A Mobile Music Device for Runners

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Master Thesis

University of the Arts Bremen

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ABSTRACT

Laufen mit Musik kann sich nicht nur positiv auf die Stimmung eines Läufers auswirken, sondern gezielt zur Trainingskontrolle eingesetzt werden. Durch musikalische Rhythmus-Vorgabe kann ein Läufer leichter Stress bewältigen, aber auch versuchen in neue koordinativ-motorische Bereiche zu gelangen. Eine technische Grundlage für die Koppelung von Musik und Laufbewegung bietet die StepMan-Technologie des Fraunhofer IGD Rostock, die die Anpassung des Musiktempos ohne Veränderung der Höhen ermöglicht. Diese Master Thesis behandelt die Entwicklung eines mobilen Musikabspielgerätes für Läufer, das gezielt die Wiedergabe von Audiosequenzen mit Trainingsfunktionen kombiniert, um einen möglichst positiven Trainingseffekt zu erreichen. Die Herangehensweise ist gestaltungsorientiert und in Bezug auf Trainings- und Nutzeranforderungen analytisch fundiert. Neben der Entwicklung des Konzepts und der Funktionsweise für ein solches Gerät bilden der produktgestalterische Entwurfsprozess und die darauf aufbauende Umsetzung insbesondere der Benutzerinteraktion wesentliche Bestandteile dieser Arbeit. Das Ergebnis ist das *System Ritmo*. Es umfasst drahtlose Kopfhörer, einen Schrittsensor und als Kernelement ein Armband mit kombinierter Funktionalität zur Musikwiedergabe und Trainingssteuerung (*Ritmo Wrist Unit*). Daran schließt sich die Empfehlung zur Entwicklung einer ergänzenden Software an, die komplexe Trainingsplanung und –analyse unterstützen soll. Während sich diese Arbeit spezifisch auf die Entwicklung eines mobilen Musikabspielgerätes im Kontext des Lauftrainings bezieht, sind die dargestellten Überlegungen, Lösungen und Begründungen oftmals potentiell generalisierbar. Sie reflektieren die vielfachen Verwicklungen, die die Arbeitsweise eines Produkt- und Schnittstellengestalters auszeichnen.

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INTRODUCTION[1]

The initial idea for this thesis came up during a conversation about different ways to improve existing digital music players, which was stimulated by a recent course on alternative interaction techniques for mobile devices. I had never before thought about such a task but it soon became obvious that a music player designed especially for runners would have to fulfil different requirements than a common MP3 player.

Every time I go for a run I have to take up the challenge to find the right music playlist for my workout as my favorite music does not necessarily match my step frequency or workout intensity and mood. Also the rhythm and meter of popular songs is seldom made public and cannot directly be transferred to the runner's pace. Furthermore, the tempo changes from song to song. As professional audio software offers beat detection and tempo adjustment functions, the idea developed to adapt the beat of the music to the runner's exercise needs in order to avoid the interference of different rhythms (music beat vs. running steps).

Inspired by the *StepMan* technology of the Fraunhofer Institute for Computer Graphics, which uses algorithms for time scale modification of music without changing the pitch of the sound, designing a mobile music device for runners as a stand-alone application caught hold of me and eventually became the topic of my master thesis. Talking to people about their experience with mobile music devices confirmed my approach. Research, investigations and conversations with experts helped me to filter the relevant functions of a mobile music device for athletes and strongly encouraged a decisive focus on step frequency guidance.

1.1 Research Goal and Key Themes

The goal of my master thesis is to explore the role of a music player as a personal training device, and how the music player can be adapted to better fit the active context. My research and design concept focuses primarily on running, although it might also be applied to other physical activities. The idea is to develop a mobile music device that proactively integrates music into the athlete's training session.

In the following I present the most important key themes related to my work:

Music In Sports. Music plays an important part in sports. Working out at a gym, aerobics, or even a professional ball game cannot be imagined without music. Besides the entertaining effect of music, different research studies have shown that working out with music can increase the motivation of the athlete and additionally improve stamina, performance, and training efficiency. Music as an element to control the runner's workout sessions—particularly her step frequency, to motivate, and to cope with exertions should thus characterize the functions of the music player.

Mobile Music Player. Most of today's music players are designed to address particular "lifestyle" markets. People wear their mobile music player around their necks or arms like a fashionable extension of their bodies or of their personal selves. Although designed for different types of users, the music players do not differ in their substance. Some of them provide extra functionality to meet the interest of a specific target group. Yet, their differences are mostly decorative. Rather than for lifestyle, in my approach the music player should be designed for a specific context. The intended mobile device addresses people who like to develop their running performance, independent of their professions or lifestyles.

StepMan Technology. Equipped with the functions of a personal running computer, a music player for runners should enhance the workout experience and integrate music into the daily training session. The *StepMan* technology of the Fraunhofer Institute for Computer Graphics incorporates deceleration or acceleration of the music played without distorting its pitch. This technique can be used to deliberately control the runner's training by on-the-fly adaptation of the music tempo to a selected step frequency.

It is important to both elaborate the potential of the *StepMan* software and to develop a self-contained mobile application which combines the features of a running computer (including a sensitive accelerometer) and a music player. The result can be the basis for a presentation targeting commercial markets. It can inspire new services and devices in the field of interaction design, providing insights into sport activities and other mobile contexts.

Design Approach. The development of the music device integrates different aspects of design, including user research, interface design, three-dimensional and service design. Designing specifically for the use during workouts, I observe the ways runners think and focus on their physiological and psychological requirements. I would like to create a design solution that is derived directly from experience, rather than from mere theoretical backgrounds. The mobile music player becomes a training device for runners, and hence it provides a motivational incentive during the workout. The design employs mobile technology and music in a way that meets the needs of an active user.

1.2 Cooperation with the Fraunhofer Institute

The work presented in this thesis has been created in cooperation with the Fraunhofer Institute for Computer Graphics. This cooperation establishes an agreed standard and allows me to purse my work based on up-to-date technology. Therefore, the device conceived and designed within the scope of my master thesis bears the potential for being turned into an actual commercial product. For detailed information on the *StepMan* technology see Section 2.3.

1.3 What It Is Not

A new Running Computer. This mobile device concept primarily focuses on the integration of music into the runners' workout session. Yet, it is not about developing another running computer. Several very good and–in regard to technology aspects, running economy, and ease of use–up-to-date running computer solutions already exist. Therefore, and as I am not an educated sports physician, solutions for planning, monitoring and analyzing training are not the primary aim of my endeavor. Instead, the combination and integration of a classic music player with running computer functions are brought into focus. However, the design solution should consider and–if possible–facilitate the opportunity to integrate add-on applications, for example for biomechanical monitoring or follow-up implementation of advanced running computer functions (e.g. the generation of individual training plans).

A Didactic Training Device. The mobile music player is a training device that provides motivational incentives during the workout. It can be used to deliberately control the training by setting the tempo of the music and hence a specific step frequency. Yet, the device will not teach the runner how to perform or judge his/her running style.

Although empiric data on average stride length, cadence or other "running style values and measurements" exists, every runner has her individual running style (Daniels 1998:4). When taking into account the runners' gender, body measurements and age, the mobile music device will not necessarily be able to calculate adequate recommendations for each runner's perfect step length, cadence or type of training (Daniels 1998:32). Even if the mobile music system would employ neural networks or other techniques from the field of artificial intelligence research to perpetually learn

about its user and her performance and biomechanical data, it would still not replace a proficient human observer and instructor to give qualified running style advice. Teaching a runner to adjust her running style according to calculated data (based on average values or limited data-sets from personal monitoring) cannot not prevent but rather produce negative side effects. This renders the development of an explicitly didactic computational running device as an exclusive training guidance irresponsible regarding the runners' health and performance.

A Step Length Monitor. Both step length and step frequency directly influence the runners' motion and speed. The rhythm of music can be directly translated to the athletes' step frequency, while the length of a step is quite difficult to affect via music. Possibly, loud music or music played in front of the runner could be translated to making longer steps and quiet music or music played behind her could be translated to shorter steps. Yet, such commands or signals for step length adjustments have to be interpreted by the runner and will not be very specific. Even if the information was provided in centimeters or inches, the athlete might still have trouble to react accordingly. As the very structure of music implies adequate means for the mutual connection of rhythm and step frequency that can be exploited using the *StepMan* technology, this will be the main focus of this work.

A Heart Rate Monitor. Runners, especially in the amateur domain, often use heart rate monitors to train beneath or above a specific heart rate value or within a target zone. Such a sensor measures the runners' heart rate, which then can be related to their bodily condition. A music device that listens to the runners' heart rate could react according to the heart rate value. For example, if the heart rate gets too high, the music tempo could decrease immediately to motivate the runner to reduce her step frequency (or the other way around).

But as mentioned before, both step frequency and step length affect the runners' pace. As the tempo of the music addresses the step frequency only, the step length value is left out. A lower or higher cadence would indirectly affect the heart rate value of the runner, but this effect would not necessarily be the economically best way for the athlete to change her running style, her running intensity or bodily stress. Besides, music playback can affect emotionally and excite the athlete, “which in turn increases blood pressure and heart rate up to the target heart rate quicker than if there was no music” (Matesic & Cromantie 2002). This effect renders the heart rate an even more unreliable value with respect to training control. For these considerations, the option to use a heart rate monitor does neither appear realistic nor reasonable for this music player concept.

BACKGROUND 2

Within the las years running—one of the oldest and simplest sport disciplines at all—became increasingly popular and the running boom apparently is not coming to an end. Whether in the forest, streets or parks—runners of every age characterize the public image. There is not doubt about the positive effect of endurance sports, such as running, on body, mind and soul (Steffney 2004). Whether running in a group or alone, it helps to improve and stabilize the runner’s fitness and health and is a great compensation for the hectic daily life.

However, in repetitive solo endurance sports many exercisers suffer from diminished motivation and self-discipline and hence have a hard time to keep up with their exercise plan. Perseverance is often needed to make up for the lack of instant rewards after and fatigue or boredom during the workout session. Besides capturing the very moment to go for a run, the athlete has to deal with the demanding exercise itself and to find methods to manage the physical stress of the endeavor (Tenenbaum et al. 1999).

2.1 Running with Music

Listening to songs and tunes may be regarded as a welcome element of motivation for sports activities as music in its diversity appeals to a large number of otherwise very different individuals. Athletes frequently report to listen to music while running, stating that it makes endurance exercising more enjoyable, and that it actually motivates them to keep up with their exercising goals. The development of mobile music devices made running with music possible without great cost or weight so it can nowadays be regarded as a complement well suited for running routines. The option of mobile music offers runners coping strategies such as offsetting the attention from the taxing exercise, encouraging through thrilling songs and stabilizing processes through frequency defaults.

In sports, music has been used for ages as a tool to help athletes succeed, inspire and celebrate their competitions, or to encourage and stimulate the audience. Moreover, music can influence and motivate athletes and their performance, it can help them to focus their attention on the upcoming event or to maintain a pace while working out. I pursued further research to acquire a better knowledge of the correlation between music and physical activity. The following section investigates how the effects of music can support the athlete's running sessions and how it may assist pacing.

2.1.1 Basic Impacts of Music on Motivation, Perception, and Performance

In general, listening to music obviously motivates athletes to sustain the endeavor of the exercise as it helps them to distract their attention from straining internal sensations. More specifically, various mechanisms exist that allow athletes to exploit the potential benefits of music, according to Tenenbaum et al. (2004). Depending on the exercise characteristics and intensity, mechanisms to affect perceived exertion and exertion tolerance may have varying effects and are potentially interactive.

Music as a Psychological Motivator. As a matter of fact, music makes the sensorial impressions while running more diversified and augments the experience by something that is potentially pleasurable. It may hence help to cope more efficiently with boredom and monotony during long-distance runs. In addition, auditory impressions tend to enhance the affective states of the athletes at both medium and high levels of work intensity (Karageorghis & Terry 1997). Especially when the exerciser is personally attached to the music, it enhances encouragement during the workout and may affect a person's enjoyment and mood. By

this manner music as a motivational and atmospheric element can also change the awareness of the runners and rise their confidence or self-esteem. As a result, this excitement may allow runners to mentally and physically enter the exercise or competition they are participating in more quickly (Matesic & Cromantie 2002). Similarly, this also applies for approaching and entering the so-called "runner's high". Especially powerful songs– as an aggressive component–may boost the athletes' overall motivation and the exertion rate of his performance (Matesic & Cromantie 2002). In contrast, music can also function in such a way that it affects the mind-sets of athletes to become anti-stressful and more relaxed. These stimulating or calming incentives of music, if used with care, can support the compliance to a training plan. Adherence to it may again ensure long-term benefits, such as a healthy and high quality life.

Perceptive Distraction from Physical Strain by Music. Besides the positive influences of music on the exercisers' enjoyment, mood and motivation, music can act as a welcome distracting stimulus during the exercise without requiring any additional dedicated activity by the runner. Under sub-maximal effort–work intensity below 70% of maximum heart rate– the athlete can voluntarily dissociate from the internal sensations of discomfort and fatigue. Occupying the mind with other things than physical discomfort through the use of music can result in a more increased work output than without distraction (Boutcher & Trenske 1990)(Szabo et al. 1999). At higher levels of exercise, dissociation– the distracting effect of music– is more difficult to be achieved. Precipitated by fatigue resulting from progressive exercise, a transition from external to internal focus takes place. Athletes cannot diverse their attention anymore and are forced to switch their attention to the feelings of exhaustion and fight directly against the pain of the training session. This implies that under the condition of an extremely high exertion level, an exercising person will no more be able to experience the potential aid of music in terms of an altered perception of that very effort (Tenenbaum et al. 1999). Yet, personal reports of exercisers still suggest the use of music during extended taxing activities. This might be due to an increased attachment of the exercisers to music, which makes them forget about mental and emotional fatigue.

The above-mentioned impacts of music may well help to sustain effort and stress. But although music significantly reduces the perception of exercise compared to non-music conditions during low and medium work intensity, the current state of research is non-distinctive as to the question whether music has a direct neurological effect on pain or discomfort (Boutcher & Trenske 1990)(Karageorghis & Terry 1997). Yet, "it has been clearly demonstrated that music can reduce factors contributing to pain and discomfort such as stress, tension, and anxiety." (Maslar 1986) Szabo et al. (1999) for example found out that the use of music, as it helps to fight against the internal focus and associative thoughts of fatigue and pain, can result in an overall performance, which otherwise would cause a higher heart-rate. All such endeavors are still within the scope of the natural abilities of a runner, i.e., could be achieved by dedicated mental training and focus instead of music as well.

Music as Support to Align Motion Sequences. To obtain a maximum impact of music on the exercise, synchronization of musical tempo to physical activity is important. In addition, music synchronized to the motion of the exercise greatly improves motor control "and as such enhances endurance even more than non-synchronized music." (Szabo et al. 1990) One possible reason for this is that music usually allows the athletes to join in its "beat" or tempo. Concentrating on a certain rhythm may encourage them to work harder in order to keep pace with the music. Furthermore, the music offers a rhythm for the exercise, which supports a more controlled motion (Matesic & Cromantie 2002). So besides the psychological effect of music and its natural ability to distract attention, music can also facilitate and support the rehearsal and adoption of motion sequences. If synchronized to exercise pacing, tempo and rhythm, it may help to sustain constancy during an exercise.

2.1.2 Considerations for the Application – Music as an Element to Affect Exercises

Although the main supporting mechanisms of music—motivational improvements, distracting stimulus and improvements of motor control and constancy—imply that music in general has a positive effect on athletes and their performance, music should be consciously applied to the runners' exercising. Even when running with low intensities athletes should not forget to stay in touch with their mind and body. "Focusing inward gives you a greater control of your run" (Udewitz 2004) and thus may help to prevent injuries.

Signaling audio sequences such as applause, cheers or explicit reminders (e.g. reminding to drink frequently or to monitor the form of running) could help to frequently "check in" with the runners' body. Such automatic reminder functions may help especially beginners to allow their minds to wander while still not loosing track of their bodily needs.

Although the possibilities to communicate with the runner via music or audio signals are apt to open up many different ideas, preserving the step frequency and supporting rhythmic motor control remain in focus as the prime directives for their direct and intrinsic applicability.

Music can be integrated into the runners' training in two basic ways to positively influence the athletes' exercising manners. For example, the athletes can either synchronize the music manually to their exercise by adjusting its tempo or the athletes can synchronize their motions to the music's steady rhythm. According to Metersdorf (1994), participants found both methods—manual adjustment and pace making—equally pleasant.

In addition, music provides not only a pacing advantage by setting the athletes' step frequency (Matesic & Cromantie 2002)

but can also support their breathing rhythm via a time signature (e.g. first beat of a bar for breathing in). In endurance running or other sports disciplines with long phases of high effort and strong oxygen consumption, the breathing rhythm needs to comply with the demand for effectiveness and efficiency."(Mackenzie 1997)
In this case, music offers a significant immersive potential, as "[b]ecoming involved in the rhythm of your breath can help your lungs more efficiently exchange oxygen for carbon dioxide and flush lactic acid from your muscles." (Udewitz 2004)

Obviously, not every type of music affects athletes in the same way. As already mentioned, music can be especially influential when it generates additional musical associations for the exerciser through personal interpretation. Moreover, melody and rhythm are more attended to than lyrics as Tenenbaum et al. (2001) revealed in their study. At higher levels of exertion—especially at the end of a run—music has to prove its arousing qualities to provide a distraction effect. Here, a higher amount of attention might be called by switching to fast-tempo music, more appealing songs or possibly even a diversified track list. This may help to fight against the internal focus and associative thoughts of fatigue and pain.

By investigating a comprehensive set of previous studies and their results, Tenenbaum et al. (2004) points out the ambiguity and indefiniteness of different such findings when compared. It is generally stated that music, be it up-tempo or slow-tempo, does indeed yield positive effects on performance in contrast to exercising without any music. While no definitive mapping of specific tasks and their demands in terms of musical types appears to be available, caution should be exercised with activities which highly depend on an athlete's focus and coordination. The excitement triggered by loud and fast music should therefore be kept within reasonable boundaries, so to not negatively affect coordinative abilities. In spite of some ambiguous and therefore hardly reproducible findings as to positive effects on performance, a literature review of Tenenbaum et al. (2004) refers to several studies

among which there is a broad agreement on either incentive or detrimental influence characteristics of faster or slower music, respectively. In connection with that, as a caveat it is to be noted that one cannot trivially deduce a symmetric correspondence that links the perception of music and motion (Eitan & Granot 2004). That is, the mere sensation of velocity may rather be influenced by a crescendo while a decrease in dynamics does not produce the same effect in the opposite direction analogically. However, this feeling-related issue does not critically affect the intent to encourage runners to align their strides to the rhythm determined by the music.

2.2 Training

For the music player design the structure and main characteristics of training are important as they may be used for workout or training plan generation. Their motivational reasons and expected effects on the athletes' performance are of less interest and are left open to be discussed with trainers, coaches, sports scientists and other experts.

2.2.1 Training Structure

All short and long ranging measures of training to gain and improve performance can be coordinated and controlled through a training plan (Steffney 2004:74). A training plan generally consists of different training phases, so-called "macro cycles" with a duration of several months. These phases usually allow for different stress intensities during the year. Ideally, a constructive preparation phase is followed by a stabilizing competition phase, which is followed by a transition phase with reduced training. Every "macro cycle" is divided into "meso cycles", shorter periods that may last several weeks, and "micro cycles" of 7-10 days (Steffney 2004:81). The specific structure and duration of train-

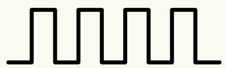
Interval	Training Type	Intensity	Duration	Graphical Representation
1	free run	varying	open end	
1	endurance run	moderate range	10 km	
1 2 3	warm up endurance run cool down	light range constant (160BPM) light range	6 min 10 km 8 min	
1 2 3 4 5 6 ...	warm up speed recovery (rapid walking) 50m sprints (until tired) 3-4 quick steps up hill ...	light range constant (164BPM) constant (100BPM) light range light range constant (160BPM) ...	5-10 min 1000 m 5 min open end open end 160-185m ...	
1 2 3 repeat 4	warm up interval recovery 2 and 3 cool down	light range constant (180BPM) light range very light range	6 min 1000 m 2 min 4 times open end	
1 2 3 repeat 4	warm up increasing recovery 2 and 3 cool down	light range 100BPM→180BPM light range very light range	6 min 800 m 3 min 4 times open end	

Table 2.1: Exemplary Training Sessions

ing phases may vary in time as they highly depend on trainers or coaches and their beliefs, approaches and training concepts. In contrast to Steffney's 10-week training plans for competitions, Daniels (1998:69), for example, proposes a 24-week training plan with four 6-week phases—a foundation and injury phase, an early quality phase, a transition quality phase, and a final quality phase—as the ideal training model.

A single training session itself can be regarded as the smallest unit of a training system. Dependent on performance and bodily conditions, time of the season, or set goals, training sessions are carried out several times a day or a week (Steffney 2004:81). The structure of a training session can be divided into different interval periods, where the duration of each interval is based on time, distance, reaching an intensity goal or it is set during the running session. That is, its intensity may stay constant, or within a range it may increase or decrease (Table 2.1).

A typical workout session includes a warm up part, a main exercise part and a cool down part. The warm up or cool down could last for 5-10 minutes with very light intensity. As the main exercise part can consist of a single or multiple intervals, it could, for example, include a 40 minute even-paced run at moderate intensity, or strain intervals at hard intensities alternating with recovery intervals.

Dependent on the workout's goal and personal preferences, various methods exist as combinations of intervals with different intensities that characterize the workout session: continuous endurance methods, interval methods, repetition methods, competition or complex methods, etc. (Neumann & Hottenrott 2005). Generally, these can be described by the above-mentioned structure of 1 to n intervals with different intensities.

2.2.2 Training control

As stated above, training is generally conceived as the sum of all measures to gain and improve performance. However, the quality of training is the result of a very complex process and cannot be simply achieved by an increased amount of intensity (Steffney 2004:78). Through bodily and mental training, performance can be improved within the boundaries that apply to genetic conditions. Stress stimuli—amount, duration, frequency and intensity—have to be well balanced in order to affect an adaptation of the athletes' body through enlargement and enhanced mobilization of performance reserves. Both physical and psychological stimuli improve the athletes' condition: the sum of bodily abilities, technical realization and personal characteristics such as willpower and motivation (Steffney 2004:74). All in all training composition and planning underlie eight generally applicable training principles, which are mainly based on biological laws (Steffney 2004:78):

- effective training stimulus
- progressive stress increase
- variation of training stress
- configuration of stress and recovery
- repetition and durability
- periodization and cyclization
- individuality and age adequacy
- increasing specialization

As these principles interact or overlap and some are very difficult to rate, training control is very complex and requires great sensitivity. In particular, the question of how to evaluate and compare relative and total training stress remains. Since the overall stress of a training session is influenced by the performance time at a certain intensity, the simplest way to log and control training is to keep track of how much running athletes do or should do at a specific intensity (Daniels 1998:38).

The training duration should preferably be measured in time, as the "advantage of this time-associated method is that it does a better job of equating the amount of stress placed on runners of various abilities. [...] [A] slower runner trying to log the same mileage as en elite runner will find doing so has taken a great deal more time, which often means that the slower athlete is subjected to a greater risk of injury." (Daniels 1998:38) The relative intensity of a training session is more complex to evaluate. It is often indicated, monitored and controlled by the maximal oxygen consumption or in percentage of the maximal heart rate Training control by measuring the runners' effort can be done via body feeling and personal estimation, via biomechanical monitoring or via performance diagnostics (Steffney 2004:74).

Training control based on performance diagnostics (lactate accumulation tests, oxygen consumption tests) is the most accurate of these methods. However it is not easily conducted by laymen and its realization is mostly tied to laboratory tests. Many athletes of the amateur domain rely on training control via heart rate data, which is measurable during the run through a heart rate monitor belt. Sensors on fingers and earlobes (plethysmographic means or pulse oximeters that monitor the blood transport within blood vessels) are another option. However they are even more affected by fast movement and shocks as they require very steady mounting points. In addition to possible measurement distortions, the heart rate varies during the day and depends on weather conditions, change of blood volume, blood availability, and oxygen-carrying capacity of the blood (Daniels 1998:61). Heart rate tracking as an exclusive means of monitoring is therefore not reliable in all circumstances, especially with regards to inter-individual comparison. And as already mentioned in the introduction, heart rate in combination with music is even more questionable (Neumann & Hottenrott 2005).

