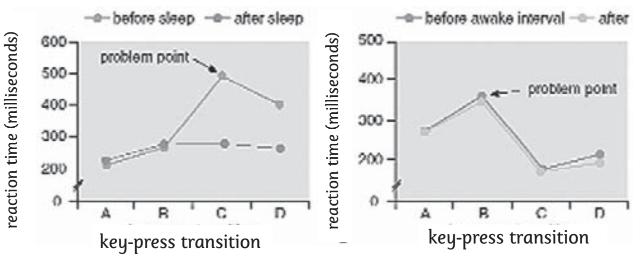

Fig. 5

These data suggest that there is a relatively fixed limit to performance enhancement in a 24-hour period. Even when one extends the period of sleep by repeated napping during the day, for example, it is not possible to exceed the daily limit of improvement. One conclusion to be drawn from these studies is that real, cumulative learning requires several sleep-wake cycles to be assimilated effectively. One 24-hour period is not enough.

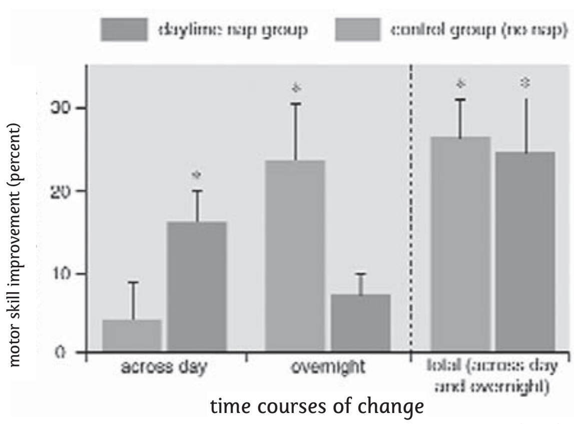

Fig. 6

Among others, an important study on the significance of sleep in learning to perform cognitive tasks was conducted by the endocrinologist J. Born and his team. Subjects participating in this experiment were asked to transform a given string of digits into a new sequence following a fixed scheme (see Fig. 7). Each string was composed of the digits 1, 4, and 9. Subjects had to follow two rules. The first was the "same rule" (for example, 1 and 1 results in 1). The second was the "different rule" (for example, 1 and 4 results in the remaining digit, 9). Initially, the first two digits of the string are transformed, and the next digit is processed with the preceding result. After the final transformation in the string, the last digit is entered as a result. This procedure allowed measurement of the time that elapsed between the presentation of the transformation task and the first result.

The relatively long procedure (duration: approximately 9 seconds) could be significantly reduced by adopting a trick that was not revealed to participants. The final result of the previous transformation permitted subjects to recognize a shortcut that would save them considerable time (approximately 2 seconds). Because the shortcut led to the final result much faster, it was easy to discern those subjects who had discovered the trick.

How many subjects detected the shortcut? After practicing three times, more than 20% reached the solution (see Fig. 9, left bar). These subjects were then excluded from further study. The remaining participants were divided into two groups: the subjects in one group were allowed to sleep the following night, and the subjects in the other group had to stay awake. Surprisingly, almost 60% of those who had a night's rest were able to discover the shortcut the following day (see Fig. 9, middle bar). Only 20% of those who had not slept discovered the shortcut (see Fig. 9, second bar from the left).

Factors that might have affected the extraordinary increase in the group that had rested were excluded by using questionnaires (for example, had subjects dreamt of a solution?) and by testing additional groups to discover, for example, the possible influences of morning or evening trials (see Fig. 9, hatched bars). These results clearly show the influence of sleep on cognitive performance. The conditions of the study are artificial, but their import for the acquisition of other, real-life cognitive skills (learning mathematical rules, for example) is highly plausible.

The studies mentioned so far involved adults only, so to what extent can these findings be transferred to children and adolescents? Some first studies are beginning to show results that demonstrate similar phenomena for the young. In one study, children had to learn correctly at least half of given pairs of words. This procedure was

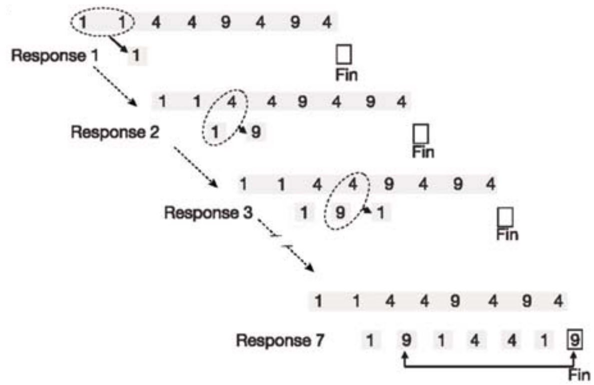

Fig. 7

performed with two groups at different times of the day: just before bedtime and in the morning. In both groups, at different points in the day, knowledge of the pairs of words was tested. The children belonging to the group that had been allowed to sleep right after studying, when tested the morning after their night's sleep, were able to remember three pairs more than they had the evening before. This result did not change when