Independent of individual influences and distortions, the time needed for running a restricted (flat) distance reflects a runner's performance in an agreed-upon and objective way. The average time needed for running a mile or kilometer, when derived from the final results of a run, is a more or less distance-independent value. Such speed rating can be used to compare results and to measure athletes' progress over time. As it allows a quick and simple assessment of running economy (less time and effort for the same track), it can also be used to calculate and control training intensities. It may be used in combination with heart rate values and other biomechanical data to improve the accuracy of estimations and support performance analysis (Spanaus 2002). This thesis focuses on pace in order to facilitate a quick feedback and comparability through a simplistic but adequate representation that is accessible to nearly everyone. It is important to devise a robust and unquestionable system that does not give rise to objections due to specific methodic training biases.

In training, runners try to improve their average-mile or average-kilometer time by trying to increase stride length, stride frequency or the overall pace. They aim to find their individual, most efficient running pace. Observations have shown that elite runners almost have an almost constant stride frequency. So improving or maintaining cadence is a favorable method to improve pace and performance, e.g. by running on a treadmill or using a metronome for outside runs.

2.2.3 Speed: Step Length and Step Frequency

In a simplistic view, there are two ways athletes can increase speed while running – either they take longer strides (Fig. 2.2) or they move their legs with a higher running cadence (Fig. 2.3). Therefore speed equals stride length multiplied by cadence.

Observational research has shown that elite long distance runners almost have the same stride rate. They maintain a stride frequency of 170-190 on flat courses regardless of distance or pace (Daniels 1998). Going uphill typically lowers the cadence to 120-130 and going downhill extends the cadence to over 200. The difference of the top runners' speeds is down to the adjustment of their stride length, as the same step frequency with a longer stride increases the runner's overall speed (Beck 2005).

Step Length. Controlling the stride length remains largely within the runners' control; so discovering a feeling for their optimal

Figure 2.2: Stride length = the distance covered by a step (Polar Electro Oy 2007)

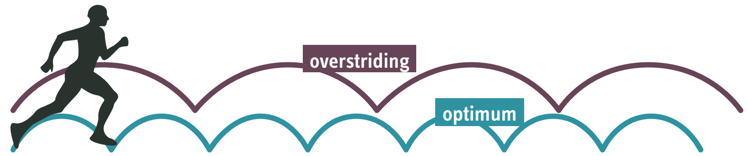


Figure 2.3: Cadence = the number of strides per minute (Polar Electro Oy 2007)

stride length is the key (American Running Association 2005). One of the most common mistakes beginners make when trying to gather speed is the deliberate over-reaching of the footfall. The so-called over-striding of runners reduces the momentum and increases the chance of injury and muscle damage (Mirkin 2005). Lengthening the stride length can even lead to a slow down in speed. The most efficient stride length is determined by the most comfortable and natural one, which appears to be just known by the runners' body. It almost automatically adjusts for speed (Beck 2005). Strengthening the leg muscle helps to drive forward with a longer stride (Run Gear Run 2004) (Mirkin 2005). The strengthening of the leg muscles can be achieved by very fast runs and runs on soft ground, as well as up hill training or even workouts using strength training machines (Mirkin 2005)(Polar Electro Oy 2006).

Step Frequency. Working additionally on stride rate optimization is more effective than focusing on the stride length alone because in turn the strengthening of the leg muscles naturally increases the stride length (Mackenzie 1997). Especially in longer runs vigor becomes a very critical factor because runners begin to use less muscle force and muscular fatigue negatively affects the stride length. A faster turnover implies short(er) strides, minimal time spent in the air, and a reduction of the force applied to the ground with each step, i.e., less ground landing shock or ground reaction force (Daniels 1998). Consequently, runners can try to conserve as much of their strength and energy as possible by increasing the number of strides to complete a run–running at a higher cadence. Working on a faster and still comfortable cadence–maximizing cadence efficiency–makes runners able to preserve the stride length in long runs and maximize their performance (Polar Electro Oy 2006)(Run Gear Run 2004).

Yet, stride rate is not developed into its optimal state easily as the athletes' body "forgets" moving at a certain speed quite quickly in contrast to endurance, which sustains well. Runners may consciously try to maximize "the efficiency of their cadence, so that when we do unconsciously adjust the stride length for speed, we do so at an optimal turnover rate."(Run Gear Run 2004) As it might be regarded as a matter of self-conditioning, cadence development relies heavily on frequent training. This may be achieved by consciously setting cadence goals and by deliberately incorporating faster cadence intervals into training sessions otherwise characterized by easy running (Polar Electro Oy 2006).

Of course, increasing the stride rate or stride length is not the only way to improve running economy. Favorable body position, (hip) flexibility, mid-torso strength, or so-called ground preparation mechanics can also influence the runners' economy and therefore his endurance and speed power (Ayer 2006).

Even though both step frequency and step length are equally important for speed development, in regards to the rhythmic nature of music step frequency puts itself forward.

In addition, as already mentioned above, monitoring and preserving the cadence during longer training runs can avoid possible problems caused by increasingly tired legs. A music device that indicates both pace and cadence can help athletes in the attempt to shorten their strides as they increase cadence while sustaining a constant pace. Obviously, a pacing or metronome

function via rhythmic music frequencies offers support to accomplish exactly that. However, the device should leave the overall control of training to the runners, their training plans and the guidelines or targets imposed by their trainers. Such a non-didactic approach is important to ensure that the use of the device as such does not imply an involuntary and compulsory adoption of a very specific approach to training planning. This would potentially interfere with a multitude of individual beliefs, biases, requirement and methods that athletes and trainers have developed throughout their professional careers, as already outlined in the introduction.

2.3 StepMan Technology

One fundamental technology used for the music player design presented in this work is the *StepMan* of the Fraunhofer Institute for Computer Graphics: *StepMan* incorporates in real-time the deceleration or acceleration of music played without distorting the pitch. This can be performed according to sensor data or pre-selected values. To change the music tempo, *StepMan* uses algorithms for time scale modification of music which process music sequences in two steps (Fig. 2.4): First, certain characteristics, e.g. recurring peaks, in the audio signal are detected to determine its beat. Secondly, the music sequence tempo is modified so it matches a target tempo that may be obtained from sensor measurements. While speeding up normally tunes results in a higher pitch and thus shifts tones when compared with the originals, such important spectral properties can be preserved using the *StepMan* technology. This process of music stretching and adaptation is done in real-time.

The *StepMan* system software analyzes the runners' sensor data, dictates the music rhythm and gives situation relevant feedback. It can be employed as an add-on software application for mobile devices, such as, e.g., smart phones or PDAs. Equipped

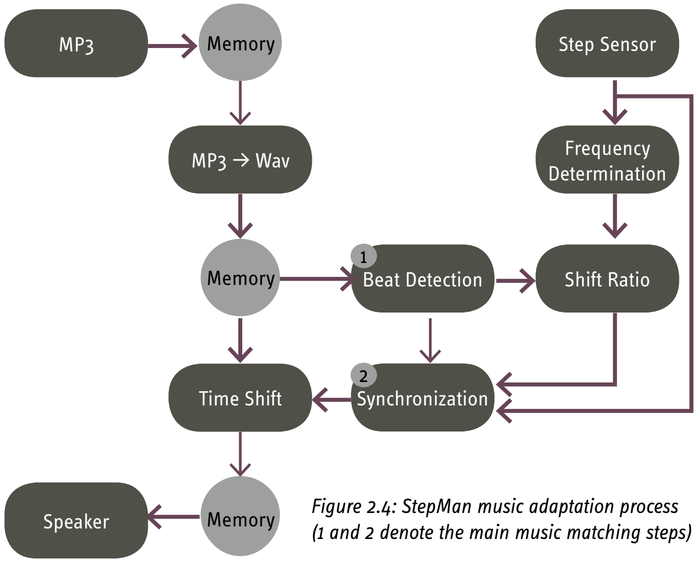


Figure 2.4: StepMan music adaptation process (1 and 2 denote the main music matching steps)

with the *StepMan* technology, computational implements with audio playback capabilities adapt the tempo of different music sequences according to an athlete's current or desired step frequency while exercising.

In order to do this, athletes have to wear a pedometer which senses recurring shocks or accelerations of the runners' body in motion. The monitored step count over time represents an athlete's step frequency. It is wirelessly delivered to the mobile device while exercising. On the mobile device, software continuously adapts the tempo of the music to the runners' "running rhythm". Due to the fact that the pitch of the audio sequence always remains the same, *StepMan* enables runners to listen to their favorite tracks even if they actually do not match their running speed in the first place. On the other hand, a *StepMan* mobile device can of course also adapt the music tempo to a preselected value. That way, athletes can set up their desired training speed initially and then match their own step frequency to the programmed music rhythm while running.

Furthermore, a heart rate monitor or other complementing sensors could be employed to adjust the music tempo according

Figure 2.5: StepMan Pocket PC (Bieber and Diener 2004)

to the runner's biomechanical data. For example, if the athlete's heart rate leaves a pre-selected pulse zone (i.e., if the pulse rate is too low or too high), this could be used as an indicator to decrease or increase the music tempo. The changes of the music tempo are assumed to directly affect the athlete's step frequency—running slower or faster—with the expectation that the heart rate also changes accordingly and hence stays within the pre-selected zone (Bieber & Diener 2005).

The first *StepMan* prototype consists of a Pocket PC (Compaq iPAQ h3970 with a 400 MHz Intel PXA250 processor), a two-axial acceleration sensor (Analog Devices ADXL 202) for step detection and an optical pulse oximeter (ChipOx sensor from EnviteC) for monitoring the heart rate (Fig. 2.5). But in practice, the weight of the iPAQ StepMan was too heavy and it was difficult to use, which called for functional optimization and a decrease in size:

> "Hauptverantwortlich hierfür war das zu hohe Gewicht des IPAQ, dass sich zudem während des Laufs durch das regelmäßige Wippen potenziert. Ferner scheint die bisherige Handhabung wenig bedienerfreundlich zu sein, da mehrere

Figure 2.6: Siemens Runster (Siemens AG 2005)

> User bei dem Versuch scheiterten, eine individuelle Musikauswahl zu speichern." (LAUFFIT Research Team 2004)

That led to the first integration of the *StepMan* technology into a mobile phone, which was presented at the *CeBIT* 2005 in cooperation with Siemens (Fig. 2.6). Here, the so-called *Runster* operated in a demonstration mode to communicate the fundamental features and ideas of the *StepMan* technology (Aschenbrenner 2005).

Currently, a second *StepMan* version exists that was developed for mobile phones (Fig. 2.7). In contrast to the first version, this *StepMan* application is not bound to a specific type of mobile phone, but runs on all mobile devices with a *Symbian* operating system and Bluetooth capabilities. This version comes with a step sensor in a small box, which can be easily attached to the hip with an integrated clip. Although this version is also very limited in its functionality as it was build for demonstrational purposes only, the small sensor box makes it very easy to set up and use instantly.

Until now, a self-contained stand-alone *StepMan*-branded product which synchronizes music with the step frequency does not exist. In this master thesis, I attend to the integration of *StepMan* into a mobile music player for endurance runners, so

Figure 2.7: Current StepMan mobile phone application

in combination the *StepMan* technology and the idea of utilizing music in exercise can be exploited to their full potential in this combination.

The integration of *StepMan* as the defining part of the mobile music player concept makes it a down-to-earth and realizable product regarding its fundamental features of music tempo adaptation. Here, *StepMan* will be used to adapt the music tempo to fit the actual situation of runners and to deliberately control training by adjusting the speed of music on the fly according to a specific training program or the desired step frequency of the athlete. In addition, this master thesis may potentially raise issues related to a stand-alone application that consciously integrates music into the athletes' training, thus explicitly stating or hinting at not yet developed or thought of features. These may challenge the future development of the *StepMan* technology and further add-on applications.

It is, for example, assumed in the scope of this thesis that the *StepMan* technology can in the future also be incorporated in low-power small-size ultra-mobile devices that are specifically tailored for sports use. A PDA or smart phone may be versatile enough to run a variety of software packages—e.g., *StepMan*—but be otherwise possibly inadequate for running due to constraints imposed by handling, power consumption and mere weight. Therefore, porting the software to small microcontrollers without relying on Symbian or another mobile device operating system may turn out to be necessary. Another option might be to devise a hard-wired *StepMan* version that comes as an integrated circuit for music adaptation.

Figure 2.8: StepMan running test with belt-mounted sensor and hand-held mobile phone

Thanks to the kind support of the Fraunhofer Institute for Computer Graphics I was able to test the different StepMan versions myself (Fig. 2.8). These personal experiences helped me to get a feeling for the implications of synchronization of music tempo and step frequency and strengthen my belief in the potential success of a stand-alone product appointed to the running segment. My own running sessions in which I tested the *StepMan* version 1.3 have been very inspirational in particular. I noticed that small jumps in tempo, did not negatively affect the running experience.

Besides my investigation and testing of the Fraunhofer *StepMan* technology, I also researched a variety of other products on the running and fitness market to gain an overview on technical possibilities, to get inspired and to generate ideas for my music player concept. A selection of my research will be introduced in the next section.

2.4 Products Research

Sports disciplines and leisure time activities have emerged as a major economic branch. Besides running shoes and functional clothes, electronic devices are the main sales products in this area. Electronic helpers add zest to endurance sports disciplines and take on additional tasks and functions. The running accessories market is a wide-ranging and multi-faceted segment. In respect of the music player design, this chapter shortly describes and evaluates the development towards and the characteristics of currently available electronic devices that support runners during their training. This research is pursued to acknowledge existing

concepts and implements, to identify features worth adopting, and to pinpoint the product placement of the music player designed in the scope of this thesis.

Wristwatches with an integrated stop function were broadly introduced to the market in the course of the eighties with the increasing distribution of the digital watch. These belong to the basic electronic equipment of every runner and are often used as a controlling device for the current run. The controls and technical terms have not changed since that time.

Over the years, sports wristwatches became more complex and capable of attaching external sensors: Integrated wrist receiver units monitor and record the athletes' performance and biomechanical data while exercising. Heart rate watches, for example, allow measuring pulse rate and heart rate variability to assess a user's fitness when combined with a chest strap transmitter. Other functional watches—running computers—receive and evaluate step frequency, speed and distance information from a speed sensor attached to the runner's foot or from connected (or integrated) GPS receivers. These watches usually offer the programming of training structures, including training sessions and training plans. In some cases, even the programming and calculation of exposure and stress times for interval runs or other details are supported. Running computer systems combine different sensors and technologies and can be used to monitor, store, analyze, replay, and compare sports experiences comprehensively. Such systems may comprise body-mounted and infrastructural components alike.

Running with music became very popular as increasing numbers of small MP3 players with flash drives were put on the consumer market. The development of small, lightweight and shock-resistant digital audio players eventually made running with music highly comfortable. Recently, more complex MP3 players especially developed for running were designed and launched commercially. With the so-called new generation of digital audio players basic functions of running computers and music players were integrated in one device (for example the Nike and Philips MP3RUN in 2004 and in 2006 the Apple Nike + iPod Sports Kit). The latest gadgets (Sony S2 Sports Walkman introduced in October 2006) offer first pace matching features. But even though set up specifically for running, their music selection and training applications are very limited.

In preparation of my master thesis design work I researched and tested existing digital music players, running computers and other mobile devices for running or other fitness contexts. I found that although music players are advertised for the specific context of sports or running (and some of them even provide training functions), none of them sufficiently joined functions of music playback and training control. The following exemplary reviews give an overview of devices and concepts that I obtained and evaluated and that influenced my design approach and decisions regarding the integration and combination of a music player and a running computer.

Figure 2.9: Nike Philips PSA 260 MP3-Run (Royal Philips Electronic 2004)

Nike Philips PSA 260 - MP3RUN (2004). At odds with the advertisement campaign, MP3RUN (Fig. 2.9) is not a "running coach with musical accompaniment", but a music player and FM tuner which tracks running time and pace based on average stride length. A small foot pod clips to the laces of the running shoe and communicates foot strike information to the music player via Bluetooth (Royal Philips Electronics 2004).

The audio announcement of running progress via button-push is a very nice and simple feature. Unfortunately, when attached to the upper arm, the clear and bright display cannot be seen. The display position and the difficulty to evaluate and confirm audio cues can lead to an awkward uncertainness whether performance data is really tracked when the training function is started or stopped. Also, the casing with its rugged, weatherproof design is hard to clean and the battery case of the sensor is difficult to close.

Figure 2.10: Apple + Nike iPod Sports Kit (Apple Inc. 2006)

Apple Nike+ iPod Sports Kit (2006). The iPod Sports Kit (Fig. 2.10) consists of a wireless sensor and receiver combination that works exclusively with so-called Nike+ shoes and the iPod nano. The iPod Sports Kit supports single-phase workouts with calories, distance or time goals and calculates speed and calories based on approximated stride length and other pre-selected user data. It gives real-time feedback during the workout and offers a *PowerSong* function to immediately play a pre-selected song when a certain button is pushed. Performance data can be transferred to a personal computer and an online community after the workout (Apple Inc. 2006).

The iPod Sports Kit predominantly addresses fitness (and amateur) runners, as it puts speed and distance monitoring in a nutshell: The iPod Sports Kit is very easy to set up; its functions are very simple and easy to understand and to use. The voice feedback is very useful. The hardware and data integration with the Nike+ website (www.nikeplus.com), which offers excellent community features that may even challenge serious sports people, works well. However, the iPod Sports Kit functionality is limited and performance data cannot be reviewed in detail. The sensor battery is not replaceable. Besides, the iPod nano click-wheel interface is very difficult to use during the workout, especially when combined with the Nike+ accessories, which even hide the display of the music player.

Figure 2.11: Sony S2 Sporst Walkman NW-S205F (Sony Electronics Inc. 2004)

Sony S2 Sports Walkman - NW-S205F (2006). The S2 Sports Walkman (Fig. 2.11) is a cylindrical, water-resistant aluminum MP3 player with an FM tuner. It supports the user's workouts via a step, distance and calorie counter and simple target setting features. A music pacer function offers to switch between running and walking playlists dependent on the users pace. Thanks to the built-in pedometer the user can shake the S2 Sports Walkman MP3 player three times to switch between different shuffle features (Sony Electronics Inc. 2004).

The S2 Sports Walkman has to be worn on the arm or be held in the hand for step counting, which can be disturbing when changing clothes. Nevertheless, the *S2 Sports Walkman* is the first commercially available MP3 player that offers basic music pacing functions. And it is a single-piece mobile device, which keeps the preparation phase for running with music very simple. The shuffle-shake function is a nice gimmick as it offers an unusual input option and may persuade the user to switch the playing order of the songs more often. Besides, the Shuttle switch control on the upper end of the player is an enjoyable interface element.

Figure 2.12: Adidas Polar Project Fusion (Adidas AG 2005)

Adidas Polar Project Fusion (2006): RS 800 Running Computer, S3 Stride Sensor, WearLink transmitter, adiStar Fusion apparel. Project Fusion (Fig. 2.12) defines a personal training system for serious endurance athletes that integrates the *Polar* heart rate and speed monitoring technology into adidas apparel to simplify their use and to increase comfort and precision. The training system offers a complex planning, tracking and analysis functionality. Its centerpiece—the Polar RS800 Running Computer—provides individual and personalized feedback to train more effectively during the workout. Most interestingly, it shows cadence and average stride length to support optimization of leg power and leg speed (Adidas AG 2005)(Adidas AG and Polar Electro Oy 2006).

The integration of heart rate monitoring into the apparel and distance measuring into the running footwear by Project Fusion satisfies the runner's need for a complex training system that is still manageable. The complexity of the system is impressive. It helps runners to consciously train their distance-running performance and to improve their running economy and fitness at the same time. Besides, no other commercially available running computer supports to work on stride frequency and stride length.

USER AND TASKS 3

Integrating the *StepMan* technology into a mobile music player offers music tempo adaptation according to a pre-planned rhythm or on the fly to step frequency. Proactive rhythmic training controlling via mobile auditory feedback becomes possible in regards to the athletes' preferences. A mobile device that supports controlling and maintaining a steady music tempo targets many different sports disciplines that include rhythmic movements such as walking, running, skipping, aerobics, rowing etc.

For this master thesis, endurance running has been taken as the main discipline because the running segment generically involves the mentioned characteristics and can be attributed an ever-growing increase in popularity. A closer look at the users, their attitude, background and environment will help to understand their needs and may reveal more specific requirements for the music player design.

3.1 User Groups: Everybody Can Run

Running combines lifestyles that are characterized by wellness, fitness and individuality. It positively affects body, mind and soul in various different ways. The individual motivations of runners are comparably complex. Improving fitness or the cardiovascular system, reducing stress and health risks, losing weight, or increasing performance for the next competition represent plausible reasons: The exercise of running is diversified, and so are the related target groups. Nevertheless, it is possible to classify runners into three different types based on a representative study published by Motor Presse Stuttgart (2006): the ambitious runner, the occasional runner and the newcomer (Fig. 3.1). Type borders

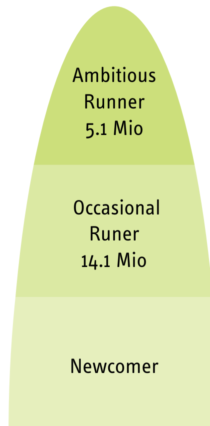


Figure 3.1: Running Types (based on German population fourteen years of age and over) (Motor Presse Stuttgart 2006)

are non-distinct and can change repeatedly in one or another direction during a runner's career.

Ambitious Runners. Runners who practice their sport regularly and intensively are so-called ambitious runners. To them, running is the central sports discipline, which takes an important place in their arrangements of life and leisure time. A great part of this group regularly attends competitions. Detailed information and suggestions on individual training and competition preparation are therefore indispensable (Motor Presse Stuttgart 2006).
↗ Ambitious runners may want to use a music player if it helps to improve their individual training. Functioning like a training device, such a music player can be used to develop or maintain, to control and monitor cadence through auditory feedback and music tempo adaptation. Joining and integrating functions of existing running computers and music players for training planning, monitoring and analysis is desired.

Occasional Runners. Many athletes use running as a basis for the practice of other sports disciplines. Occasional runners intend to establish, keep or improve condition. In spite of being a basic, concomitant or supplementary sports discipline, running is practiced conscientiously and with great attentiveness. Information on adequate and effective training methods, product innovations, and running-trends are perceived with interest (Motor Presse Stuttgart 2006).
↗ Occasional runners may also adopt a music player that supports their training session and its planning through music sequence control. However, they may equally appreciate just being able to listen to music without running rhythm and music tempo interferences. As they are into various other leisure time activities, they may favor a device that is not only suited for running but also for different contexts.

Newcomers. Generally, all people who are interested in and attracted by sports activities without much prior experience or

proficiency count as newcomers in the broadest sense. In the first place their motivation is compensation through movement, promotion of their health, or simply expense of calories. For the particular group of beginners, tips for the right entrance are extremely important: On the one hand due to medical aspects, on the other hand to avoid motivational setbacks caused by wrong training methods (Motor Presse Stuttgart 2006).
↗ Newcomers may appreciate a music player that supports the entrance into running via confirmative guidance. Getting the right feeling for running and breathing rhythm via music may encourage their workout motivation and improve their motor control. Moreover, the adaptation of music tempo according to runners' step frequency can prevent beginners from joining into too fast beats.

Each of the three runner types may use a mobile music player with a different emphasis as a potential user of the product. However, the main benefits—music tempo adaptation and controlling—of the device remain the same and its main functions do not need to be compromised by that. As the research goal is a music player that proactively integrates music into the training routine of runners, the ambitious type is selected as the primary user. Choosing ambitious runners, as the main target group will tease out the full potential of such a music device for the simple reason that running is their primary sports discipline. From a marketing perspective, ambitious runners are valuable circulators who may have gained a good reputation for their own expertise among peers and can thus effectively propagate the qualities of a new product via recommendation and advice to other runners.

Apart from the classification of runner types according to training prevalence, it is also possible to divide the running community into types of interests and motivations. In a survey the *AOK* (a major German health insurance agency) identified the performance, health, and fitness oriented runner, based on an evaluation of selected data on motivation and concepts of training (Predel & Almer 2003).

With a music and training device performance-oriented runners will predominantly try to improve their performance by setting individual training goals, as well as controlling and analyzing their data. However, such a music player will have to be individually adjustable and hence can also be programmed according to fitness or health-oriented—or even additional—goals, as the basic structure of training sessions is generally the same. When health- or fitness-oriented runners share such a music and training player, they may need extra guidance for setting up training plans according to their goals and needs before training, and extra support in analyzing their performance according to their requirements while training. The device conceived in the scope of this thesis will not follow a didactic approach in order to not lull its users into a false sense of security. Therefore those runners either have to inform themselves on their own (e.g., by reading books, talking to other runners, or taking part in running groups) or they have to take the advice of experts, such as trainers, coaches, or doctors to support their training.

The interests of coaches, trainers or other experts overlap with the runners' requirements for a training and music device but with a shift of focus. Coaches or trainers may want to include functions for programming training plans, which can be reproduced on various mobile music players to supply several runners with training tasks. They may also like to collect and analyze performance data—maybe already stored in profile files that can be retrieved and sent to a computer station at their place of work—after their runners' training. On top of that, they may consider to set up or to record reminding audio sequences for their athletes to help them stick to training plans and tasks.

Although the music player concept focus remains on the demands and requirements of active runners, it addresses runners independent of their running motivation. The following user and task analysis, design assessments and decisions rely on the users that regard running as their main sports discipline: the ambitious runners. Thus, wherever runners or users are mentioned hereinafter without any further distinction, these terms refer to the target group of ambitious runners.

3.1.1 The Ambitious Runner

The following statements are made according to the studies "Laufen in Deutschland" (Motor Presse Stuttgart 2006):
More than 19 Million German citizens occasionally run in their leisure time—this corresponds to a gain of 41,5% since 1998. Within the same period, the number of people running regularly—the so-called ambitious runners—has almost doubled to 5,1 Million. The running market records economic growth and the participation in running competitions has increased.

Running by now is a typical unisex sports discipline performed by people of every age (14 to over 70 years-old). The largest amount of ambitious runners on record is between 30-49 years of age—the average runner is 39,9 years old. Ambitious runners distinguish themselves by communicative skills, interest in innovations, as well as a distinct consumerism.

Every second ambitious runner has a high socio-economic status and corresponding living standards, almost three quarters hold a higher educational degree. Runners are success-oriented people who are generally attributed strong personalities and a greater willingness to take risks in comparison with the rest of the population. Running shows many intersections with other sports disciplines and many runners are so-called "multi-athletes", The bandwidth of runners' interests even outreaches the sport discipline itself. Runners show a high interest in technology and consumer electronics, as well as in telecommunication and networks. Runners are very active and get around, i.e., sport a high degree of mobility.

Ambitious runners are willing to invest more than average in sports and fitness gear or accessories, if the products feature high quality, functionality, and performance. Running products have to be lightweight, very durable, and show high wearing comfort.

Apart from the reported sense for technology, functionality, and practicability, aesthetical and exclusive design plays an enormous role in a runner's life. In many cases the design incorporates the soul of a product, pronounces personality and signifies an individual life style, innovation, zeitgeist, and often status and prestige. Even technical equipment, such as heart rate monitors, running computers or music players, can appear as elegant and impress through their suitability in daily life on top of the sports discipline itself.

In spite of the usefulness of such generic attributions, personal conversations, impressions and observations are indispensable in order to develop a serious notion of and sensibility for the product.

3.1.2 Observations, Interviews, Questionnaire—Getting in Touch With the User

To accomplish the goal of designing a music device that suits the runner in form and function I wanted to get in touch with and learn more about the potential user group—their ideas, thoughts and running behavior. With this in mind, I joined a weekly running group, visited locations that are frequently used by runners and developed an online questionnaire to approach a wide range of potential future users. The distinct insights I gained are very useful and valuable for my project and will re-emerge through all parts of my master thesis (Figs. 3.3-3.5).

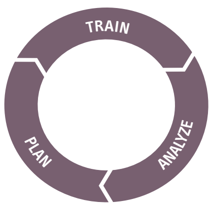


Figure 3.2: A runner's typical workflow (Polar Electro Oy 2007)

Observations. Individual runners have very different training preferences; they may train at all times of the day and week. The workflow of a typical running session can be divided into a planning, a training and an analysis phase (Fig. 3.2). All phases relate to very different mindsets and requirements. In the planning phase the runner reflects her past and future training and prepares for the workout. She may adjust or reset training devices according to a training goal and gets changed. In the training phase, the runner begins to work out while recording her progress.

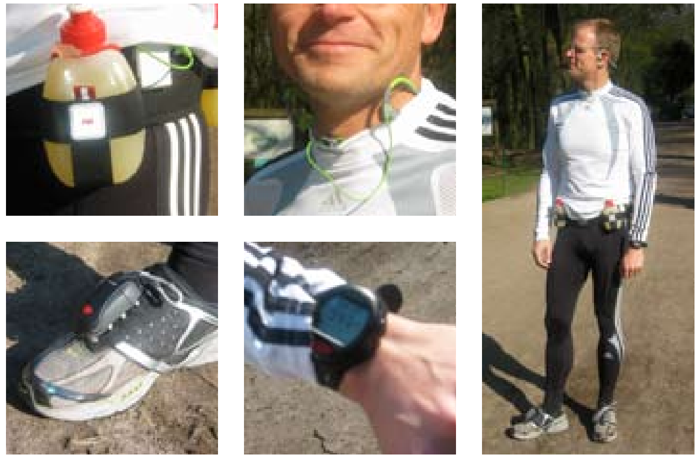


Figure 3.3: This typcial ambitious endurance runner needs some time to prepare for a workout because he has to carry several things:
- drinks clipped to a belt
- a running computer combined with a wireless heart rate and shoe sensor
- a music player and neckband sports headphones with a cable clip

Figure 3.4: This small and lightweight MP3 player is difficult to use and uncomfortable to wear with the supplied armband:
- The runner has to wear a longsleeve to protect her skin from the scrubbing armband. This prevents her from taking off the top and from hiding the headphones cables.
- She has to unwrap the protected device to use its controls and its display during the workout.

Figure 3.5: This runner cannot use the supplied headphones, because the earbuds drop out of his ears when running. His new, foldable neckband headphones have a very long cable, but stay put. However, to wear the music device he still has to carry the unusable in-ear headphones, because they are inseparably connected to the necklace of the MP3 player. The cables are very long,

Above all, she concentrates on the activity of running. After the training, the runner enjoys the merits of her efforts by checking, analyzing and comparing the results.

QUESTIONNAIRE. In the following I present the most predominant results of my questionnaire without analyzing and evaluating them at this point, so to not preempt tasks, requirements or solutions (these are addressed in subsequent sections of this document). The complete results of the questionnaire can be found in the appendix.

The questionnaire on running and music was announced through communities and forums on the Internet and through email dissemination. A substantial group of 38 runners within the age of 19 to 55 years completed the questionnaire, however it is only intended as an encouragement for my design contemplations and must not to be used for representative statistical conclusions. The average participant is 38 years old, male and considers himself as an advanced runner. 75% of all participants enjoy listening to music while running (29/38), whereof more than 40% regard the music player as an essential part of their training (12/29).

The prime reason for listening to music while running is an increase of motivation. Most interviewed people claim that they choose special music for their training and that this music selection plays an important role for their encouragement. The types of music participants listen to while training covers a wide variety of music genres such as, e.g., rock, electronic, techno, pop, charts, lounge, classic and even audio books. Some participants stated that "dynamic, beat, pushing, happy, emotional" are attributes they deem more motivational than others. However, the selection of music depends on the participants' moods and training styles. Approximately 80% (23/29) athletes run in time with the music they listen to.

Runners do not only listen to music while running, but also for example when getting to the training place (15/29), during the warm up (15/29) or cool down part (13/29) or during other

daily activities in their life (20/29). Most participants who use music during their workout use in-ear headphones (24/29) and about half of them carry the player in their pocket (14/29). Apart from these results based on music and music player integration, approximately 89% (31/38) like to monitor their performance and would like to collect and analyze running data. According to the participants, the most important pieces of information while running are: distance, duration, progress over time, speed, and biomechanical data (in this order).

Most interesting in respect to the aim of designing a device directly derived from experiences and wishes were the answers to question 14 (What don't you like about your music device for running?) and 15 (What features should your ideal mobile music device have?), as the participants were asked to freely describe their problems and wishes about music. Both answers correspond with each other but yield a distinct emphasis. I also asked those people who do not run with music how their ideal music player should be, as the existing music players could be too limited and that might be why they do not run with music. Even though slightly different issues and wishes were stated, the following results for the ideal music player can be summarized:

First of all, the music player has to be easy to attach and wear in fixed positions close to the body and hence it has to be light and small. It should be easy to use before, after and while running, preferably without looking. Long lasting battery life, a large storage capacity for music, sweat-resistance, as well as shock-resistance is taken for granted. Volume control, play/pause and skip seem to be the most important functions of an audio player that need direct access. Some people wish for a music device that supports their training by monitoring their performance (e.g. via integrated chronometer, speedometer, or a heart rate monitor), by organizing music (e.g. music selection and categorization according to their training intensities and goals) or by adapting music (adjusting the music rhythm according to the runners performance). Interestingly users that do not run with music argued they do not like to be disturbed while running, which was either attributed to the general rejection of music ("I want to enjoy the nature.") or to the interference of music tempo with running rhythm. Headphones should be comfortable to wear, stay put, and ideally allow wireless use.

A selection of answers to question 15 given by different users:

> "Es muesste auf jeden Fall ein sehr kleines Geraet sein, poppige, schnelle Musik, alles im gleichen Rythmus, weil man seinen Laufschritt automoatisch der Musik anpasst." (User 17)

> "Magically adapt to my running pace, or set a training speed. Speed up or slow down the music like a DJ." (User 1)

> "Toll wäre wenn der Player [...] automtisch einen passenden nächsten Song auswählen würde, so zum Beispiel beim Cool Down was ruhiges etc." (User 18)

> "A mixture of music with a high BPM-rate for sprints etc, that would push me - and also a calm music for warming up, cool down and interval breaks" (User 30)

3.1.3 Goals and Tasks—What Runners Expect, Demand, Wish

Based on my reviews, observations, and the determination of my target group I divided interactions with existing devices as well as the wishes and the demands of ambitious runners into several problem and activity categories. To get a feeling for the implications of my research goal, I then developed specific examples of tasks runners perform or want to perform with a music playing training device, corresponding to these categories. During this process I frequently communicated with athletes, trainers and sports managers whenever questions arose, when I got stuck with a train of thoughts, and when I needed feedback on my considerations. This close cooperation was extremely helpful to extract some basic functions the music player should support.

Manage Training Plans. As running is a motivational problem, runners try to encourage and remind themselves to go out and run and stick to their training plans. In order to remind and persuade themselves to work out regularly, runners manage and organize their plans in advance. They declare goals and set them down, which involves facilities to program training sessions and workout plans that may be associated with specific dates and times.
↗ Conceptualize training goals; define overall training period; subdivide training period into week plans; schedule training sessions for specific dates; model workout intervals and parameters; set reminder function for workout tasks; check calendar and workout plan for a certain date; etc.

Categorize Music Sequences. Selecting the perfect music based on mood and training intensity before or while working out is a familiar problem to all runners as music sequences are difficult to order and evaluate based on classically available information such as album, artist, or song title. As the personal relation to a song and the music rhythm itself highly influence the running session—in particular style and pace—appropriate music must be carefully chosen.
↗ Process, annotate and categorize meta data of music sequences based on classic parameters, rhythmic values (i.e., meter, tempo) and individual characteristics (e.g., melody, instrumentation, harmony, arrangement); order and browse music library by meta data; rank, rate or tag songs according to runners' personal preferences (e.g. to indicate whether they like or dislike a song for a specific training); listen to a music sequence sample; etc.

Generate Playlists. Manually planning training via playlist preparation can be very time-consuming and tedious, especially when it comes to more complex training sessions. Playlists have to be set up for particular training sessions, based on the earlier-mentioned categories, values and tags. Tracks can be browsed by various specified orders, upon that selected, and eventually ar-

ranged. A technique that allows clustering by similarity of musical qualities might be employed, in order to achieve a better categorization and more appropriate recommendations.
↗ Retrieve characteristics of workout phase; search library for music similar to workout characteristics, tempo range, and personal preferences; order found songs by user rating; calculate BPM divergence; calculate song duration when stretched according to workout tempo; find songs with similar attributes; repeat for the next phase; listen to a music sequence sample; annotate playlist with a name based on the attributes of included songs; repeat the process for the same workout to generate alternative playlists; choose favorite playlist for workout; etc.

Synchronize Music Rhythm. Most music sequences are not equal in pace and rhythm. It is thus difficult to ensure the use of various music sequences while avoiding interference of running and music rhythm. Even if music sequences match the training style or a runner's mood, every time a new song is played the runner can either adjust her running style to the song's rhythm or skip to the next music sequence. Conversely, an adaptation of the rhythmic rate would allow to match the beat and the runner's step frequency regardless of the track currently played.
↗ Ensure a hassle-free, motivating, and stimulating workout and music experience; start the music playback before or while beginning the training; use auditory stimuli to (rhythmically) control the runners; adjust the tempo of arbitrary music sequences on the fly to running motion; adjust tempo of arbitrary music sequences to pre-selected workout characteristics specified by the user; etc.

Control the Training. Intensity and performance control during a workout is important regarding the overall training goal. Relying on personal sensation and bodily feelings only can only be misleading in terms of subjective wrong estimations of pace, intervals, and the overall time elapsed. Reliable objective means can be employed to support conscious training, with the aim to improve performance and cadence or motor control.

↗ Start/stop workout; pause/resume workout; skip/end phase; trigger cruise control; indicate the playback rhythm numerically; check the state of the system and workout phase (e.g. goal is reached, phase ends, phase starts); insert cue point; get feedback on training progress and intensity; etc.

Save and Share Performance Data. Endurance running brings along the lack of an instant reward after training other than release from the physical exertion, which can lead to motivational setbacks. Besides, keeping track of only a single training session but not of the overall training period and of long-term stress factors can have the same setback effect or even lead to injuries. Therefore an immediate and long-term post training analysis of training parameters and progress is needed. Access to a history of saved training results for later reviews facilitates re-experiencing the events and sharing the results with trainers and other runners.
↗ Accurately monitor and record the runner's training progress (e.g. elapsed time, cadence, average step length, average and maximum pace, distance, list of songs played); check the workout summary immediately after the training session and compare the results with the workout goals; store and process workout data for historical review and complex post-training analysis; analyze details of different phases; save the workout in a single files for file sharing with other devices or people; etc.

Classic Music Playback. Digital music players offer key functions such as the control of music playback and changing play lists that users are already familiar with. Users browse their music to get an overview and select a particular album or song for playback.
↗ Turn device on/off; select music ordering; select play order; browse music; select music sequence or category; view category track list; select track for playback; start/pause playback; start track over; play previous track; play next track; increase volume; decrease volume; etc.

3.2 Technology

The previous sections dealt with the requirements and demands of the user group for a mobile music device. In the following I will outline how available technologies promote or limit functions, features and design of the music device.

3.2.1 Digital Audio Player

Flash based players store the music on a small, embedded memory chip. Unlike hard drive based players, these devices do not contain any moving parts, which could be damaged through strenuous physical activity. That is, portable flash memory devices are very shock-resistant and small in size. Flash based DAPs are relatively low-storage devices which in most cases cannot hold a users' entire music selection, so users exchange the music files frequently. Compressed digital audio file formats are favorable in comparison with uncompressed waveform file formats. Especially MP3 can nowadays be regarded a quasi-standard among digital audio file formats for consumer applications. With acceptable quality for enjoying music on portable devices, one minute of music requires approximately one megabyte of storage space. Flash based DAPs can commonly be connected with a personal computer to upload and download digital music files via a Universal Serial Bus (USB) connection. This connection also represents an energy source for a music device equipped with an internal rechargeable cell which may be considered beneficial over using AA or AAA batteries. It is easy to recharge the player while synchronizing and USB sockets are commonly found in personal computers. Infrared as an optical wireless interface did not prevail for slow transfer speed and the requirement of a direct line of sight between two devices. Radio-based wireless connections like Bluetooth are on the rise. However Bluetooth can obviously not be used for charging (on the contrary, such connections need extra energy) and is neither suitable for the transfer of larger amounts of data. In the case of the mobile music player as a training device, Bluetooth compatibility might be a valuable extra for hassle-free synchronization of workout plans and performance data, but a USB 2.0 connection should be preferred for its superior speed, availability, and charging capability.

3.2.2 Speed Monitoring for Runners

Matching the music rhythm with the running style requires knowledge of the runners' stride frequency, i.e., cadence. Information on stride length and step count can be used to calculate distance and speed. Pedometers with integrated simple mechanic sensors (i.e., switches) attached to a person's hip are generally known to accurately count a user's steps. Some pedometers work with manually entered or calibrated average stride length to estimate speed and distance. However, a constant stride length assumption leads to very inaccurate measurements because an individual's stride length varies during a walk or run. It is therefore insufficient for a running device that might also be used for longer distances, such as a marathon, where an error accumulating up to several kilometers is too high and not acceptable.

A competing method for accurately measuring a user's speed and distance without calibration would be based on infrastructure, using GPS technology. Unfortunately, a direct line-of-sight to at least four positioning satellites is required and may not be given in woods or close to buildings. Also, with GPS technology alone it is not possible to determine the stride frequency at all, which is essential for the process of music adaptation.

In order to assess an athletes' movement for step frequency and stride length, it appears as a preferable solution to utilize electronic acceleration sensors. The zero-crossings of an acceleration magnitude signal also tell the step frequency. Tri-axial acceleration sensors attached to a runner's foot– inside a foot pod or running shoe, closest to the stride action–can measure the foot's inertial characteristics and this data can be double-integrated to approximate velocity and position in space of the foot for each

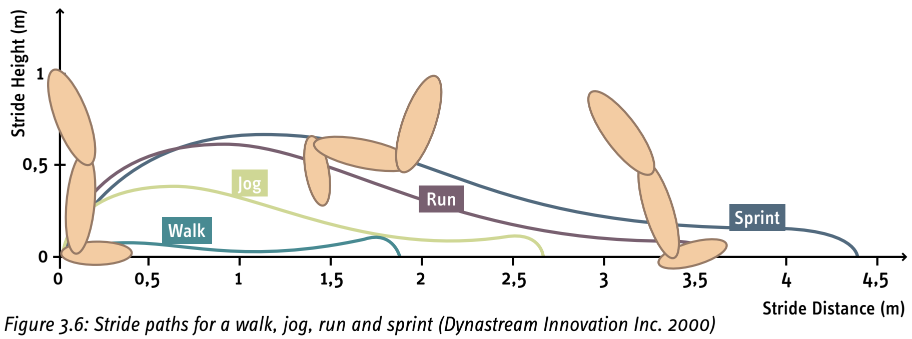


Figure 3.6: Stride paths for a walk, jog, run and sprint (Dynastream Innovation Inc. 2000)

and every step, thus computationally recreating the runners' foot movement to determine the stride length (Fig. 3.6). The accuracy of user-independent step-length-based distance computation comes to 97% with an accelerometer-based technology developed by Dynastream Innovations Inc., and after calibration the accuracy even comes up to 99%. The sensor will "never be perfectly aligned to the direction of the running motion" and hence calibration fine-tunes the calculations with the personal running motions to provide the best possible distance data. This is fundamental because pronation or supination of runners causes "lateral-rolling motions of the foot during running [that] may result in small and repeatable measurement inaccuracies for some users." (Dynastream Innovations Inc. 2000)

3.2.3 Wireless Body Area Network

The sensor has to send the measured data of the runner's movement to the receiver unit of the mobile device. The data link between the shoe sensor and the digital music player should be wireless, as a cable from a foot to the music device (usually attached to hip or arm) is unsuitable. The same applies for the headphones. Depending on the type of wireless communication interference with other systems has to be minimized. The sensor should be engineered to ensure that it does not interfere with Bluetooth, Wi-Fi, cellular phones, or similar electronic devices. Furthermore the shoe sensors should not crosstalk while running in groups with athlete's who use the same music system. To avoid such unwanted interference effects the sending units transmit their own unique ID code as a part of each message. A "pairing" operation assures that two devices recognize each other and the music player will only listen to a specific paired sensor or headphones. If the music device is once paired, it will only look for that specific ID unless a new pairing is performed with a different partner. This avoids interference with close running partners or competitors. To minimize energy consumption of the stride sensor, messages can be transmitted via very short radio-frequency bursts on each step occurrence only. This is superior to Bluetooth connections in terms of lower power consumption so that the sensor can be on by default without shortening the battery life considerably. To wirelessly transmit digital music to headphones, in contrast, the Bluetooth advanced audio distribution profile (A2DP) is preferable because of its robust connection after pairing (no interference with other runners) and satisfactory digital sound quality without noise (no static interference).

3.3 Information Architecture and Application Structure

In this section I will explain the essentials of the organization of functions and the application structure process in this chapter. Although many aspects of this matter cannot chronologically be separated from the design process that is outlined in the subsequent chapter, I believe that this chosen division of content is much more comprehensible.

System Components. Based on the above outlined requirements, constraints, and possibilities, the basic set-up for the intended training and music device must include an integrated mobile music player plus running computer device which is capable of playing music adjusted to match a given tempo, headphones for audio output, and a sensor for measuring a runner's stride. In addition, a personal computer is needed to transfer music onto the mobile music device.

List of Functions. Based on my research and the demands of my user group I collected and conceived functions the music system should cover (Table 3.7). To start with, I analyzed the features of existing music players and running computers, which I complemented with well devised functions in respect to the planned music device concept. To determine missing functions, I created fictional use cases or scenarios based on the gained user group knowledge and investigated how the required components (e.g. chronometer, speedometer, music player, headphones, sensor) work together. Once I had collected all possible functions, I started to order them by their relevance in regard to my research goal, user demands and the majority of use (Baumann & Thomas 2001). Then I reduced the list by dropping dispensable functions. I put aside the functions that only a small minority of the users wanted for later accommodation if the overall design permits a simple, easy and non-hindering integration.

During this course of action I faced the challenge to decide which features should be assigned to the mobile device and which should better be outsourced to a software on a personal computer. In the beginning, I was confident that the user should be able to do everything on the mobile device so she is free and independent of a stationary machine. The increasing storage capacity of music devices facilitates this idea. However, it became apparent that a detailed post training analysis could be done better on the large screen of a personal computer than on the small display of a music device for sports whose size is limited by its very purpose. Moreover, I had to realize that it is very difficult to program complex workouts on a small music device when I tried to model workflows and structures for programming workouts. Besides, none of the existing commercial solutions provides the full programming of workouts on the mobile units. That is why

the idea arose to design a music device that includes the personal computer in the workflow with the aim to avoid awkward interaction with the mobile device due to function overflow and a limited scope of controls, display or overall size. If a workstation computer makes programming and analysis of workouts more comfortable, the music device should in fact even persuade the user to habitually connect it with the computer, cf. Fogg (2003). Yet, the personal computer should not become part of the typical workflow by forcing the user to connect before or after each training session. A reasonable integration of the personal computer, e.g. once a week, would allow the user to benefit from both applications while retaining the mobility of the music device and hence a considerable amount of freedom.

Application Structure and Navigation. The development of a user-friendly application structure by arranging and reorganizing the different functions became the most challenging task of the music player concept. I raised the claim to come up with an application structure and navigation that allows handling high complexity while being pleasurable and easy to use. To solve this problem I had to think about the structure from several angles and I had to re-think and rearrange the function categories several times. On the one hand I tried to reduce the problem by creating categories of functions, on the other hand I estimated the type and number of interactive elements to connect the categories. Both processes were inseparably linked with each other and both took place simultaneously. Based on my intermediate results I created diagrams (application structure) and tables (interactive elements) to present and communicate my thinking in conversations with users. Furthermore, I developed very basic interactive models of the system structure, which I tested with users on a personal computer (Fig. 3.8). Their problems and experiences helped me to file my ideas and thoughts and to find an suitable solution.