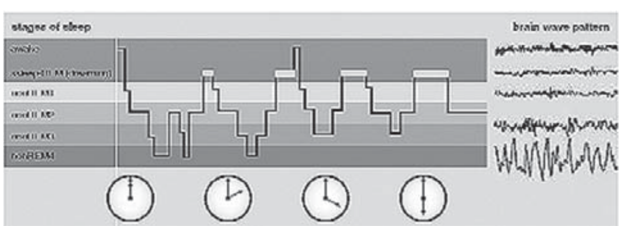

Fig. 8

tested a second time on the same day. When the pairs of words were studied in the morning, the children were able to memorize a new pair by the evening and to remember a set of two pairs the next morning after a night's rest. Studying just before going to bed yielded the best learning results. These findings lead to the conclusion that what was discovered to be valid for adults is likely also valid for children and adolescents. The conclusion for all groups is the same: sleep considerably enhances both motor and cognitive learning performance.

Learning Conditions

Clearly, sleep is an exceptional learning aid. (We may even be tempted to infer that a lot of sleep is beneficial to learning, but this is not necessarily so. Again, studies demonstrating this are beyond the scope of this paper.) The starting point for each of the studies included here was the subjects' first attempt at the task. Studies demonstrated that repeated practice, at intervals of a few hours, led to minor but constant improvement of motor skills. On the other hand, engaging intensively with the assignment did not lead to immediate improvement of cognitive skills. In both cases, however, intensive engagement with motor and cognitive challenges forms the basis for what is then carried into sleep. No subjects, however, awoke from their sleep able to master the tasks of the previous day immediately. An essential point here is that the task had to be resumed before it was possible to register a significant improvement. Given these results, we can formulate the following conditions for a learning process that includes sleep:

1. Initial practice of a motor or cognitive skill;
2. Sleep;
3. Resumption and practice of the skill.

Thus sequenced, it becomes apparent that the learning process has its own rhythm, one that builds on the circadian rhythm. Each of these three conditions may be further divided and treated as a rhythmic process involving practice and rehearsal followed by rest. We know, too, that sleep itself is a rhythmically structured process (see Fig. 8). Learning, then, clearly involves rhythmic processes that occur in different time scales.

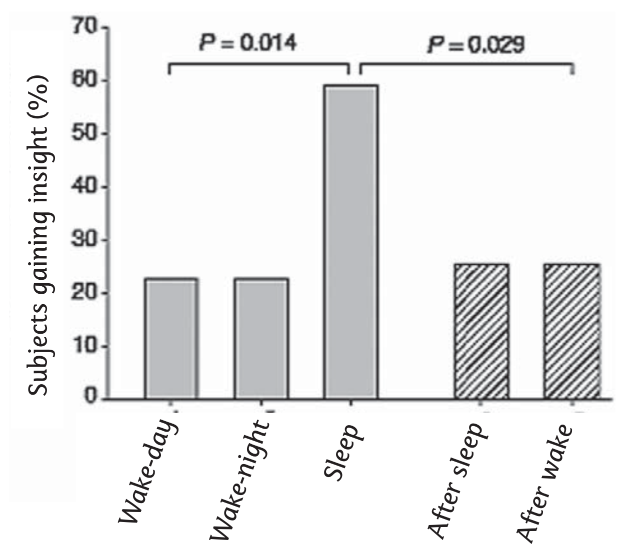

Fig. 9

Conclusion

Sound sleep is essential to wellbeing and regeneration, and sleep also sustains learning processes, especially, as we have seen here, for motor and cognitive skills. Educational concepts, of course, must take into account various time scales, from the very small—within a class hour, for example—to the very large, even vast—the lifespan. Further, we should bear in mind that the learning effect for one day is limited. The learning objectives we set must be realistic for the children and adolescents whom we teach. Finally, we should acknowledge that the phrase, "I need to sleep on it," is not empty procrastination, but a valid truth for human learning processes and, therefore, for education.

> [T]he phrase, "I need to sleep on it," is not empty procrastination, but a valid truth for human learning processes . . .

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Dirk Cysarz *is Chair of medical theory and alternative medicine at the University of Witten in Herdecke, Germany.*

This article was delivered as a lecture at the World Teachers' Conference in Dornach, Switzerland, on March 17, 2008. Thanks are due to the Waldorf Journal Project #12 *for permission to publish the article in the* Research Bulletin.