List of Functions

BEFORE	DURING	AFTER	TRAINING	MUSIC	PLANNING	LOGGING	SETTINGS	SENSOR	HEADPHONES	COMPUTER	TASK DESCRIPTION
x											turn device on
		x									turn device off
x		x	x	x	x	x	x				set date and time
x							x				inform about date and time
x		x					x				inform about music (songs, folder)
x		x					x				inform about player status (capacity, , firmware)
x	x	x									inform about battery status, warn if almost empty
x	x	x									inform about user input
x			x				x				set voice feedback and signals: off | female | male
x			x				x				set voice feedback interval: off | n min | n km
x			x				x				set synthetic sound type: off | clap | bass | etc.
x			x				x				set synthetic sound interval: 1/1, 1/2, 1/3, 1/4, etc.
x				x			x				set play order: shuffle all | shuffle folder | repeat all | ...
											sort music: by artist | by album | by folder
x			x				x				set countdown timer: off - 59min
x			x				x				set countdown music preferences: song | artist | album | ...
x			x				x				set repeats of interval1 (and interval2): 0-99
x			x				x				select duration of interval1: open end | time | distance
x			x				x				select tempo of interval1: varying | const | range | incr/decr
x			x				x				set duration of interval2: off | open end | time | distance
x			x				x				select tempo of interval2: varying| const | range
x			x				x				set duration time: hh:mm:ss
x			x				x				set duration distance: 100m - 42km
x			x				x				set tempo value1: bpm
x			x				x				set tempo value2: bpm
x			x				x				set workout music preferences: folder | all | off
x			x				x				create new workout preset
x			x				x				delete workout preset
x			x				x				select workout type: free | ...
x			x								start workout (start recording/recorder)
	x		x								lock music tempo
	x		x								unlock music tempo
	x		x								record training progress
	x		x								give voice feedback about progress
	x		x								pause workout (and pause music playback)
	x		x								resume workout (resume music playback)
	x		x								start interval over
	x		x								end interval / start next interval
	x		x								inform that interval end has been reached
	x		x								inform that new interval starts
	x		x								inform that workout end is reached
	x		x								inform that workout end is reached
	x		x								end workout
		x	x								save recorded workout data
		x	x			x					inform about workout results
		x				x					review workout data
		x				x					review workout totals
		x				x					delete workout data
		x				x					delete all workouts
x					x						set workout task
x					x						delete workout task
x					x						set workout task reminder
x					x						review workout task
x					x						review all workout tasks
x					x						delete all workout tasks
x							x				set recording rate
x		x					x				reset player to factory settings | format player memory
x			x	x							start music playback
	x		x	x							pause music playback
	x		x	x							play next song
	x		x	x							play previous song
	x		x	x							start song over
x	x		x	x							increase volume
x	x		x	x							decrease volume
x								x			attach/connect headphones
x			x					x			check headphone connection
x							x	x			inform about headphones battery status
x							x	x			pair headphones with player
x			x						x		wake sensor
x							x		x		pair sensor with player
x							x		x		calibrate sensor
x			x						x		check sensor connection
x		x								x	connect player to computer
x		x								x	inform that player-computer connection is busy
x		x								x	eject player from computer
		x								x	upload workout data to personal computer
x										x	download data (workout and music files) to player
x		x								x	update player settings and software
x		x								x	charge battery

Table 3.7: Exemplary list of important functions organized by workflow, category and system components

Figure 3.8: Users test different interactive models of the system structure

My workflow to develop an adequate application structure can be summarized as follows:

1: Make a collection of all functions independent of the application's physical representation

2: Divide the pool of functions into those that should be available on the mobile device and others that should be outsourced or maybe re-assigned later on

3: Sort the functions based on task flows

4: Categorize the functions based on logic groups (simultaneously with 5)

5: Work out the basic interactive elements needed to navigate between the categories and to use the features of the music player (simultaneously with 4)

Function Categories (Fig. 3.9). In my first approach I attempted to structure the functions based on the users' workflow of a typical training session to facilitate a process-oriented user experience. The categories planning, training, and analysis seemed very distinct in the first place, but it turned out that system setting or classic music playback functions could not strictly be assigned to one category. I came to the conclusion that the training functions are almost as important as the classic music player functions, dependent on the user's time and context of use (e.g., training vs. daily life). So in my second approach I tried to treat the trainer and player functionality as equal. Both tool categories had their own subordinated setting categories that were arranged at the

same level with the task list and logbook category. This approach failed for the reason that it was impossible to precisely assign interactive elements to navigate between the different categories. Moreover, the music device seemed to consist of two poorly integrated devices instead of offering a music player and a trainer tool. In the end, I isolated all sections of the mobile music device into self-contained mini-applications connected via a home screen as the central crossing point. This "hub and spoke" approach provides a very simple and clear structure and reduces the clutter of the sections as it promotes the focus on one section at a time and a familiar route via the hub to get to any other section (Tidwell 2006:68-69). I also decided to provide extra shortcuts for advanced users to immediately navigate to the player or trainer application without following the home circuit.

Interactive Elements (Table 3.10). I defined the essential and indispensable types of interactive elements of the music player to solve the problem of navigation between sections and the execution of functions. All categories—settings, trainer, player, task list and logbook—contained groups of functions the user should choose from. Presenting a large number of functions on a single miniature screen required structuring the content into a very clean and organized panel—a reduced menu of options. Such menus commonly require four functions for navigation and execution: next item, previous item, select item, scroll back (Lindholm et al. 2003). The two self-contained mini-applications player and trainer did not rely on this menu but brought along different requirements. A simple music player needs a play, pause, skip and repeat track function and an increasing and decreasing volume function that should always be accessible. The trainer necessitates direct access to even more functions during a workout (Table 3.10).

Based on these lists of interactive elements for each case, I developed different application structures with different numbers of overall interactive elements. My focus was to ensure a distinct and faultless interaction during the running session, which is the most demanding and stressful activity for the user. Moreover, interac-

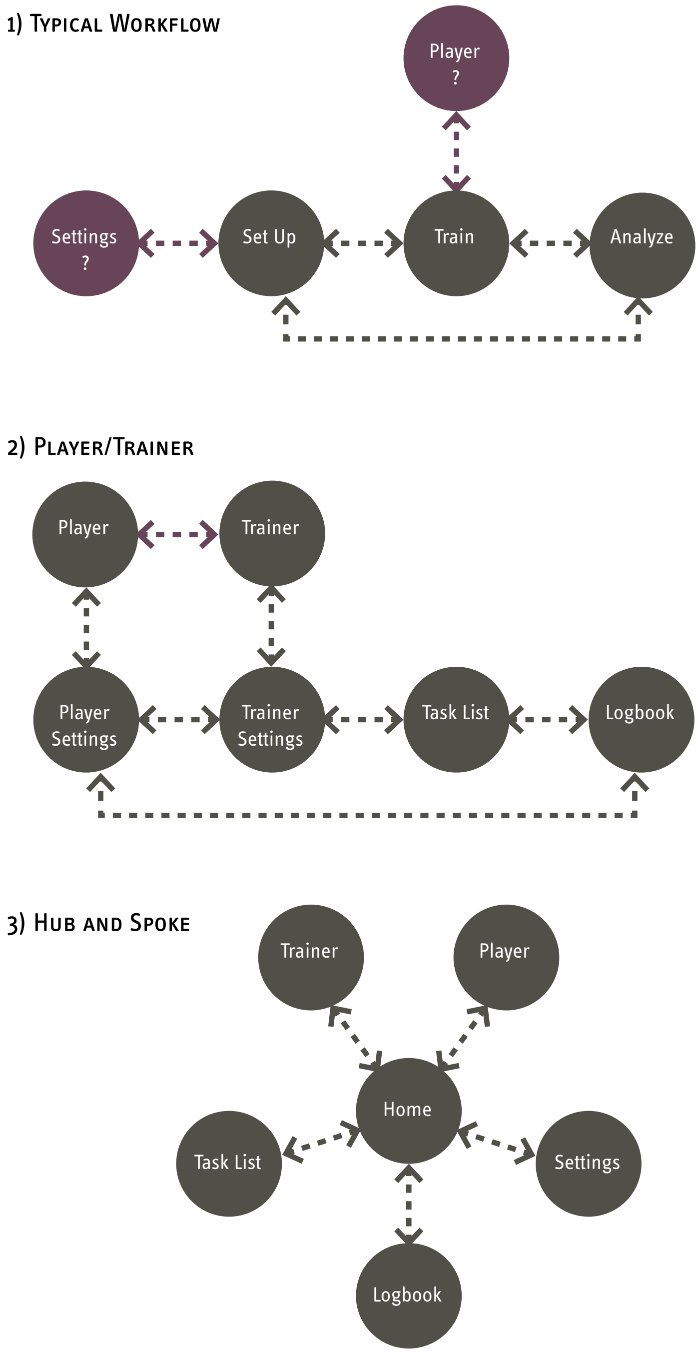


Figure 3.9: Three different application structure approaches

General	Trainer	Player
▸ increase volume	▸ increase volume	▸ increase volume
▸ decrease volumen	▸ decrease volume	▸ decrease volume
▸ selection: open item/ sublevel, apply a function to selected item	▸ give immediate voice feedback on workout progress	▸ play/pause: start or pause music playback
▸ scroll forward: point at the next item	▸ scroll forward: point at (and play) the next song/folder	▸ scroll forward: point at (and play) the next song/folder
▸ scroll back: point at the previous item	▸ scroll back: point at (and play) previous song/ folder	▸ scroll back: point at (and play) previous song/ folder
▸ backstep: return to higher level	▸ pause recording	▸ switch folder-song
	▸ increase tempo/phase	
	▸ decrease tempo/phase	

Table 3.10: Important functions to control the music device

tive elements associated with a positive character should not have negative effects in other states of the device or in other mini-applications. Hence, all similar activities of the different mini-applications should be assigned to the same interactive element. Besides, the navigation and interactive elements should prevent the user from making mistakes. Again, I also wanted to provide shortcuts for advanced users, for example to switch between the mini-applications or to simply stop the workout without further hassle.

The overall result was that the “hub and spoke” application structure in combination with six interactive elements works best. I therefore chose this approach for my final design.

DESIGN PROCESS 4

This chapter illustrates assessments and outcomes of the design process with regard to the training and music concept for runners. My whole design process consists of several iterative cycles, each with a different duration, volume, and subject matter. Even though each section distinctively describes a specific aspect or research focus, it must be considered that new insights and results mutually affected other facets of the design.

4.1 Audio Sequences—Can you join in and keep up with the beat?

In order to design a music device that adapts music according to training preferences it was essential to research and experience how music can be integrated into the training session. I wanted to find out how the beat of music can influence the running style and how it affects the runners' sensation and perception. Moreover, Matthias Diederichs—himself a runner and trainer for running and aerobics—called my attention to the question of how far music can be stretched while still being convenient for running pursuits. From the Fraunhofer Institute for Computer Graphics and from my own research I learned that it is possible to stretch music within a very wide range when using the *StepMan* technology. Also, if music is accelerated to 150%, this speed can also be treated as 75% if the runner takes only every second beat.

To gain further clarification and personal experiences, I arranged a testing environment in a gymnasium and invited runners to participate (Fig. 4.1). The very simple setup consisted of a notebook with two speaker boxes. To manually shift the music tempo

Figure 4.1: Music adaptation tests and experiences

I used a music playback software with a free plug-in for real-time tempo adjustments.

During the test, users were asked to join in with the beat of the music and to verbally express their experience, while I manipulated the tempo of the music sequences. I also put up a series of tasks the user went through, e.g., matching the running movements to the music beat and keeping up with the beat as it suddenly changes. Moreover, the users were asked to spontaneously interact with the music playback facility which I impersonated in this case. In this context, we began to communicate via audio commands, audio cues and spoken feedback—even though not planned—to simulate a virtual music system.

The test demonstrated that it was easy to join in with the beat of music for the runners as long as the rhythmic structure was easy to identify. Clapping or tapping the beat on the ground helped the users to detect the rhythm. Here, the idea arose to provide an additional synthetic sound feature for the music player, which layers a synthetic beat on top of the music sequence. Most users agreed that they would appreciate rhythmic accents as long as they matched the music style. Similarly, during the test the idea was developed to provide a music player function for intermittent audio sequences, such as cheers and commands, which is what commonly trainers or an audience usually call out to runners to motivate them to keep up the pace. Increasing or decreasing the music tempo did not confuse the runners when done slowly. It just seemed natural to keep in pace with the rhythm of the music, which might also be based on the runners' intention or will to do so. Yet, when a hard, sudden shift in music tempo occurred, users felt awkward especially when no prior announcements were given. Addressing the users via audio sequences and spoken words worked very well because it did not interfere with their running in a disruptive manner. However, it was difficult for the runners to speak because they had problems to concentrate and got out of breath. Referring to the music device concept, audio and voice output could be used, but voice input is not favorable

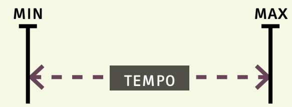
Constrained Music Matching	Alerting Music Matching
	
The tempo of the music adapts to the runner's step frequency within the range only. If the runners' step frequency gets too low or too high the tempo of the music remains within the range limits.	The tempo of the music changes to the runner's step frequency without constraints. If the runners' step frequency gets too low or too high she gets warned.
Didactic Music Matching	**Proactive Music Matching**
	
The tempo of the music adapts to the runner's step frequency within the range only. If the runner's step frequency comes to the range limits, the music changes its tempo in the opposite direction to motivate the runner to change her step frequency.	The tempo of the music adapts to the runner's step frequency without constraints. If the runner's step frequency comes closer to the range limits, the tempo adaptation is retarded to gently persuade the runner to stay within the range.

Table 4.2: Thoughts on range music matching

and should be avoided.

This test and my research on training methods helped me to derive different types of music adaptation for the mobile device concept, such as constant, ranging and varying tempos (Table 4.2). Moreover I can confirm that music sequences can be stretched to the extreme since users keep up with the beat by using for example only every other beat. And even though small skips may appear during adaptation, this does not affect the overall positive experience. Nevertheless, it became apparent that the music sequences should be distorted as little as possible to preserve the original feelings associated with the music.

Figure 4.3: Runners with their music players and favorite positioning

4.2 Position—Where Should the Music Device be Placed?

Position and weight of the music device are very important because it should be comfortable to carry and easy to operate while running. The results of my questionnaire point out that the music player should be lightweight, small, and stay put while running. It was shown that runners prefer different positioning for their music device, ranging from hand to wrist to pocket. To visualize this aspect I asked runners to take pictures of themselves carrying their music devices the way they typically do (Fig. 4.3). Moreover, I went to the park and took pictures myself while interviewing runners about their preferred attachment of devices.

I found that the choice for positioning a device is less dependent on personal preferences than on the limited attachment possibilities on running clothes and the available accessories.

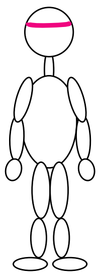
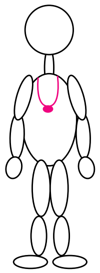
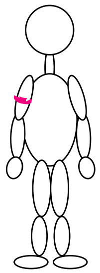
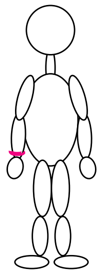
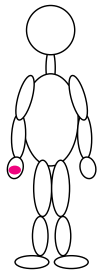
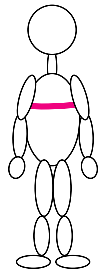
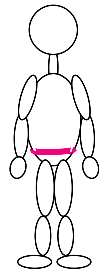
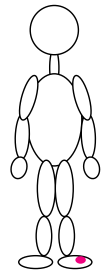
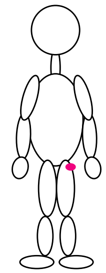
That is why I built small music player models to gather criteria for the physical design of the music device and its best position during the workout. I used small matchboxes and battery packs for the music player models. Each box was different in size and weight, and had a small clip so it could be fixed to the users'

Figure 4.4: Test with different matchbox models

clothes. I asked runners to attach the models at different positions and to freely interact with them while running, pretending the models were real music devices (Fig. 4.4). Based on the user reports and my observations I created a list of pros and contras concerning different aspects of the tested positions (Table 4.5).

During the process it became apparent that—especially lightweight—products can comfortably be worn or carried at various positions, while securely keeping them in place, i.e., so they are not bouncing up and down or scrubbing on the athlete's body. Only few positions were easy to reach and to handle with minimum effort and attention of the athletes. The smallest fraction of all positions was easy to see, i.e., allowed to have a display in sight. Based on these findings, my further design concept moved forward to a wristband solution, which is comfortable to carry, easy to reach and easy to use while only slightly interfering with the running style. Furthermore, the wrist position is very common for running computer devices and can also conveniently be worn during other activities in everyday life.

Assets and Drawbacks of Positions

	Head	Neck	Upper Arm	Wrist	Hand	Chest	Hip	Shoe	Pocket
Wear	-	o	+	+	o	o	+	+	+
weight*	<=22g	<=22g	<=78g	<=81g	<=81g	<=44g	<=81g	<=44g	<=44g
fixed position	o	-	+	+	+	o	+	+	o
familiar position	-	o	+	+	-	-	o	-	+
Comment	headband, needs to be very lightweight, may interfere with hats, earrings, glasses	necklace or collar-clip, needs to be very lightweight, bounces up and down even when worn underneath the clothes	needs to fit different arm sizes, may interfere with longsleeves	wrist band or cuff with thumb hole (compare glove), needs to be thin so clothes can be taken on/off easily	glove, may feel uncomfortable, may interfere with opening a drink or when a second glove is used against the cold	comfortable to wear with sports bra, chest strap is difficult to fix and may scrub into the skin	comfortable when clipped to a belt or tight pants	easy to wear attached to shoe laces or inside the shoe, weight balance with other shoe, watch out for mud or puddles	comfort depends on pocket type and size
Use	o	o	o	o	+	o	o	-	o
1 hand	+	o	+	+	+	o	+	-	o
2 hands	o	+	-	-	+	-	+	-	-
Comment	difficult to use with two hands, pressing buttons against the ear / fumbling around the head may feel akward	needs to be held with at least one hand, may be difficult to catch/grab while running	easy to use with the other arm's hand, not possible to use with both hands	easy to use with the other arm's hand, not possible to use with both hands	easy to use with fingers inside the glove or the other arm's hand	difficult to use above and underneath the clothes, ok when attached to sports bra (compare with neck)	easy to reach with one and two hands, needs to stay put to be easily usable	not possible	difficult if pocket is closed, far away or small
See	-	o	o	+	+	-	o	-	-
before/after	-	o	o	+	+	-	o	o	-
while	-	o	o	+	+	-	-	-	-
Comment	not visible	difficult if underneath the clothes and if not held with one hand	possible to see from the top when head is moved, more difficult to see when running	easy to see, especially when arm is moved	easy to see, especially when arm (and hand) is moved	not visible when top is worn	difficult to see, better to see with tight clothes and when runner is skinny	feet are too far away and move while running	not visible inside the pocket

** based on weight of the tested models*
+ = positve, - = negative, o = neutral

Table 4.5: Comparison of different mounting points on the human body

4.3 Physical Parameters and Design Aspects

Output Devices.Spoken feedback and audio cues perfectly meet the characteristics of a music device and inform the user about the workout or system status without interfering with the physical activity of running. The display outputs additional information on the system status, settings and options of use to facilitate user interactions especially before and after the workout. But even during the workout the display can be beneficial. It allows the user to scan her training progress at a glance. In contrast to sequential audio output different information elements can be gathered in parallel and quickly be associated with each other. Multimodal perception does not only imply redundancy, but achieves mutual augmentation by combining the specific assets and drawbacks of different media. In this sense, displaying graphical information is not just meant to please runners who prefer to visually track their training progress. Combining audio and visual output provides an immediate, direct, and distinct feedback and overview.

Display. Section 4.2. demonstrated that the wrist is the perfect position to attach and wear my mobile running device. In the next step I wanted to define the display parameters for the wrist unit. Since many screens of existing running watches that display the runners' progress are not designed in a distinctly organized manner that promotes legibility (which is not always due to technical constraints) I was motivated to find a clearly readable solution. As I have already discussed in Section 3.3, several functions of the mini-applications called for a menu or list structure. According to Nygren (1996) it was found that displayed menu items can be better processed by 20% in columns instead of lines, in contrast to reading sequential texts where the horizontal space is more important than the vertical space (Jones & Marsden 2006). I created different screen designs to find out if the menu presentation could also be adapted to the numeric information of the training progress (Figs. 4.6-4.9). Showing the screen sketches to users affirmed my presumption that a vertical arrangement of the items

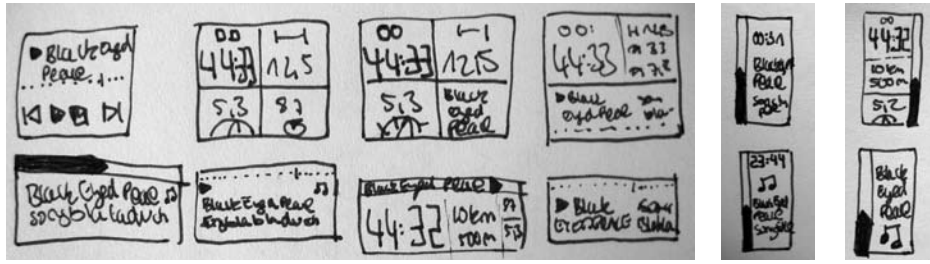


Figure 4.6: Early sketches with portrait, compact and landscape format

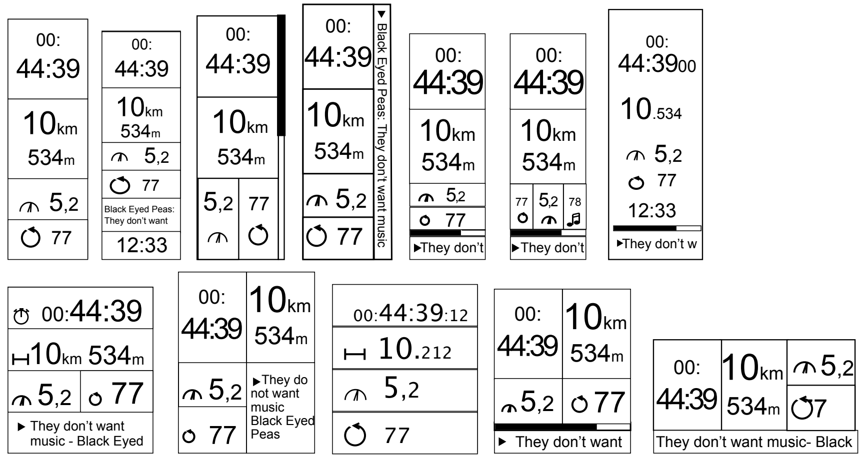


Figure 4.7: Digital sketches with portrait, compact and landscape format

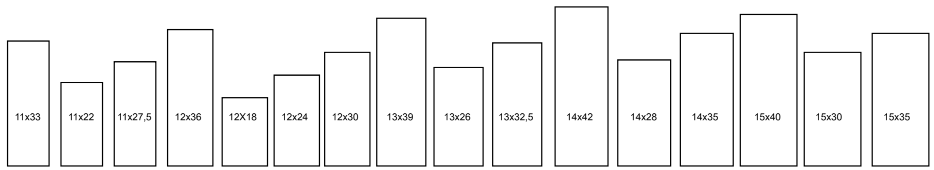


Figure 4.8: Portrait format variations for assessment

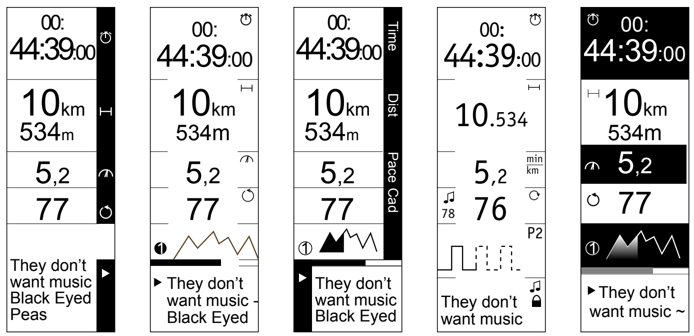


Figure 4.9: Detailed display arrangement sketches

 PORTRAIT	0°	30°	45°	60°	90°
HANDLING	0	-	-	-	0
READABILTY	+	+	+	0	-
SYMMETRY	+	-	-	-	+
INTERACTION	+	0	0	0	-
PORTRAIT	+	+	+	+	+
SUMMARY	++++	0	0	-	0
 LANDSCAPE	0°	30°	45°	60°	90°
HANDLING	0	+	+	+	0
READABILTY	+	+	+	0	-
SYMMETRY	+	-	-	-	+
INTERACTION	-	0	0	0	+
PORTRAIT	-	-	-	-	-
SUMMARY	0	0	0	-	0

Table 4.10: Comparison of a portrait and landscape format display in different angles

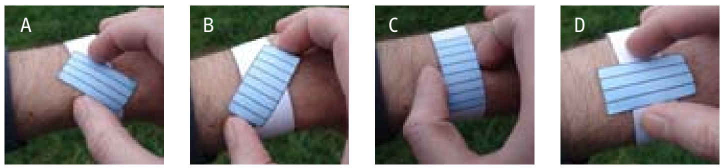


Figure 4.11: Assets and drawbacks of display formats and viewing angles: (A) landscape format display with large interaction area in user-friendly viewing angle, (B) portrait format display with limited interaction area in user-friendly viewing angle, (C) symmetrical potrait format display with large interaction area, (D) symmetrical landscape format display with limited interaction area

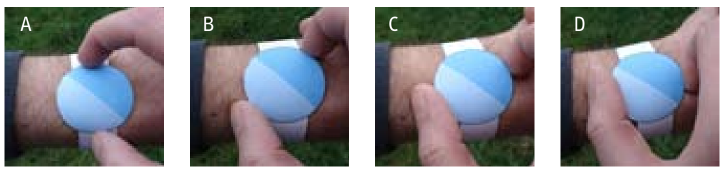


Figure 4.12: Comfortable interaction areas for opposite fingers

works best. For my music player concept, presenting the information on a portrait format screen seemed to be the right choice for the desired quick cognizance.
In a second step I again prepared different paper models to test the physical position and format of the display when worn on the arm. Each model was characterized by a different angle of a rectangular display. Table 4.10 and Figs. 4.11-4.12 illustrate my findings and point out the opposing characteristics of a vertical portrait display and a wide landscape arrangement with respect to flanking buttons, sliders or other controls.

BUTTONS. Different solutions for the music device input were playfully tested with the matchbox models, which I originally built to assess position and weight. Moreover, I collected relevant control elements and scribbled different ideas that meet the demands of the users and the constraints of a mobile device (Figs. 4.13-4.14). Unused but potentially interesting interface options will be presented in Section 4.5. For the wrist unit design concept, the requirement to control the music device without looking came down to one-shot keys or buttons that provide direct tactile and acoustic feedback. Besides it was crucial that each button meets the physical characteristics of the user (e.g. size and position of finger and hand, support of the opposite finger), but also to consider personal preferences and alternative usage (e.g. device being attached to the wrist vs. holding the device in the hand). After careful deliberation, I designed a symmetrical wrist unit with a centered display (Figs. 4.15-4.16). The buttons aligned along each side and each can be pressed from the top, the side or both directions.

GENERAL DESIGN ASPECTS. The symmetrical design allows left- and right-handed athletes to equally enjoy the music player when attached to the wrist and provides a harmonic and sleek look and feel. Similarly, the vertical format of the miniaturized display provides best readability, while not making the wristband too bulky. For this reason, runners can additionally wear a sweatband or take off clothes during the workout without getting stuck at the

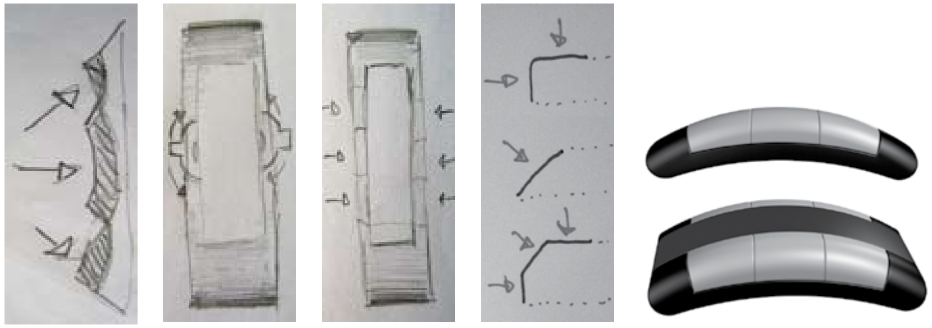


Figure 4.13: Scribbles to find controls that can be used from different angles (right: 3D rendering of digital sketch)

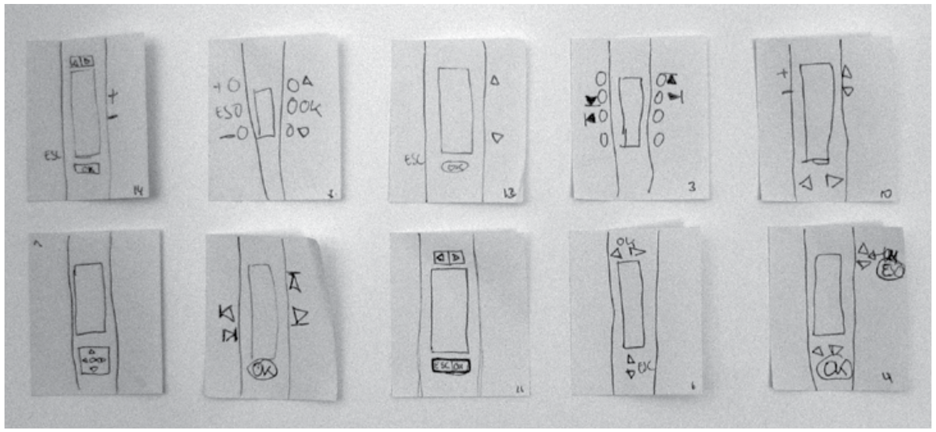


Figure 4.14: Sketches and thoughts on controls and their positionings

wrist unit. I adapted the exact display size to follow the well-balanced style of the wrist unit. In the final version it consists of a basic grid of three squares that are aligned with the three buttons on each side.

Further I had to find a narrow and compact typeface to create a working screen design for the extreme vertical format of the small display. Moreover, the screen design was going to be ruled by presenting many numeric and menu-item-like information in a “one-window drilldown” pattern (Tidwell 2006:36-37). I decided to use the FF Info Display typeface, which was originally developed for signs and offers very distinct characters. It perfectly met my requirements to create a very plain but expressive and legible screen design without dragging the users focus of attention away

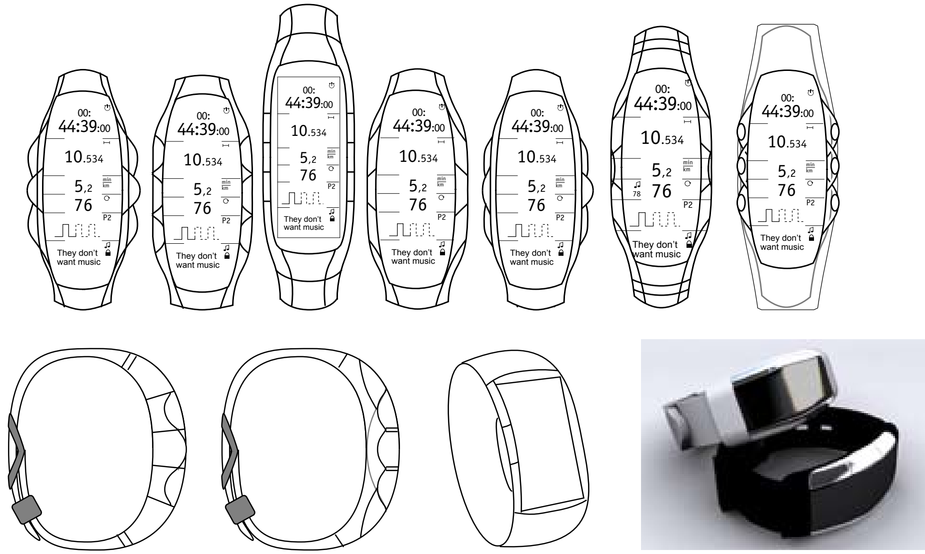


Figure 4.15: Sketches of wrist unit cases: The transition between strap and case should be fluent in the final version.

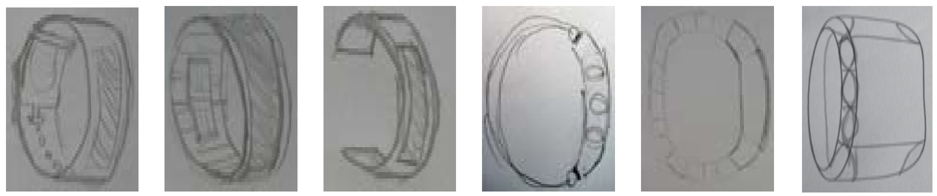


Figure 4.16: Sketches and thoughts on different bracelet types

towards decorative elements.

Based on my user group research the overall appearance and form of the wrist unit had to support the sports spirit while pleasing the elegant and noble design taste of go-ahead sports people. My first idea was to create the product design based on waves that resemble the step frequency variance in the course of a run, thus communicating the product’s very subject matter. Yet, it turned out that in connection with the small form and comparably large display and buttons the waves made it appear too playful and over-decorated. In my second approach I radically simplified the design of the wrist unit and other components—headphones and sensor—down to their basic elements for minimal fashion without distracting the attention from the screen design. Form and size were restricted to the requirement of housing electronic circuitry in a ruggedised manner. Coloring most parts of the components black followed the line of making them unobtrusive. I then added a second color to produce the jaunty and unique look and feel of a sports training system and to highlight important functionality. The well-groomed final color scheme chosen for the *Ritmo* product line appears luster and yet is very subtle, as it mainly draws from contrast and simplicity. Details on the final version of the training and music system follow in Chapter 5.

4.4 Headphones—Make them wireless and have them stay put

Delivering high fidelity audio quality is important but plays a subordinate role when headphones are primarily being used for running. The choice for the perfect earphones is dominated by a secure fit. No matter how intense the activity is, earphones have to provide wearing comfort and stay put. At this point the music device design concept affected the form of other components of the music system. The disposed cable-connection between the music player and the headphones made me rethink the design of the wireless earplugs in terms of stability and comfort to avoid losing the separate headphones during or before the workout.

On account of that I researched different headphone styles and attachment concepts in addition to the positioning of the music player and talked to runners about their preferences. Many sports designs use open-backed headphones in order to allow the ambient sound to be heard, so to keep up the runner's awareness of her environment. Open-backed headphones often come with a vertical band that arches over or behind the head for secure fit, but especially the often-praised sporty neckbands are difficult to adjust to the head and ear and may move up and down during the workout. My observations and my online questionnaire showed that most athletes use earbuds that directly sit on the ears or even in the ear canal, even though many people find

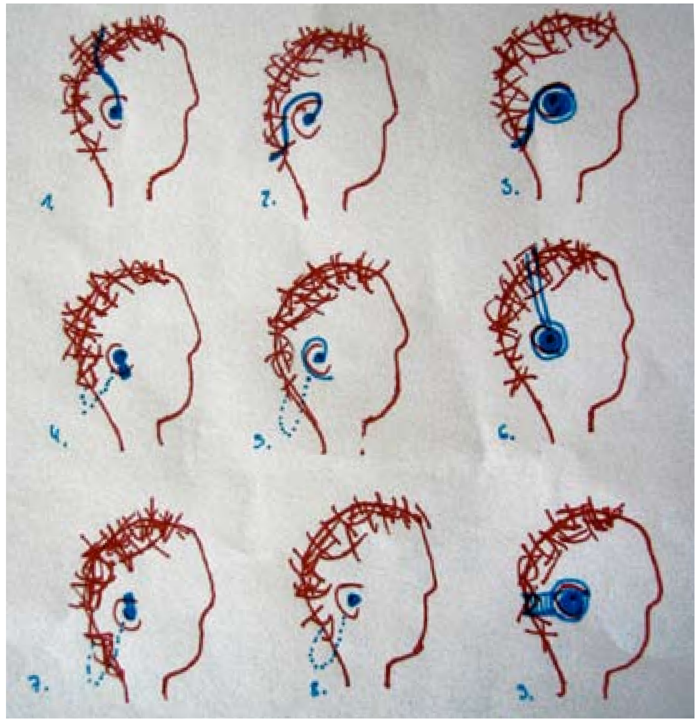


Figure 4.17: Sketches of headphones with connected speakers that achieve secure fit via a flexible headband (1)(6), a flexible neckband (2)(3), a soft neckband (9), an ear-clip and a light cable lace (5) or differnt earbud solutions with a light, flexible cable lace (4)(7)(8)

the idea of inserting foreign objects into the ear is awkward and uncomfortable. These earbuds are very compact and lightweight and do not interfere with earrings, glasses, or hats. In spite of that all, both headphone types—open-backed and in-ear—have assets and drawbacks in regard to sports usage. Their comfort can only be judged subjectively. The pressure exerted by in-ear plugs, the warmth of closed earpads, or the overall weight—all such aspects are perceived differently by individuals not only because of the varying forms and sizes of heads and ears.

In any case, lighter headphones can be expected to contribute to comfort rather than heavier ones. A flexible clip or headband provides secure fit and prevents the earpieces from falling out, especially during the training session. Moreover, connected earplugs cannot get lost as easily as separated solutions and some headband styles can even be worn around the neck when not being used, preferably without having the earplugs shaking around. Last but not least, compact headphones solutions are better to transport and store. Figure 4.17 gives an overview of my ideas for different types of headphones. My final headphones design solution—the *Ritmo Sports Headphones*—has been created based on this research, observations and user experiences. For more details please see Section 5.3.

4.5 Unrealized Ideas

During my work for this master thesis, every now and then design and concept ideas for the music device emerged which I eventually rejected for the final product. This section is dedicated to alternative design approaches and unrealized ideas, because they may indirectly explain my decisions for the final design concept. If nothing else, they have at least brought along vivid discussions and provided valuable stimuli for this project.

Figure 4.18: The grooveRider shirt allows users to operate their iPod directly through a smart fabric interface (Urban Tool 2007)

Remote Control and Smart Textiles. Many music players utilize a small remote control with basic transport functions and enable the user to wear the player hidden in a pocket or bag. However, the idea to split the music player into 2 pieces—remote control and processing element—was not used because it is desirable to carry as few devices as possible and three devices—music player, sensor, and headphones—are already a lot. In contrast, existing smart textile solutions integrate remote controls into clothes, which does not increase the overall number of separate devices (Fig. 4.18). Yet, existing concepts that embed electronics in clothes are not automatically easier to use. Moreover such garments are more expensive and less durable than normal sports gear. The nature of these smart textile products interferes with the runners' behavior to take off or put on clothes for temperature compensation during the workout. Moreover, the runner would be asked to purchase several products considering changing weather conditions. A music device designed as a wearable wrist unit or bracelet avoids these problems while providing the same functionality.

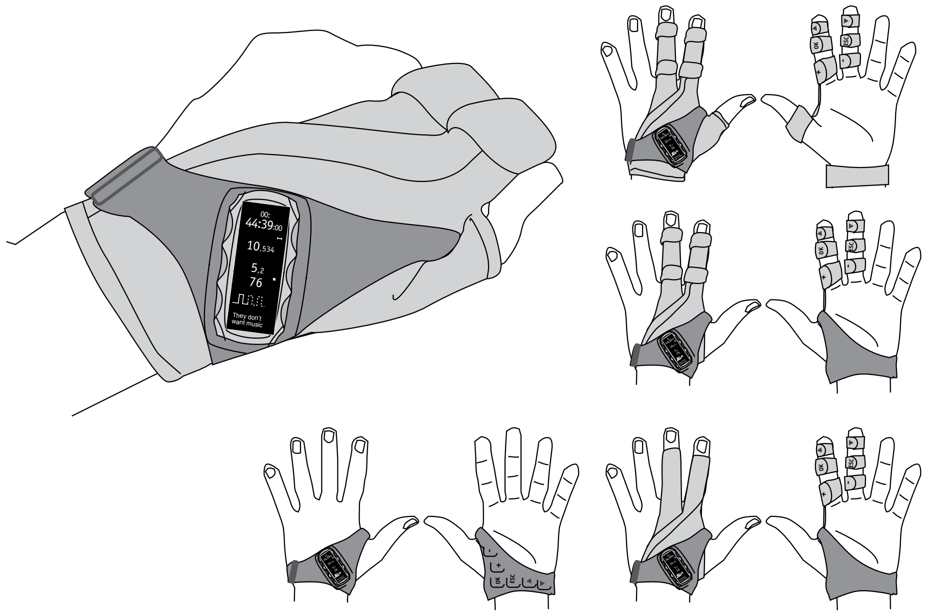


Figure 4.19: Sketches of a running glove

Figure 4.20: Paper model of a running glove

Glove. During the test with the matchbox models it turned out that the wrist is in fact the best position for the main unit of my music player concept. Based on these findings I began to scribble different ideas for a music device that is attached to the wrist or hand. I was eager to find a solution for the wrist unit that can be operated with one arm and hand only, which is not easily possible with a bracelet or watch design. I developed different glove designs with integrated switches that may all work when tailored fairly (Fig. 4.19). The one-hand-interface idea is very attractive in regard to both hassle-free intuitive use and market positioning, even though the necessity of different glove-sizes will make an industrial production more expensive. From a user point of view, the glove is more difficult to attach and adjust than the wrist unit (Fig. 4.20); it is not suitable for everyday life activities and needs to be washed often. All theses characteristics make the glove a more complicated solution than the wrist unit alone. With the goal to provide a simple product for one of the simplest sports disciplines, I decided against the glove.

Gestures. Finding alternative and more intuitive input solutions has been researched for decades. It is often suggested that gestures are more intuitive than pushing buttons. Current technologies make it possible to control electronic devices via gestures. The music player Sony S2 Sports Walkman for example can be shaken to change the play order of songs. Therefore I looked for gestures that would work during the activity of running without consuming too much energy or involving unusual movements, but I could not find any distinct solution that would not lead to a loss in performance due to high concentration or interference with running cycles.

Touch Display. When I generated ideas for the wrist unit display and its controls I investigated whether an up-to-date (multi-) touch display which can be directly controlled with the fingertips would enhance the interface and provide a pleasurable experience for runners. At first, I liked the idea to not just reduce the music player design to its elementary form but also to diminish the number of movable elements. In regard to my music player design, however, the largest drawback of touch screen devices turned out to be that they are very tricky to control without looking. Especially during the workout runners would have to face difficulties in finding the right spot for accessing a specific function on the touch screen. Although I found research work on touchscreens that provide haptic feedback via slight vibrations, using different frequencies depending on the finger position (Immersion Corporation 2007). I discarded the idea of a touch display simply because it seemed too awkward to be used with sweaty fingers while rhythmically moving the body.

Vibrations. Regardless of using a vibrating touch screen or not, I had the idea to employ a vibration feature into the music

player with the aim to offer elite runners a pacer function when used without headphones. An email conversation with Mareile Kitzel—professional short distance runner and sports student—and my following tests with my mobile phone vibrating on my arm brought me back down to earth. Vibrations get very annoying after a while and besides they consume too much energy, as a little off-balanced DC motor within the device has to be powered to create the vibrations.

DESIGN SOLUTION 5

While design activities are mostly based on facts and establish facts, not all assumptions and assertions have to be proven scientifically. Neither do design decisions always have to be justified by revenue expectations. The following design solution, although based on extensive research of its underlying foundations and down-to-earth technological considerations, aims for a product that is desirable for runners instead of a maximum of technical feasibility or convenience. Some aspects may therefore impose moderate challenges on present-day engineers in terms of miniaturization and cost. Nevertheless, most ideas presented herein can easily be adopted for current product development.

5.1 The Ritmo System

Ritmo (Spanish for "Rhythm") proactively integrates music into the runners' training. Through auditory feedback and music tempo adaptation *Ritmo* supports and stimulates the athletes' workout. *Ritmo* can be used to consciously train cadence and speed, rhythmic movements or just to listen to music while avoiding an interference between music and running rhythm. *Ritmo* provides performance monitoring and post training analysis functions. *Ritmo* can be adjusted to runners' individual goals and tasks and provides motivational support for everyone who likes running with music.

Ritmo consists of a wrist unit, a stride sensor (incl. clip), wireless headphones, software and a USB (charger) clip (Fig. 5.1). A personal computer is needed for uploading audio and workout files to the wrist unit, as well as for downloading performance data files for post-training analysis.

Figure 5.1: The Ritmo Sensor, the Ritmo Wrist Unit, and the Ritmo Headphones

Ritmo stands out among sports products because of its reduced but noble gestalt. All parts of the *Ritmo System* are very compact, easy to wear, and convenient to transport and maintain. The visual coherence regarding function, shape, and appearance gives the *Ritmo System* its distinctive sporty but graceful style.

5.2 The Ritmo Wrist Unit

The *Ritmo Wrist Unit* (Fig. 5.2) is the heart of the *Ritmo System* and the part that I regard as the main focus of this thesis. The wrist unit is a mobile training device that combines and unifies functions of a classic music player and a running computer. It perfectly integrates into the physical activity of running, as it does not interfere with the runner's motion or other running gear and communicates wirelessly with headphones and speed sensor for a hassle-free running experience. Via a USB clip, the wrist unit can quickly be connected to a personal computer for uploading or downloading training plans, music files, as well as performance data. Charging the battery is effectively fulfilled whenever the convenient clip is slid over the wrist unit's data and power contacts (Fig. 5.3) and connected to either a personal computer (using

Figure 5.2: The chosen Ritmo Color Scheme

the USB-supplied voltage) or to a power adapter that provides a USB-style socket.

The *Ritmo Wrist Unit* is designed for active use in sports and is therefore very durable, lightweight, and thin. Six buttons are aligned symmetrically around the display—three on each side. A *Flip* function makes it possible to mirror all key bindings around the vertical axis, so the watch is a pleasure for left- and right-handed sports people alike. The buttons may be pressed from the top, the side, or diagonally, allowing for the users' personal preferences and different situations of use. The color of the clearly perceivable buttons emphasizes their interactivity by dragging the user's attention towards them—an invitation to touch and play.

Figure 5.3: Metal contacts on the back of the wrist unit case for data and power connection via clip

The *Ritmo Wrist Unit* features a thin curved electronic paper (e-paper) display within a matt casing that extends into an adjustable strap. The uni-body enclosure contains the circuitry and frees the design of any discontinuity in form. The negative white-on-black display embedded underneath the bracelet-shaped surface achieves the illusion of disappearing when the device is turned off entirely. In default sleep mode, the wrist unit functions as a watch that tells time. The employed e-paper technology—and the distinct screen design—make information displayed on the *Ritmo Wrist Unit* easily readable during the workout, as it provides a full viewing angle, high contrast and brightness even in the sun. Furthermore, e-paper technology is lightweight, durable, and highly flexible. It hence perfectly meets the requirements of running.

5.2.1 Functions and Features (Fig 5.4)

Home. *Home* is the starting point and marks the central intersection that structures and holds together all *Ritmo* features. The user activates the *Home* hub to go training, to play music, to check upcoming tasks or recent workouts, or to change settings.

Trainer. In spite of my earlier decisive statement not to design a didactic training device, I call the training-supporting feature *Trainer*. That makes it an excellent counterpart to the music feature named *Player*. On top of that, it is an appealing and catchy minimization of its very purpose of usage: training. The *Trainer* covers all stages of a typical running session: planning, training, and analysis.

From the opening screen the user can immediately start the default exercise, provided that the *Ritmo Stride Sensor* connection has been set up successfully. Immediately upon entering the *Trainer* the sensor connection is made automatically within 15 seconds and the sensor index sign stops flashing when the *Ritmo Wrist Unit* has found the stride sensor signal. Also, music starts playing automatically (the pre-selected music sequences of an already selected or of the default workout are played) to enable the user to adjust the volume before the workout. Still, the user can also select another workout or change the workout settings on the first *Trainer* screen.

When the user starts the workout, the wrist unit begins to monitor and record performance data (time elapsed, distance, speed, cadence, music parameters, songs listened to, and user interactions) and the music sequences are adjusted according to the predefined parameters.

By default, the wrist unit offers one special workout program, the Free Workout. In this open-end workout the music rhythm

adapts to the runners' step frequency in real-time to avoid interferences between running motion and music rhythm. The user can manually lock and unlock the music tempo through button push on the wrist unit, just like with a cruise control. In addition to the Free Workout, pre-planned workouts can be transferred from the *Ritmo Software Suite* on a personal computer to the *Ritmo Wrist Unit*. During the workout, music is played according to the pre-planned workout setup and guides runners through the different phases like a rhythmic pace maker. In contrast to the Free Workout, here the music tempo cannot be locked or unlocked as the training was consciously planned in advance. Instead, the user is able to navigate between the different phases of the workout. The basic music and audio control functions are available at any time of the training session.

During the workout the user can get spoken feedback on her status automatically or manually triggered, even though the most important training data is also displayed on the wrist unit. Audible indications are used as general feedback and to inform about workout changes (e.g. phase ends/starts) or when training intensity is either above or below the current phase target.
The user can manually stop the workout session at any time during the workout. The wrist unit saves the recorded performance in the *Logbook*. A summary will be shown on the display immediately after the training for quick review.

Task List. Workouts created on the computer can be associated with training dates and times. When uploaded to the *Ritmo Wrist Unit*, they appear in the *Task List*, waiting for execution. The *Ritmo Wrist Unit* automatically sets an alarm for the reminder date and time that can be specified for each training task.

On the TasksList screen, workout tasks will be displayed in order of time according to their due date; the most urgent workout tasks will be displayed at the top of the list. The state indicator next to each task visually describes state and urgency of a workout: An unchecked checkbox displayed next to a workout indicates that it is a regular coming workout task. An alert symbol (with an exclamation mark) indicates that it is past its due date. A cross means that the task has been deactivated. If a workout task has been accomplished, it will disappear from the *Task List* and appear in the *Logbook* for later reviews.

The user can check the *Task List* whenever she wants to. She can view information (e.g. name, description, target duration) about single workout tasks, or a summary of all workout tasks. The user can execute workout tasks (this is possible even if workouts are not yet due), activate/deactivate workout tasks or set, change, and delete reminder times. If a reminder is set, the wrist unit will remind the user to train according to plan on the scheduled date and time. The user can check the planned exercise information when the reminder has gone off. An automatic reminder to connect the wrist unit with the *Ritmo Software Suite* will be triggered when there are no activated workouts left in the *Task List* and by default also when de device has not been connected for more than a week.

The *Task List* may therefore appear very constrained in its functionality. In point of fact, it was designed that way to guide and assist the user in managing her training plan and to decisively encourage her to consciously make decisions. A workout task can only be created and deleted on the personal computer running the *Ritmo Software Suite*. However, the user can deactivate (and re-activate) a workout task, so the wrist unit system will ignore the task and deal with it as if it was deleted. If the user wants or has to change the training plan (this would be possible by deactivating tasks), these later changes made on the wrist unit will not be hidden away. The presence and persistence of these changes may influence the user for upcoming training decisions. The idea is to urge the user to stick to the training plan she consciously created on the computer in advance. For a similar reason, an unfulfilled and workout task is still displayed as the most urgent task at the top of the list, highlighted with an exclamation mark. Again, the user keeps the control and may decide whether she wants to work off the training task or deactivate it.

The described aim to promote conscious training planning rather than rigid fulfillment of plans is based on an email conversation I had with Dieter Bremer, triathlon and marathon specialist and sports instructor at the TU Darmstadt, about training management and different ways of dealing with missed workouts sessions.

LOGBOOK. The *Logbook* keeps track of the runner's training history—it stores accomplished workouts for a later review, uploading to the *Ritmo Software Suite* and subsequent analysis. Workouts are displayed in chronological order; the most recent workout is displayed at the beginning of the list. The user can view and delete workout information by session or as a summary of all workouts (history totals). Workout information on exercise (name, description, date, time), performance (duration, distance, pace, cadence, stride length), user interactions (changes, cue points), and music parameters (folder, songs played, BPM) is saved, but only a selection of aspects is accessible on the wrist unit. For a detailed post training analysis, the workout data has to be transferred to a personal computer. When connected with the *Ritmo Wrist Unit*, the *Ritmo Software Suite* automatically acquires the workout data by default.

PLAYER. Apart from the *Trainer*, the *Ritmo Wrist Unit* provides the functionality of a classic music player that plays songs in their original tempo. The *Player* screen provides information on the current and upcoming tracks or collections, their cover images, the playing order, and the music playback status. The user can start and pause music playback and skip through the music files on different organizational levels. Several single songs can be grouped in the *Player* by albums, artists, or collections that were compiled and uploaded in combination with a workout. The user can shift these sorting rules conveniently in order to find and play related songs.

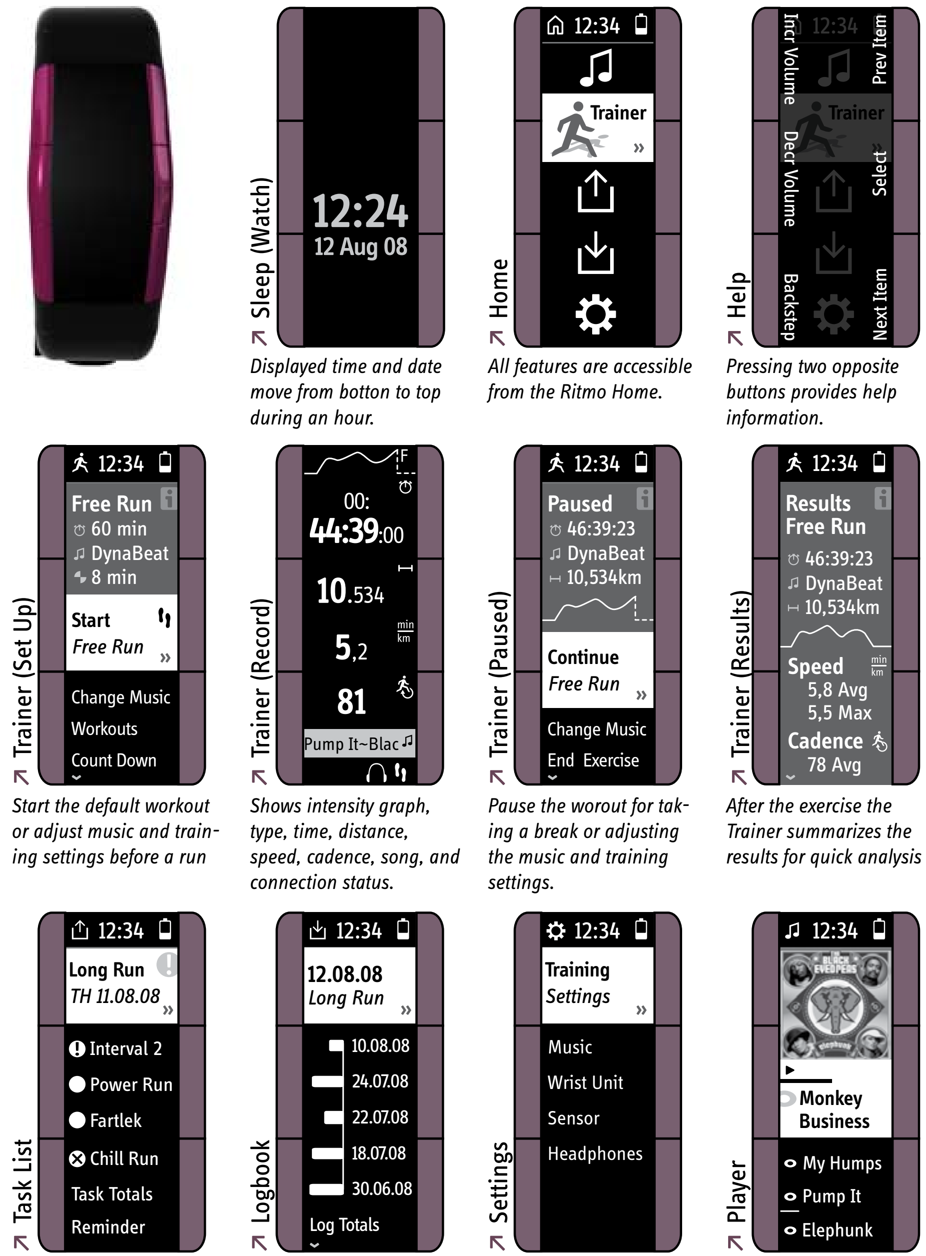
SETTINGS. In *Settings* the user can adjust the *Ritmo Wrist Unit* to her personal preferences. As many adjustments are standard functions that are similar in most common popular music and running devices, I will briefly describe non-standard functions and ideas only.

Countdown. The user can set up a timer and a special music that should be played within this period as a countdown or prelude to a workout session. The user can for example use this feature to concentrate or relax before each workout or to do a special warm up running or stretching.

Synthetic Sounds. The user can select a synthetic sound snippet (e.g claps, drums, bass, and applause) and its rhythmic interval to be layered onto music sequences that are played during the workout. The feature can be used to emphasize a rhythm (continuous repetition of sounds, e.g. to consciously train breathing) or as a reminder function (intermittent sounds with longer intervals, e.g. to remind to drink or to recall important body movement techniques). The synthetic sound type collection is associated with attributes connecting to the workout music collection to offer only sound types that match the music sequences. The user can edit synthetic sounds or even spoken words with the *Ritmo Software Suite* on the personal computer.

Automatic Light. E-paper is not luminous by itself. The Automatic Light function makes the *Ritmo Wrist Unit* usable even during the night or during dark and cloudy days. It can either be set to provide constant illumination of the display, or light is switched on for about 5 seconds every time a button is pressed.

Battery Life. Communicating information on the battery status is important to avoid running out of energy in the middle of a workout. The *Ritmo Wrist Unit* asks the user to charge the battery, when less than two hours of battery life are remaining. Thus the user will be informed if it can be foreseen that the battery will not last for the total workout time she has just started. When the battery runs down to a critical zone during a workout, the *Ritmo Wrist Unit* will automatically turn off the music and the Bluetooth radio connection, to preserve the remaining battery power for basic features and workout logging, and especially for keeping the watch function alive.



Displayed time and date move from botton to top during an hour.

All features are accessible from the Ritmo Home.

Pressing two opposite buttons provides help information.

Start the default workout or adjust music and training settings before a run

Shows intensity graph, type, time, distance, speed, cadence, song, and connection status.

Pause the worout for taking a break or adjusting the music and training settings.

After the exercise the Trainer summarizes the results for quick analysis

Workout tasks are organized by due date. Deactivated tasks appear at the end of the list

Recent workouts are organized by date, bars are used to compare the training duration (in time) .

Settings are divided into subcategories for the essential conceptual and physical system parts.

The classic music player displays folders or single songs and cover images for collections

Figure 5.4: Screenshots of the Ritmo Wrist Unit mini applications

Figure 5.5: The Ritmo Sports Headphones

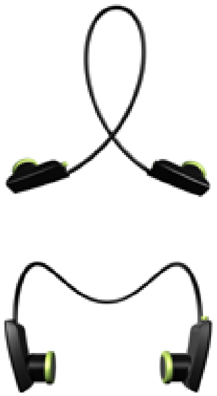


Figure 5.6: The flexible arch ensures both wearing comfort and easy transport

5.3 The Ritmo Sports Headphones

The *Ritmo Sports Headphones* (Fig 5.5) wirelessly connect to the *Ritmo Wrist Unit* via Bluetooth. The wireless connection retains the runner's freedom to move during the workout without getting tangled up in a bothersome cable-connection. The overall design is consciously adapted from the Sennheiser Sports Line (in particular the LX 70 Sport), even though I know that this design has a patent pending. In point of fact, I designed the wireless headphones for the *Ritmo* music system based on the cable-bound Sennheiser LX 70 Sport design because I came to the conclusion that it is an outstanding product which not only perfectly matches the requirements of running and my target group but also the *Ritmo* music concept and spirit. The following description will address the most important headphone characteristics based on my own findings and research, even though parts of it have been already realized in the Sports Line of Sennheiser (2006).

The *Ritmo Sports Headphones* consist of two earbud speakers, which are connected via thin wires within a flexible arc (Fig. 5.6). Connecting both earbuds disposes of an extra power supply for separate Bluetooth connections of each component, so that only one battery cell and one Bluetooth chip are required. Thus only one on-off slider is needed (here integrated in the right earbud

enclosure with regards to the fact that most users will be right-handed) and only one charger socket must be present (integrated on the left side). This makes the headphones cheaper, lighter, easier to maintain, and less power consuming. The connection between the two earbuds is used as a headband to stabilize the earbuds and have them stay put even during heavy runs. When runners want take off the headphones, they can wear the headphones curled around the neck without extra support thanks to the flexible arc. Also, when traveling the curled up flexible headphones do not need much space in a hand or sports bag or business chemise pocket, as they are foldable for easy transport and storage.

Highly durable and water-resistant materials protect the ultra-lightweight *Ritmo Sports Headphones* against perspiration and weather. The headband and potentially an ear adapter set for adapting the size of the earbuds makes these headphones very comfortable to wear for every individual runner. The sound quality of the headphones is very good as is ensured by the employment of high-class dynamic driver technology and the Bluetooth advanced audio distribution profile (A2DP).

5.4 The Ritmo Stride Sensor

The *Ritmo Stride Sensor* (Fig. 5.7) wirelessly transmits stride information to the *Ritmo Wrist Unit*. Stride lengths and thus running

Figure 5.7: The Ritmo Stride Sensor

Figure 5.8: The Ritmo Stride Sensor can be put inside the sole of a running shoe or it can be attached to the shoelaces with a fork

speed as well as overall distance measurements are calculated from that data. Based on physiological models, the accuracy of distance calculations is already high "out-of-the-box" but it can be enhanced by a calibration phase, i.e., running a defined distance in calibration mode as offered by the wrist unit. Whenever the *Ritmo Wrist Unit* is turned on it automatically connects with the *Ritmo Stride Sensor* which is on by default and transmits upon strides. So it measures every single stride and gives perfect readings wherever the user takes it because it does not rely on satellites. The user can exchange the battery manually, however it will last for several months even if left within the enclosure because of the carefully chosen energy-preserving transmission policy.

The *Ritmo Stride Sensor* is so lightweight that runners can benefit from its measurements without feeling it during the workout. The sensor is very small in size and therefore allows fitting in the sole cavity of a specially developed running shoe. However, for those runners who prefer to use a certain running shoe brand without such a preparation, the sensor can also be attached to the shoelaces with a supplied fork (Fig. 5.8).

The *Ritmo Stride Sensor* works best when attached correctly. Therefore, the sensor is not symmetrically shaped, but top and bottom and front and back can be distinguished clearly. Moreover, it can only be attached to the fork in one way, so it will be correctly aligned with the foot. Furthermore, the colored space points out where the fork should be connected to the sensor when attached to the shoelaces. Both fork and sensor match each other's shape and ensure that the sensor does not move while running, as a firmly attached sensor facilitates more accurate speed and distance measurements. The extra lace of the fork provides extra security to avoid loosing the sensor.

5.5 The Ritmo Software Suite

In order to enable management and maintenance of music, training plans and workout data on a very user-friendly level, the *Ritmo Software Suite* complements the wearable *Ritmo Wrist Unit*

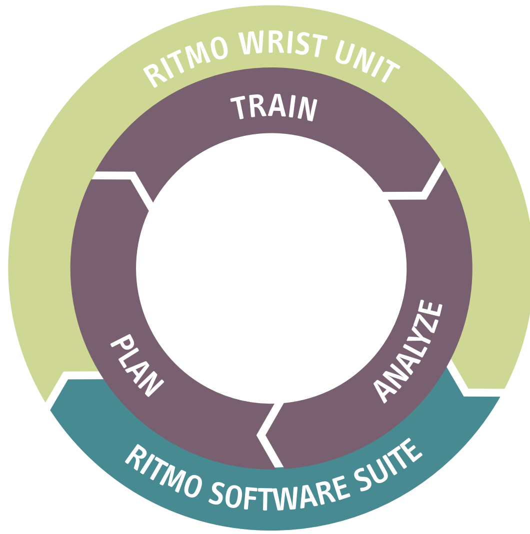


Figure 5.9: The Ritmo Software Suite complements the Ritmo Wrist Unit to fully support the typical workflow of endurance runners

(Fig. 5.9). The reason for outsourcing this functionality is the fact that a detailed state-of-the-art analysis would at best be very awkward and tedious on a small-scale device with limited display capabilities, however perfect it would fit the requirements while running. Also the storage capacity of current laptop computers or desktop workstations allows users to maintain a comprehensive music library. Large high-resolution displays facilitate graphical analysis (graph views) and annotation tasks (workout analysis and music database) intuitively and conveniently, based on a well-established user interface paradigm that most users are familiar with already. In spite of all flaws that the WIMP paradigm may have, its omnipresence supports this argument. The *Ritmo Software Suite* should be offered for all the main operating systeform platforms. A USB connection is used for connecting with the wrist unit and for uploading music. An established Internet connection allows sharing training plans and exercising data via email or web services. The following description outlines the indented *Ritmo Software Suite* capabilities in terms of training planning and music management by giving brief examples.

5.5.1 Workout Characteristics

The music player offers the possibility to integrate music into training sessions. A training session can, for example, include a warm-up phase at a slow pace followed by a fast pace phase, followed by a slow cool-down phase. The *Ritmo Software Suite* can be used to construct up to 10 or more of such complex workout sets. These comprise up to 6 phases, each with different intensity characteristics and with an unlimited amount of repetitions. A phase can be defined by its duration and by a pre-selected tempo style. The following paragraphs give an overview of different phase durations and tempo styles to outline the workout phase options of the music player.

Open-End Workout The user can set an "open-end" workout phase, which means that user has to manually end the phase. For example, when the user wants to go for a run until she gets tired, she selects "open-end" as phase duration and manually ends the phase when she is done.

Time Goal Workout The user can set a "time" goal for a workout phase, which means that the phase ends when the defined time is over. The music player informs the runner when the goal is reached. If it is followed by another phase, the next one starts automatically. If the phase is the last phase of the workout set, the phase time is saved automatically as a "lap time", but the timer itself has to be stopped manually by the runner.

Distance Goal Workout The user can set a "distance" goal for a workout phase, which means that the phase ends when the defined distance is reached. The music player informs the runner when the goal is achieved. If it is followed by another phase, the next one starts automatically. If the phase is the last phase of the workout set, the phase time is saved automatically as a "lap time", but the timer itself has to be stopped manually by the runner.

Constant Tempo. The music tempo is based on a manually entered BPM value, which is predefined by the runner according to his or her personal preferences regarding the intensity of the workout. The BPM value must be within the overall rhythm range allowed by the system. Music will be played in constant tempo according to the desired BPM value. If the rhythms of the songs equal the BPM value or if they require less tempo adaptation than others, these songs will preferentially be used for the workout phase, as outlined in Section 5.5.2.

Varying Tempo. The music tempo adapts to the runner's step frequency within the overall range of music rhythms stored on the music player. The music starts at a tempo of 100 beats per minute (BPM)—since less than 80 steps per minute is considered walking—and in the course of the workout its tempo is adapted to match the runners step frequency. That is, when the step frequency increases the music tempo also increases, and when the step frequency decreases the music tempo decreases accordingly.

Tempo Range. The music tempo starts at the lowest value of a zone's BPM range. As soon as the runner's step frequency and music rhythm match, the music begins to adapt to the runner's step frequency within the zone range by increasing and decreasing its tempo. The closer the runner's cadence gets to the boundaries of a zone (she runs too slow or too fast), the less the music will adapt to the runner's step frequency - trying to prevent him or her from leaving the zone. This inhibiting function is only active when the runner gets towards the zone's limits but not when he or she moves away from them. If the runner leaves the given zone's range, the music tempo stays at the last BPM value that is still within the zone. This way the music player encourages the runner to adjust his or her step frequency back towards the zone.

Decreasing/Increasing Tempo. The incremental tempo style is especially provided for climax runs. The user must provide BPM values for the start and for the end of the phase plus a constraint of either duration or distance. The tempo of the music played starts at the initial BPM value and ends with the target BPM value. The music device calculates the music tempo between both points based on the given duration (time or distance). The tempo curve of a climax run is usually linear.

5.5.2. Music Clustering and Music Suggestions

The digital music player has to match the music to the runner's workout plans with respect to tempo and rhythm, either according to the actual or to the desired motion during the training. That is, the music is adjusted using the *StepMan* technology which is capable of adapting most music to the required BPM. However, even though the *StepMan* preserves the pitch of music, too extreme resampling will result in a clearly perceivable deviation from the original, be it only by speed. This can be taken as acceptable for short periods but over long terms may have a negative impact on the runners' sensation of well-known songs and disturb the relationship with their favorite music—and also the trust in and relationship with the *Ritmo System*. Therefore, moderate adaptations within tolerable limits are preferable (Wijnalda 2005). A careful selection from an available music database should thus be made in addition to the employment of the *StepMan* technology to ensure that mainly songs which come already close to the tempo characteristics of running are stored on the music player. As the music collection of a user can usually be expected to be much larger than the storage space of the mobile music player, algorithms are employed to find out which tracks best fit the characteristics of a running workout. These collections are then suggested to the user for fine-tuning the arrangement and eventually downloading to the music player. The suggestion process is constraint-based and extended by an automated assessment of musical features and their similarity. Such a sound analysis technique can also be used to ensure matching synthetic sounds for overlay purposes to stress certain aspects. While not described

within this document, an audio processing program should also be part of the *Ritmo Software Suite* so it can be used as an electronic synthesizer and voice recorder.

The song selection process encompasses the following stages:

1: Analyze songs from the database, create or update tags and determine which tracks most probably fit within a playlist for running activities (within the specified tolerance thresholds);

2: Look up user preferences and other constraints to further shrink the library to a pool of songs that are suitable for a given workout and that the user likes, use the result as a pre-selection pool;

3: Create music clusters from the pre-selection pool based on musical similarity and suggest these to the user for name tagging (a sample could be played like the ring-tone preview on a mobile phone), also update user preferences and tags;

4: Present to the user pre-calculated groups based on categories, constraints and clustering, allow a manual re-arrangement and fine-tuning;

5: Transfer the chosen final collections of songs to the portable device so that each workout has three (or at least one) suitable pools of music associated, also allow for a sufficiently comprehensive range of songs that can support a free exercise in the adaptation mode.

To illustrate the process in more detail, the following exemplary criteria constrain and influence the selection:

- Each song has to be automatically analyzed and tagged with a value for its rhythm (beats per minute). In the course of this process, songs are also checked for an even meter, such as two-four time or four-four time, because these match the bipedal locomotion rhythm of humans and can thus be synchronized easily. Tracks that are within a BPM range that can be mapped to step frequencies commonly regarded as running are tagged accordingly. If the music player is used for other disciplines the overall minimum and maximum BPM values have to be changed accordingly. The user should be able to perform these changes in the software preferences.

- At least 2 hours of music within the overall running BPM range have to be provided for pace matching because it cannot be foreseen at which BPM value the user will do her workout, especially when she chooses real-time music adaptation to her step frequency (as in the Free Workout). The granularity of the covered BPM range may be finer in the more important average zone based on an empirically determined probability distribution of running speeds in unconstrained exercise. The storage capacity of the portable device has to be taken into account. 4 GB of flash memory can hold approximately 66 hours of music (depending on the amount of compression) which is sufficient for 10 different workouts with 3 optional music pools of 2 hours duration each, assuming that there are no overlaps between different playlists. The remaining capacity can be used to store a comprehensive set of songs that supports a free workout. The files that are already present on the portable music player for planned workouts augment this set. The *Ritmo Software Suite* takes care of compression and re-encoding, if necessary.
- Songs the user especially likes or dislikes should be either preferred or suppressed. A history of music played during the workout can be used to fine-tune the music selection process over time. The main idea is too derive implicitly stated preferences, e.g., to filter out songs that are often skipped under similar conditions, or to analogically rate songs higher that have been repeated or considered for a one-song-only workout.
- Music files can be clustered by an algorithm on the basis of musical features such as melody, instrumentation, harmony, arrangement, etc., rather than artist, genre, or BPM only. The main clusters of similar music in the library can then be transferred to playlist groups tagged with moods, music styles, or other user-friendly classification models, e.g. descriptions like “modern r&b style, use a string of ensemble“, “electronica and disco influences, subtle use of vocal harmony” or “rhythmically complex rapping with slow moving bass line and a dry recording sound”. This may be achieved by the taxonomy of collected musical information of The Genome Music Project (Westergren 2005), which analyses music sequences at the fundamental level, using several hundreds of individual attributes to describe songs. This technology is currently applied by Pandora.com to suggest and play music for Internet users. Their preferences are derived from user-specified example songs and from a user rating of suggestions.

In summary, a recommended collection of songs should already come close the characteristics of the given training program in duration and tempo distribution. If possible, all songs for a workout set should be different and, of course, appeal to the user. The objective is to always satisfy as many of the outlined constraints as possible and as well as possible. Different penalties can be associated with constraint infringements as outlined by Wijnalda (2005) and Wijnalda et al. (2005). If no tracks are available in the user’s music collection that satisfactorily meet the workout requirements, the system might produce a notification that announces lower quality standards of adaptation. This is meant as an encouragement to ramp up the library of accessible songs by adding new tracks from another data source, e.g., an online music store or a personal record collection that is yet to be digitized.

5.5.3 Post Training Analysis

For a detailed post training analysis all measurements and captured events are transferred to the *Ritmo Software Suite* on a personal computer. Then every aspect of a training session can thoroughly be analyzed based on the workout data, which also facilitates a direct comparison of plans and the actual performance during the exercise. In a multi-graph view, speed, distance and cadence are shown on a time axis together with information on what music was played at a certain time. All user interactions with the device during a run produce cue points, which divide the displayed data into sections and have little name tags and color codes that specify the kind of action that caused a particular cue point. In the analysis phase using the *Ritmo Software Suite*, cue points can also be added later, annotated, or erased by the user. These cue points also serve as convenient handles to adjust the display scope (i.e., to focus on certain workout phases) and to keep an overview of the overall exercise. Specialized analysis instruments may be offered in a toolbox to facilitate trend comparison between data points and to produce plots that can be printed. Workout data and annotations can be saved in an easily accessible file format so it can be added to an athlete's profile or shared via the Internet.

CONCLUSION 6

My research goal was to develop a music device that proactively integrates music into the runner's training based on the *StepMan* technology. I have designed *Ritmo*—a concept for a rhythmic training and music device—to satisfy this goal based on extensive research, user demands, technological constraints, (interface) design guidelines, and user tests. Therefore *Ritmo* can be regarded as a straightforward, inspiring and pleasurable concept and design solution.
Nonetheless, six months of time made it impossible to fully address all the implications of a project that targets various different disciplines and fields of interest, including sports theory, medicine, music analysis, psychology, cognition, electronics, computer science, as well as both product and interface design. Improvements can be made, extensions may be developed, and further research should be conducted as encouraged by many topics raised within the scope of this thesis. Finally, there are numerous indications of commercial opportunities that may be exploited. The following paragraphs will shortly summarize my further recommendations in regard to a training device for runners.

Improvements. A working prototype of the *Ritmo System* and in particular of the *Ritmo Wrist Unit* could be developed. It may yield new insights and unforeseeable hints as to adjustments and changes when tested with users. The design solution for the *Ritmo Sports Headphones* and the *Ritmo Stride Sensor* might be improved and developed further within separate research endeavors, even though a consistent and adequate design solution based on state-of-the-art existing products is already given here. Besides, a complete and elaborate design solution for the *Ritmo Software*

Suite, especially regarding to the user-friendly music selection and training planning process, may lead to new ideas for organization and visualization techniques for training software in general.

Extensions. The *Ritmo Wrist Unit* offers essential features and functions to profit from a mobile music device during the workout, while leaving control and application to the user. However, the *Ritmo Wrist* Unit may be extended with extra functions, sensors and input devices to shift the focus of the target group, to make the device more marketable, or to exploit future technologies. The *Ritmo Wrist Unit* could, for example, become a "virtual coach" that praises, rewards and nags at the user. Or it could become an "intelligent emotional music box" that searches for music sequences, which match the actual measured condition of the runner, or perfectly fits her environmental surroundings during the workout. It could also become a "competitor" that virtually interacts with the user, e.g. by doing races and indicating the position of a virtual runner ahead or behind, making the user jealous for more motivation. As the wrist unit also has Bluetooth capabilities, it could potentially also be connected wirelessly with a personal digital assistant (PDA), for instance, to review and edit workout plans but without music transfer. The *Ritmo Software Suite* could be enhanced by functions that recommend training plans or by functions that not only support the exchange of data and messages between trainers and runners but employ network capabilities to access implements on various levels in order to derive environmental data and additional measurements.

Commercial Opportunities. I received enthusiastic feedback of athletes, trainers, coaches, sports scientists and other experts, as well as the unexpected but very affirmative responses to the online questionnaire. These stress the commercial potential of a rhythmic music application with the very capabilities enabled by the *StepMan* technology as developed by the Fraunhofer Institute. No matter whether the rhythmic music application is integrated into a mobile (smart) phone, realized as a stand-alone mobile de-

vice or as an infrastructural element, the positive effects of music tempo adaptation to training preference have been discussed and confirmed not only in this master thesis. Strategic cooperation for such outstanding, integrated sports systems appear to be very promising in the running business and its market. Similar to the Nike-Apple (Nike 2006) or the Adidas-Polar strategic (Adidas AG & Polar Electro Oy 2006) strategic partnerships, synergies in research and development and especially in marketing such as mutual propagation and bundling opportunities can be exploited. In this case, for instance, the technology architects of the Fraunhofer Institute for Computer Graphics could cooperate with headphones specialists such as Sennheiser and also with selected manufacturers of running shoes and sports garments.

Besides, a rhythmic music device may also be useful for other sports disciplines and areas. It may be applied to the cycling segment as the pedal revolutions can easily be measured and translated to rhythmic values. A fitness application of a rhythmic music player could be developed integrated in a skipping rope, adapting the music to match each bounce. In occupational therapy, a rhythmic music device may help people to get a feeling for the beat and to learn the rhythmic use and coordination of their body and its capabilities.

Research Topics. In regard to the previously described potential improvements, extensions, and commercial opportunities, many different and wide-ranging research topics are directly or indirectly connected with the development of a rhythmic music device. Apparently, more research is necessary in the domain of interrelated physiological and psychological effects of music, "intelligent" user interfaces and applications that facilitate suggestions for training planning and the music selection processes, as well as with respect to dedicated sports body-area-networks, etc. This design master thesis combined functions of running computers and music players based on sports research. Once divided disciplines and research areas begin to merge through convergence and networking. Wearable technologies, mobile phones that track biomechanical data, and other current examples underline the spanning characteristics of this development. Therefore not only stand-alone products should be explored but also networked services should be carried forward as a field of research in the running segment and similar areas.

Currently many different running systems and training devices are available and different formulas to calculate and analyze the running data are widespread. However, functions are not changeable and their calculations are not made transparent. During the past months, the most fascinating research idea became to develop an open training system for runners. Such an open training system—comparable with a construction kit—would consist of a main mobile training unit that could be extended by sensors, modules and software packages. The runner could personalize the system to her individual needs based on a multitude of possibilities in terms of computation, representation, and transparency. The runner decides which information should be tracked and how it should be calculated, visualized, analyzed and processed. Intermediate and advanced system users could author their own modules, functions, and extensions, potentially using a visual language especially designed for that purpose. The open training system would grow with the runner and the available services, and hence would guarantee long-term relationships. Such an open running system could be regarded as the big brother of *Ritmo*—or the mother of all future mobile training devices—and presents a great challenge not only for an interface designer.

PERSONAL REFLECTION[7]

My personal aim was to create a design solution that is derived from experiences and that stimulates, supports, and motivates runners. Moreover, I wanted athletes to become proud of their music device, as listening to music is commonly proclaimed to be done by "joggers" only. During the past months I faced the challenge to conceive a reasonable design solution that matches these requirements.

The work on my master thesis showed that users (next to experts) are the most valuable input for creating design solutions, which I had not experienced that intensely before. From the very first day questions and problems occurred that I was only able to solve by getting in touch with users and domain experts. Through conversations and user tests I gained unforeseen insights, which above all were very stimulating. But I also learned that runners are individual persons with a distinctive personality who tend to eagerly demand a device with complex technologies and extra features. On top of that, experts also proposed their wishes, demands, and even solutions for a training and music device. Therefore, I was challenged to filter the suggestions and ideas I had gathered in order to retain consistency and the overall control of my project.

One of the most difficult tasks was to provide high functionality while not making the mobile device too complicated to use. I had to approach this endeavor with reason and common sense on the basis of serious reflection to find the right balance of complexity and simplicity, cf. Maeda (2006). The device had to provide several standard functions from calibrating the sensor over setting the recording rate to adjusting the play order of music. Other functions, such as monitoring heart rate or measuring altitude, were not particularly problematic to integrate with respect to processing power, size, and weight, if they were needed for marketing reasons. However, I decided against any such extra features in order to clearly underline the prime functions of music and training support and to preserve the user from a function-overload. I also considered minimalistic music player solutions. For example, the idea to design a single-piece music device—similar to a second-generation Apple iPod Shuffle—that has a simple slider for setting a constant tempo value caught hold of me. Independently of my personal wishes and preferences, I studied the assets and drawbacks of different solutions several times and thoroughly checked my final decisions with respect to the ambitious runner. The overall result—Ritmo—meets the requirements of a serious training device and provides a reasonable amount of functions. Its simplified, symmetrical form and uncomplicated application structure hides its underlying complexity, while the selected color scheme and materiality stress its value as a product. In this way features and appearance of the training and music device form an intriguing contrast. As I am personally very fond of small, reduced, and charming products, I hope that the "Pleasure of Ritmo" will win the runner's heart not only as a purposeful training device but also as a delightful product.

During the past months it became explicit that a music device for runners addresses a wide range of research areas. Even though I had originally been looking forward to working on the interface design of a given product exclusively, this early false assumption soon gave way to necessary research into various different fields of study, such as music analysis, sports theory, product design, etc. Looking back, this perceived drawback turned into a very refreshing experience, since it allowed me to learn a great deal more about these domains than I had originally expected. All in all, before this thesis I had not known how complex the design process of a music player can grow and yet how simple and

pleasing a solution can finally be, and especially how important the involvement of users in the design process is.

APPENDIX[a]

ONLINE QUESTIONNAIRE RESULTS

#	Question	Result	
	Participants	38	
	Age	31,8 yrs. 19 yrs. 55 yrs.	average youngest oldest
	Gender	26 12	male female
(0)	Do you listen to music while running?	29 9	yes no
(1)*	How often do you listen to music while running?	12 5 12	everytime every other time once in a while
(2)*	What kind of music do you listen to while running?	different music genres	
(3)*	What kind of music motivates you the most?	highly dependent on mood and training	
(4)*	How often do you change your music/playlist?	2 14 12 1	everytime once in a while everytime other time never
(5)*	Do you skip songs while running?	22 7	yes not specified
(6)*	Do you repeat a song while running?	18 11	once in a while not specified
(7)*	Do you ever run in time with music?	16 7 3 3	everytime every other time once in a while never
(8)*	I listen to music during... (Multiple answers possible)	15 15 9 21 20 13	getting to the training place warm up walk jog run cool down
(9)*	If you also use your music device for other activities?	20 9	yes not specified

** Only asked when partcipants stated earlier that they listen to music*

(10a)*	What kind of mobile music devices do you own? (Multiple answers possible)	25 1 1 0 6 5	mp3-player discman walkman md-player mobile phone radio
(10b)*	Which one of these do you use for running?	23 2 4	mp3 player mobile phone not specified
(11)*	What type of headphones do you usually use for running?	24 3 1 1	in-ear over the head clip not specified
(12)*	Where do you place your music device while running? (Multiple answers possible, selection)	14 3 3 3 2 1 9	pocket hand arm belt necklace bra not specified
(13)*	What I like most about my music device for running... (Multiple answers possible, selection)	13 8 5 2 2 1 1 1 1 1 1 1 1	light and small easy to use motivating music battery life relaxation through music storage capacity good sound quality freedom of turning it off shock resistance helps to concentrate water proof robust distance recording
(14)*	What I do not like about my music device for running (Multiple answers possible, selection)	6 5 5 4 2 1	difficult to use headphone cables music selection difficult to carry/attach/wear no display, display too small sound quality
(15)	What features should my ideal mobile music device have? (Multiple answers possible, selection)	11 10 8 6 6	small/light easy to use (esp. while running) music selection based on training easy to wear, fixed, close to body comfortable, fixed headphones
(16)	What kind of runner are you?	4 29 5	professional runner advanced runner beginner runner

** Only asked when partcipants stated earlier that they listen to music*

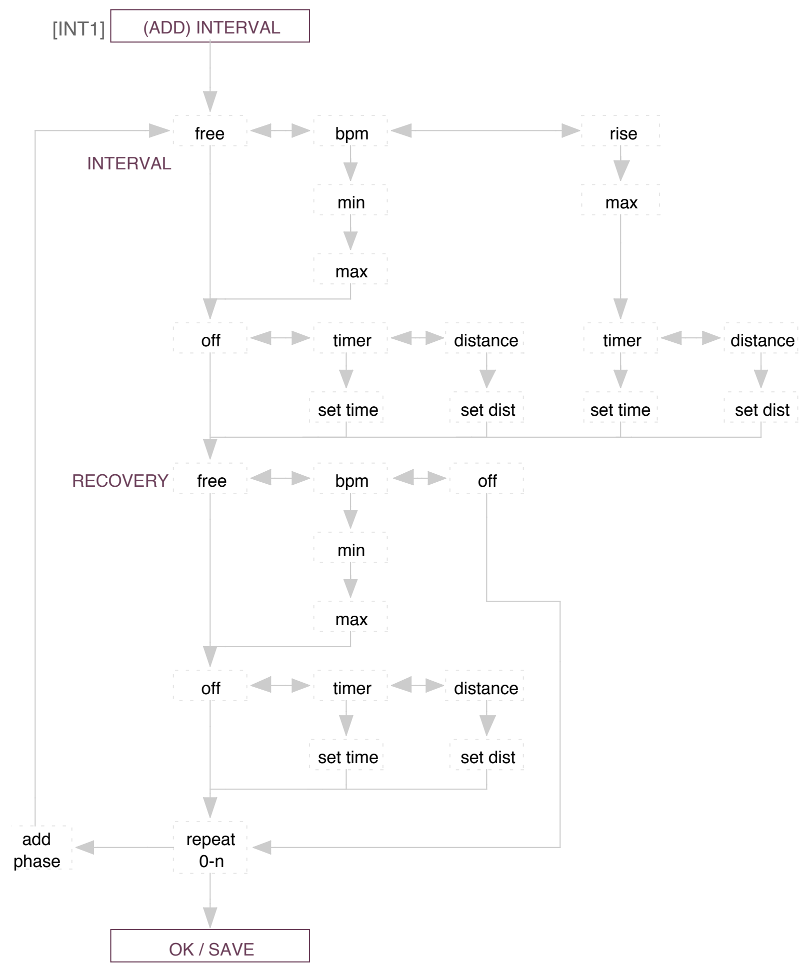
(17)	How often do you go for a run?	7 17 10 4	3 per week 2 per week 1 per week less than 1 per week
(18)	How long do you regulary run?	57,5min	average duration
(19)	How do you motivate yourself to go for a run? (Multiple answers possible, selection)	11 8 8 6 5 4 4 3 2 1	no motivation needed performance improvement good feeling (afterwards) health and fitness running with friends reward after run audio relaxing, clearing my mind fixed timetalbe/ training plan burning calories
(20)	I run because I want to...	10 16 8 3	improve my fitness relax train for a competition regularly work hard
(21)	My favourite type of workout is...	18 16 2 1	distance goal workout time goal workout open end workout calorie goald workout
(22)	Do you regularly warm up before/cool down after a run?	24 14	yes no
(23)	Would you like to have any training guidance for your run?	22 16	yes no
(24)	Would you like to monitor your performance while running?	31 7	yes no
(25)	Would you like to collect and analyze your running data?	31 7	yes no
(26)	Do you use a heart rate monitor?	22 16	yes no
(27)	Which information is most important to you when running? (1=not important, 4=very important)	2,9 2,7 2,4 2,3 1,9	distance duration progress over time speed biometrical data
(28)	Do you regularly participate in other sports activities?	28 10	yes no
(29)	What other running gear do you have?	shoes, chronometer/running computer, breathable clothes, caps, windbreaker, gloves	
(30)	What other running gear woud you like to purchase?	shoes, mp3player, running computer, sun glasses	

(31)	What brand and type of mobile phone do you have?	31 7	named brand of mobile phone not specified
(32)	Do you carry a mobile phone while running?	6 32	yes no
(33)	Which electronic device do you find exceptionally easy to use?	ipod, watch, running computer, toothbrush, walkman	
(34)	Have you heard of the new Adidas Polar Fusion Project	17 21	yes no
(35)	Have you heard of the new Apple Nike + iPod Sport Kit?	16 22	yes no
(36)	What kind of online Service do you use? (Multiple answers possibile)	32 23 28 28 25 10 8 4 10	online communication online news services online knowledge services online shopping online geographic information online subject communities online self-expression online project planning online file sharing

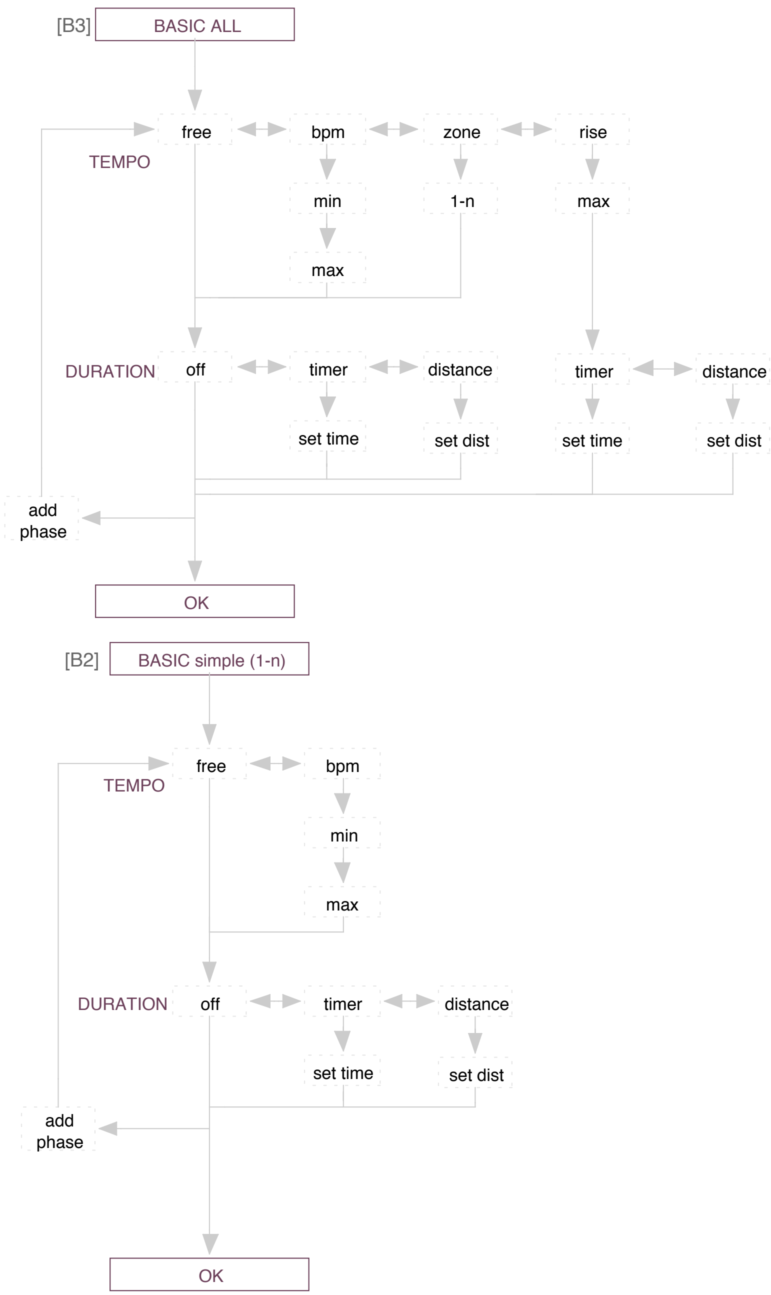
Online questionnaire results (September 2006-January 2007)

APPENDIX[b]

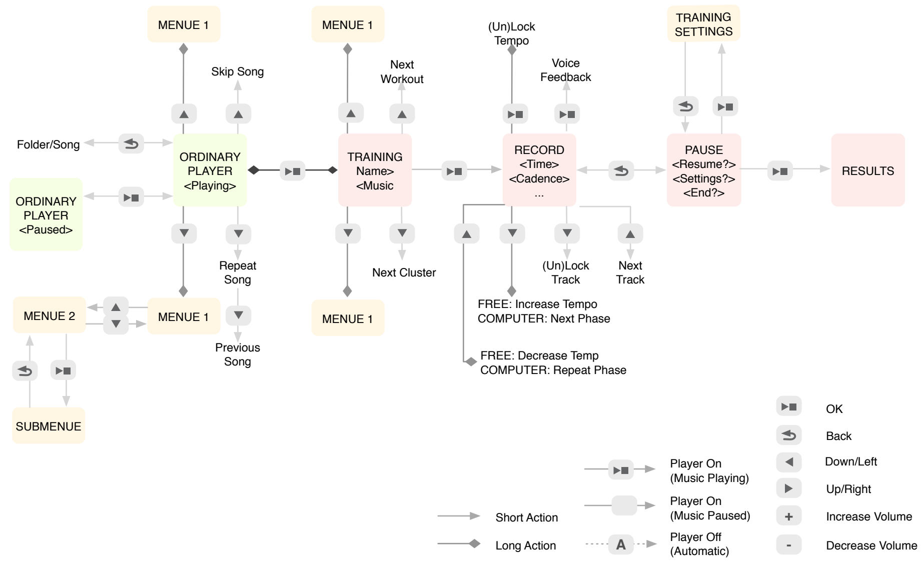
WORKOUT AND APPLICATION STRUCTURE DIAGRAMS



Exemplary pathway to set up interval workouts on the mobile device

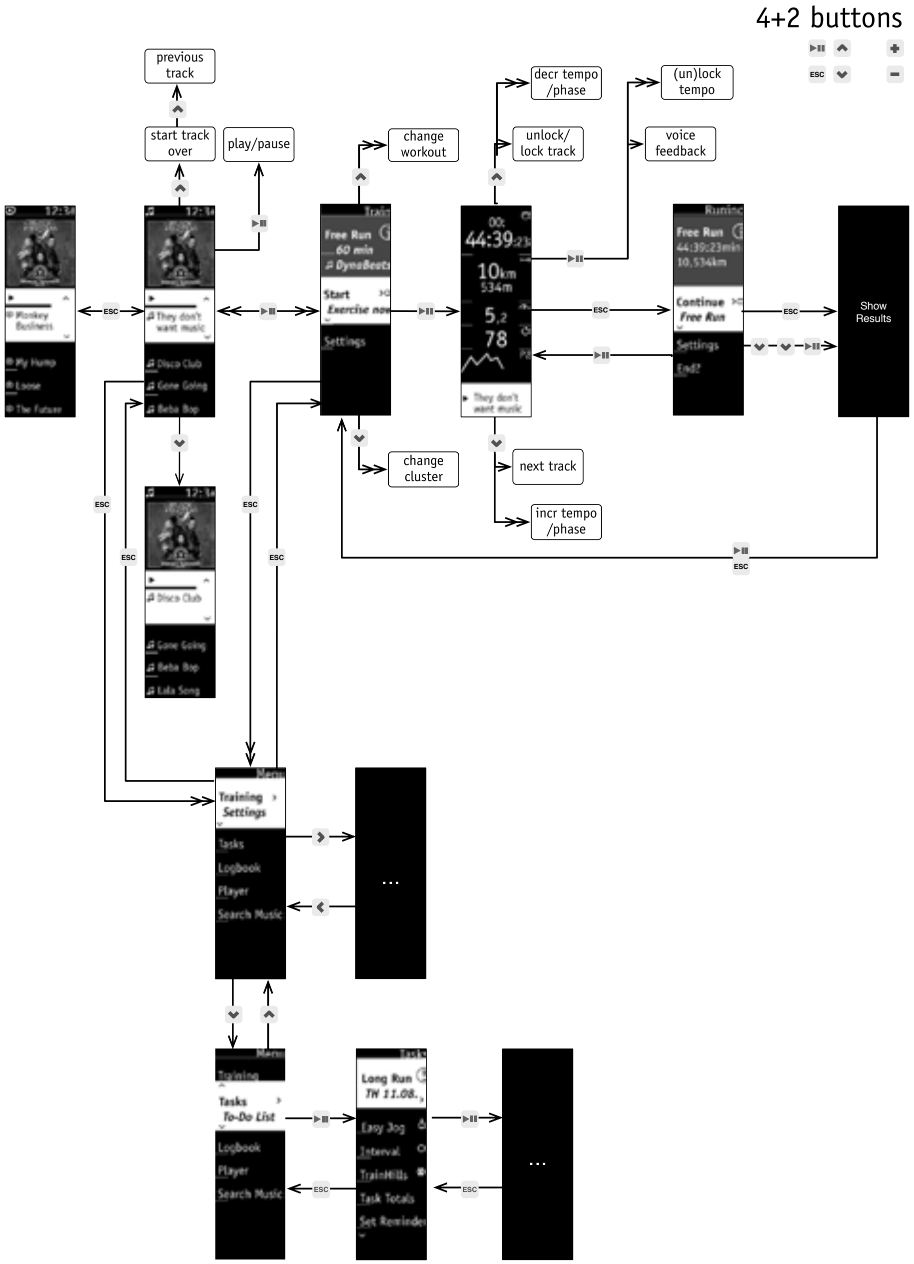


Exemplary pathway to set up basic workouts on the mobile device

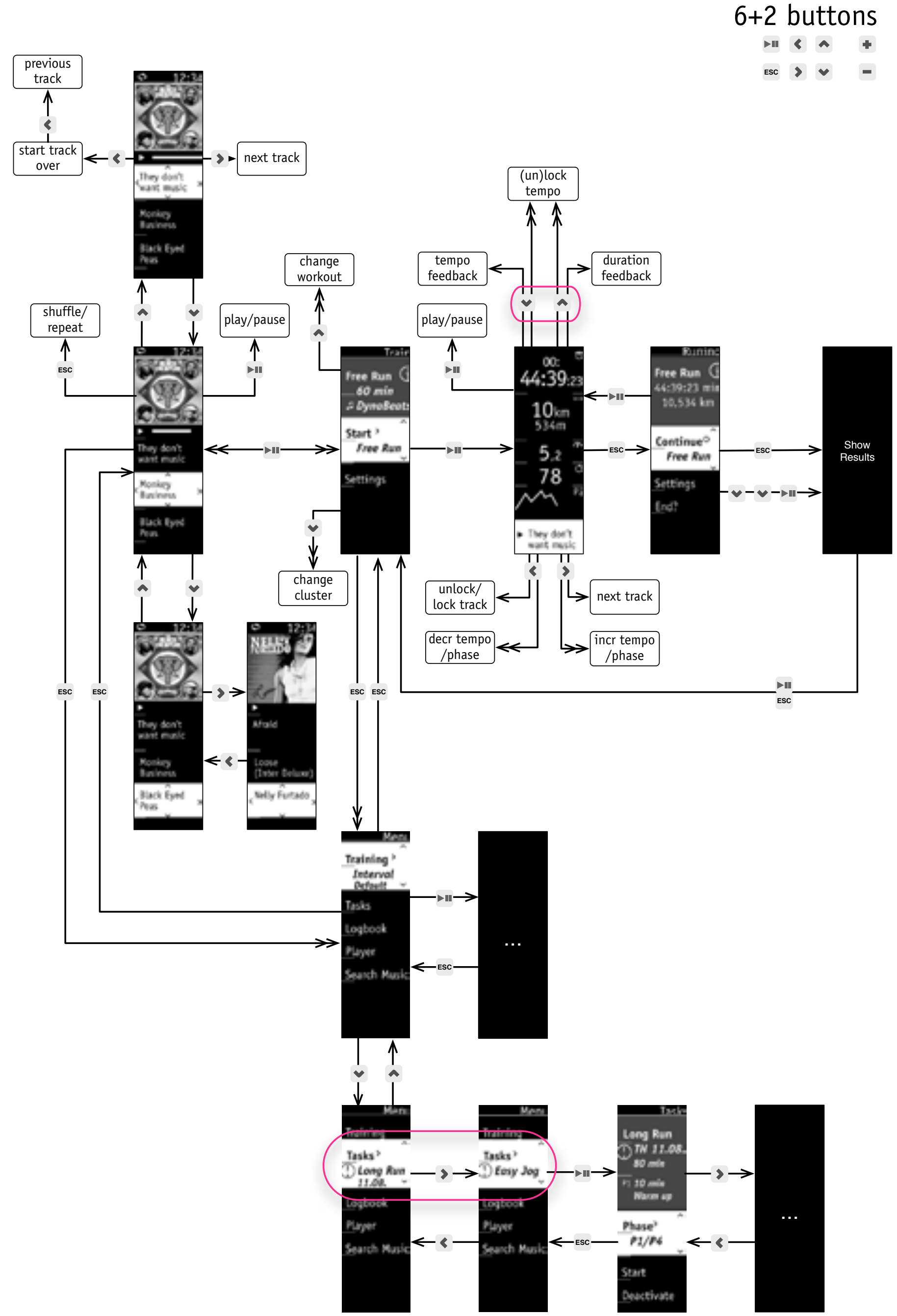


Application Structure based on the Player/Trainer approach

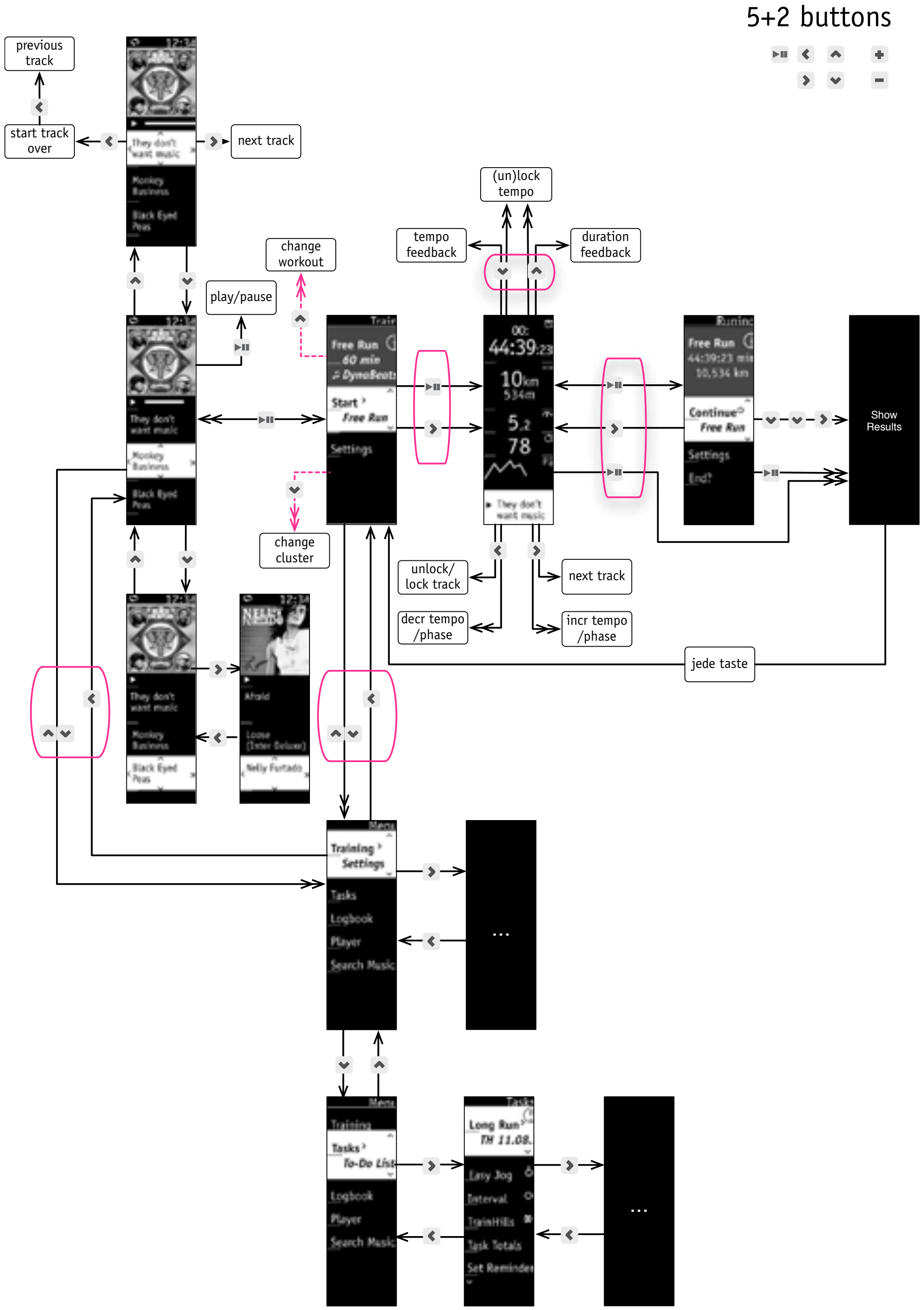
Exemplary menu structure



Thoughts on an application structure for 6 controls



Thoughts on an application structure for 8 controls



Thoughts on an application structure for 7 controls

APPENDIX C

ANALOG AND DIGITAL MODELS

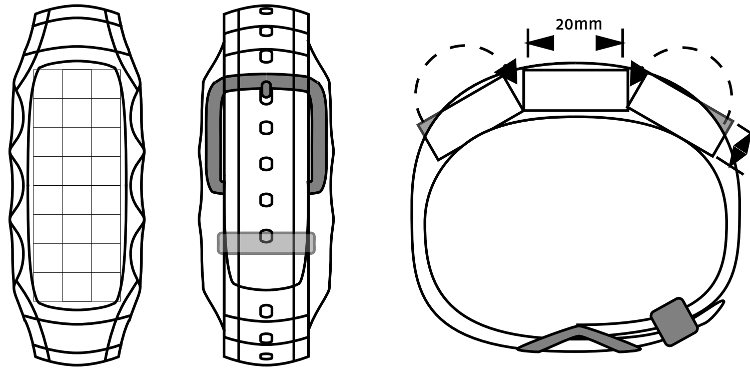
Different Wrist Models

Display on the inner side of the arm

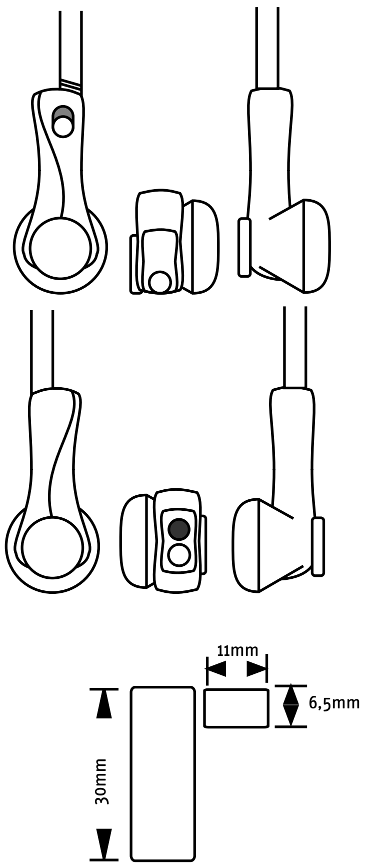
The full original Ritmo color palette

Wrist model with separate case and strap

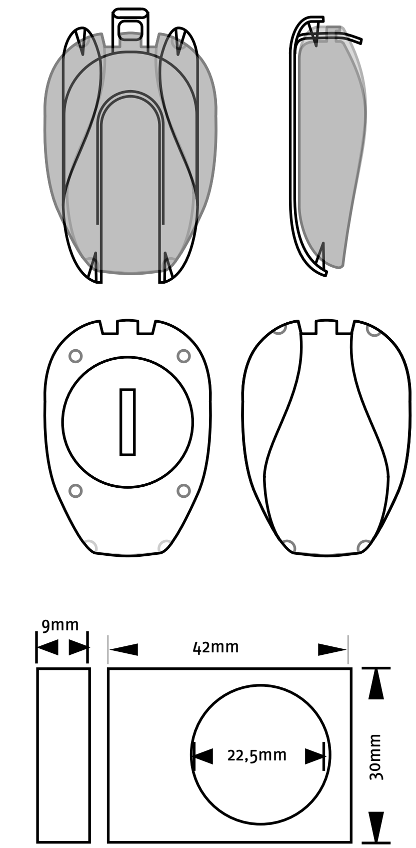
First sensor coloring



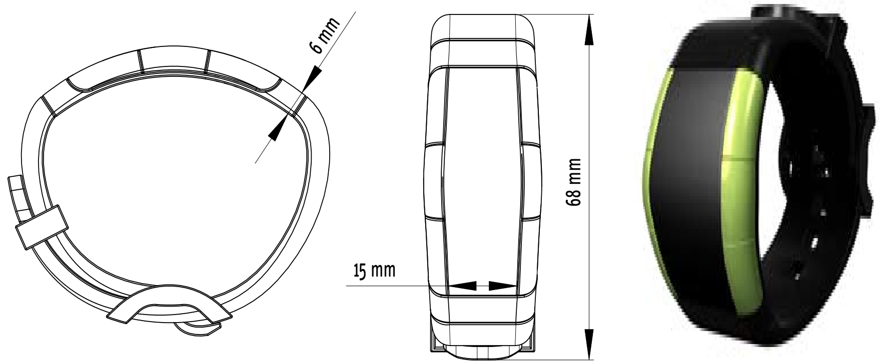
Wrist unit in wave style



Headphones in wave style

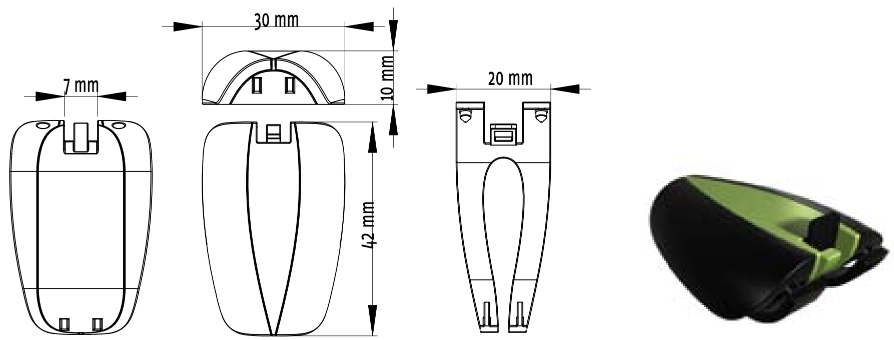


Sensor in wave style



Ritmo Wrist Unit

Ritmo Sports Headphones

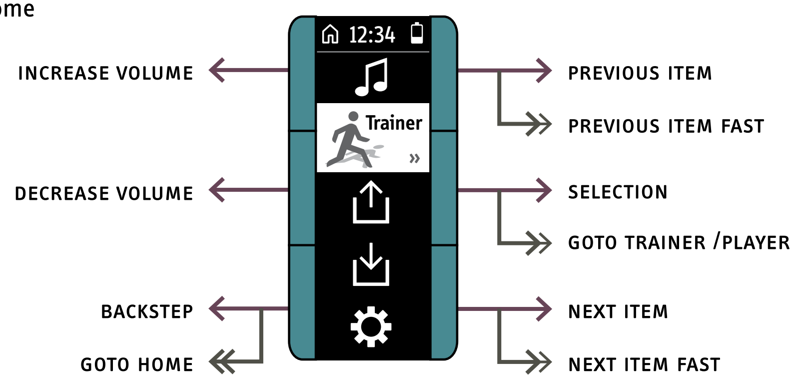


Ritmo Stride Sensor

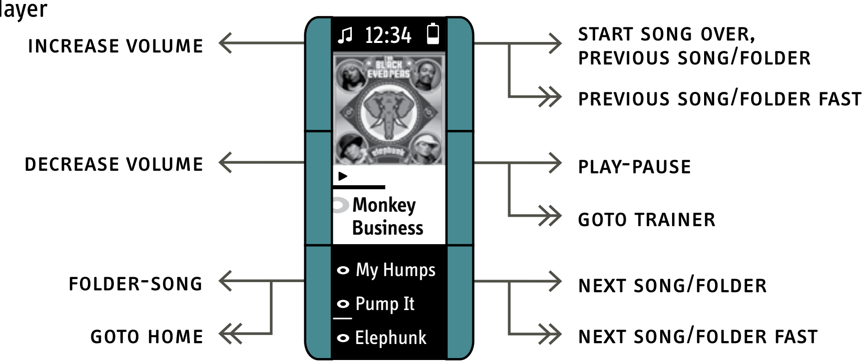
APPENDIX[d]

SCREENS AND BUTTON FUNCTIONS

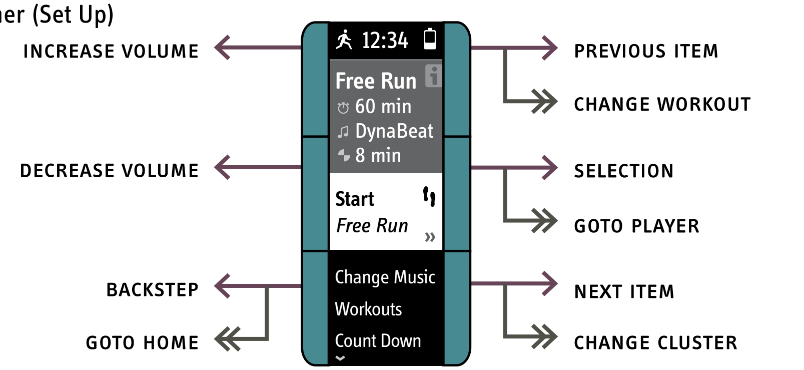
↗ Home



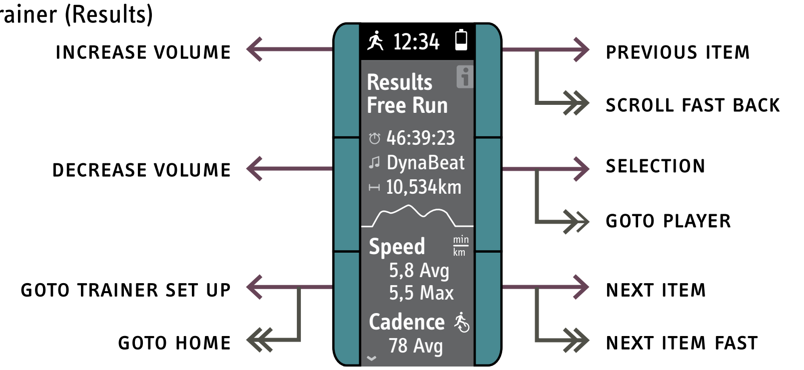
↗ Player



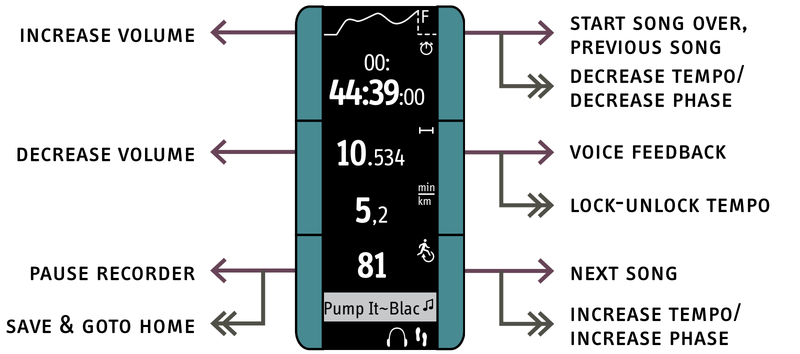
↗ Trainer (Set Up)



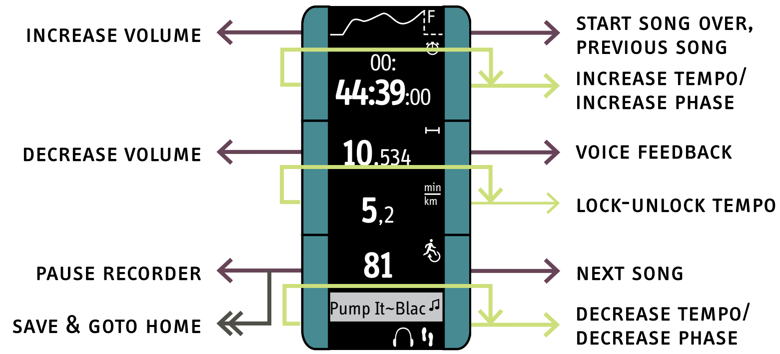
↗ Trainer (Results)



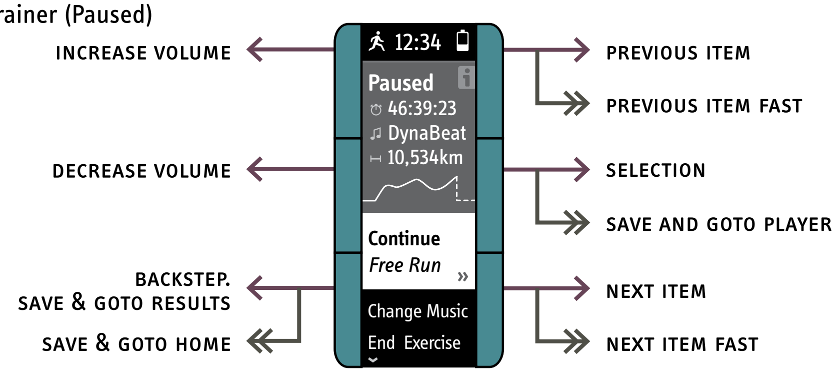
↗ Trainer (Recording) Version 1



↗ Trainer (Recording) Version 2



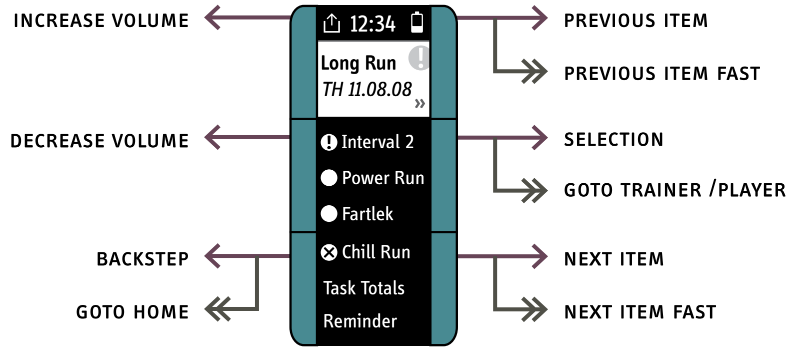
↗ Trainer (Paused)



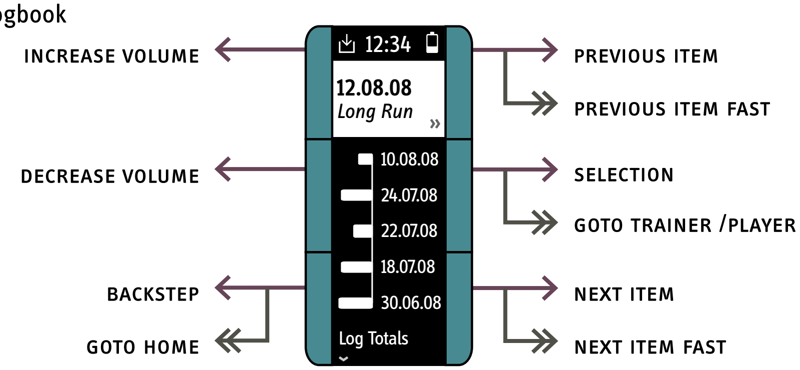
→ = *short button press* ⇉ = *long button press*

Double Button vs. single Button Interaction. With the final symmetrical *Ritmo Wrist Unit* design the idea arose to rethink the assignment of keys. Apart from using short and long single clicks only to activate functions, pressing two opposite buttons simultaneously can be considered as a possible "natural" means of interaction. In particular, during the workout (Trainer recording) "press and hold" to lock/unlock tempo may be substituted by a quicker "grasp and squeeze". The question when to use which manner of pressing buttons also pertains to turning on or off the device and to triggering the help function (see Page 123). The activation point of the physical buttons as well as their haptic experience are likely to play an important role. Without user testing, however, no definite preference can be assumed and stated. This decision must therefore be suspended until a working model or an actual prototype of the device envisioned herein is available for user testing.

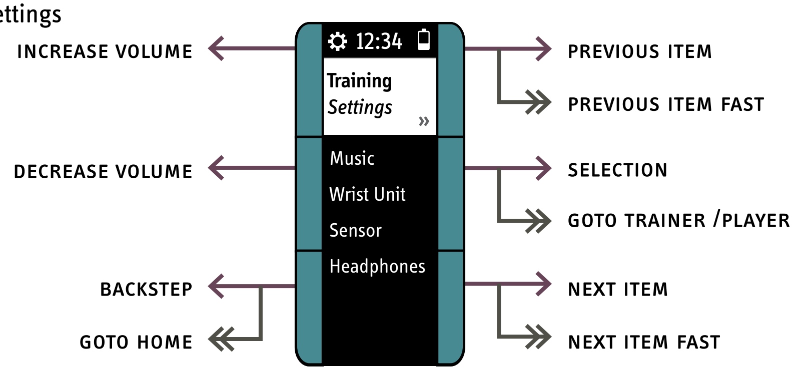
↗ Task List



↗ Logbook



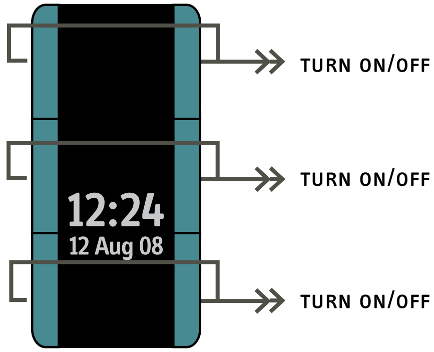
↗ Settings



→ = *short button press* ⇒ = *long button press*

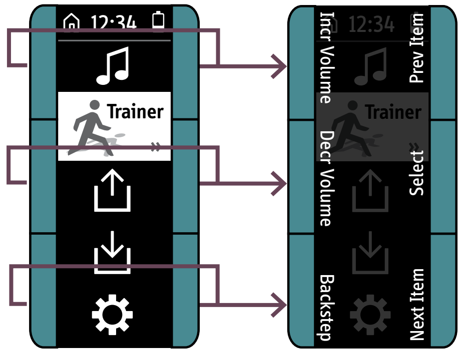
↗ Sleep (Watch)

The Ritmo Wrist Unit falls asleep when no user interactions take place for a given time while neither workout recording nor music playback are running. Pressing two opposite buttons for more than two seconds sends the device to sleep or turns it back on.



↗ Help

Overlayed help information on the key assignments can be triggered at any time by pressing two opposite buttons simultaneously.



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DECLARATION

I hereby declare that this thesis presents my original research and design work. It was accomplished without any assistance from third parties other than those who are stated within this document. I used only the indicated resources and sources. All text passages which were adopted from these sources literally are marked accordingly.

Bremen, 24th of April 2007

IMPRINT

The following fonts used in this book and were kindly sponsored by the FontShop Group:

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I would like to thank professor Peter von Maydell, professor Simon Obitz and Holger Diener for their guidance and assistance and the Fraunhofer IGD for the cooperation and their support. I would also like to thank all runners for their commitment and patience, all experts for sharing their insights, my family for their encouragement, and Steffen Gramsch for converting my ideas and *Ritmo* drawings into 3D renderings. This project would not have been possible without the support of my friends, in particular Lutz and Philipp. I dedicate this work to my father whom I owe my love for running.

Marion Fröhlich
April 2007

University of the Arts Bremen

Fraunhofer Institute for Computer Graphics in Rostock