8th Workshop
on
"Computer Science and Sport"

Carl von Ossietzky University in Oldenburg
June 2002

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Full Papers

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APPLICATION

Editorial

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Dear Readers,

This special edition of the e-Journal presents the lectures that were given during the 8th Workshop on "Computer Science and Sport" at the Carl von Ossietzky University in Oldenburg, June 2002. The articles are structured in four major categories: modeling, theoretical multimedia aspects, computer-based systems and applications.

Modeling

- Frank Bächle (Tübingen) presents a model for optimization of throwing movements by using evolutionary algorithms on the basis of multi-body systems.
- Jürgen Perl, Peter Dauscher and Michael Hawlitzky (Mainz) report on the long-term behaviour of the performance-potential-metamodel PerPot.
- Werner Pitsch (Frankfurt a. M.) discusses a model of socioepidemiology of success in top-level sport.

Theoretical multimedia aspects

- Josef Wiemeyer (Darmstadt) presents two papers handling the topics evaluation and development concepts of multimedia applications.
- The research group Ulrike Rockmann, Stefan Thielke & Miriam Seyda (Oldenburg) present four contributions concerning the research project "New Technologies" focusing on (1) the general design, (2) the learning results of experts and novices, (3) learning strategies and (4) the influence of current motivation on learning.

Systems

- Florian Seifriz et al. (Köln) describes the use of GPS for continuous measurement of kinematic data and for the validation of a model in alpine skiing.
- Jörg F. Wagner (Hamburg-Harburg), Volker Lippens (Oldenburg) et al. present an instrument for quantifying human balance skills and explain the theoretical concept.

Applications

- Frank Schiebl (Tübingen) focuses on the use of modern multibody-system (mbs) software in sports biomechanical education.
- Andreas Hebbel-Seeger and Birgit Koch (Hamburg) present two multimedia applications "Wassersportwissenschaft online" and "Snowboarding – Guide to Ride" and discuss the theoretical concepts.
- Arnold Baca and Christian Eder (Wien) introduce to an internet-based information system for the sport scientific theory of selected sports disciplines.
- Gerd Thienes, Stefan Weigelt, Stephan Starischka (Dortmund) report on the integration of internet-based teaching- and learning-systems into teachership studies in sport
- Ronald Knoch (HU-Berlin) discusses the design and the results of an empirical study about the internet-utilization for the sports-scientific education.

The papers of the two invited lectures are already published in Edition 1 of this journal.

- Jochen Mester et al. (Köln) discuss the scientific basics and commercial interests in sport information technology.
- Hans-Ulrich Bierhahn (Hamburg) reports on the security of IT based learning systems.

The optimisation of throwing movements with evolutionary algorithms on the basis of multi-body systems

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Abstract

The objective of the research is to find a pattern of movements of kinetic links that will result in a maximum throwing distance.
The solution of the problem shall be approached with different methods:
On the one hand by the formulation of the movements on the basis of classical physics, on the other hand by computer simulation with the help of evolutionary algorithms and algorithms based on models.
In the following the arrangement, first experiences and first conclusions with the use of the evolutionary algorithm (in fact the evolution strategy) will be described.

The throw – a complex movement

The observed throw is a throw with both hands above the head (cf. football throw ins) (figure 1).

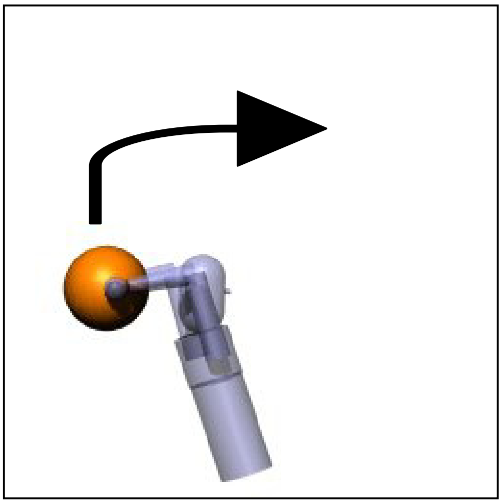

Figure 1: The throw with both hands above the head.

The aim of this computer simulation is to reach a maximum throwing distance. A maximum throwing distance can be reached by a maximum throw-off velocity in an optimal throw-off angle. Therefore the maximum throw-off velocity of the kinetic chain will be observed.
There are different alternatives to approach the problem. The movement pattern could be traced by trial and error by entering (randomised) parameters. But this search for an optimum throwing movement that will result in maximum throwing velocity is highly time-consuming. Apart from that, with this method it is impossible to make sure if the optimal movement was found or if there could be better movements with more trials.
Therefore the systematic approach with the evolutionary strategy is likely to solve the problem.

The model: The model is a fraction of the model in Hanavan-specification (figure 1). It includes three joints (hip, shoulder and elbow), which are composed of “massless” motors. The range of movement of the joints is limited according to anatomic average values. The accelerated ball has got a mass of m = 0.3 kg.
First, the construction of the system will be described. It explains the link between the evolutionary strategy code, the constraints and the multi-body system. Second, the modules will be looked at in more detail.
Finally in this exposition, I will present the first conclusions and an outlook for further proceeding.

The construction of the system

The construction of the system consists of three modules. After the overview the modules will be described in detail.
The evolutionary strategy code (ES) is implemented in the first module (Matlab) (figure 2). The ES is transmitting the run of the torque for each joint to the second module (Simulink). Here, the second module has only got the purpose of an input-output module and is passing this curve of torque to the third module. without modifying it.
The third module (VisualNastran) is used for the simulation of the multi-body system. The fraction model is implemented in this module. The torque causes a movement in this module. The tangential velocity of the distal limb is available as an output and is switched to the second module at every time step.
The second module (Simulink) includes a constraint, which evaluates the velocity of the throw in relation to the quality of the angle of the throw.
This “filtered” velocity will be transferred to the first module as the fitness function and thus to the ES.

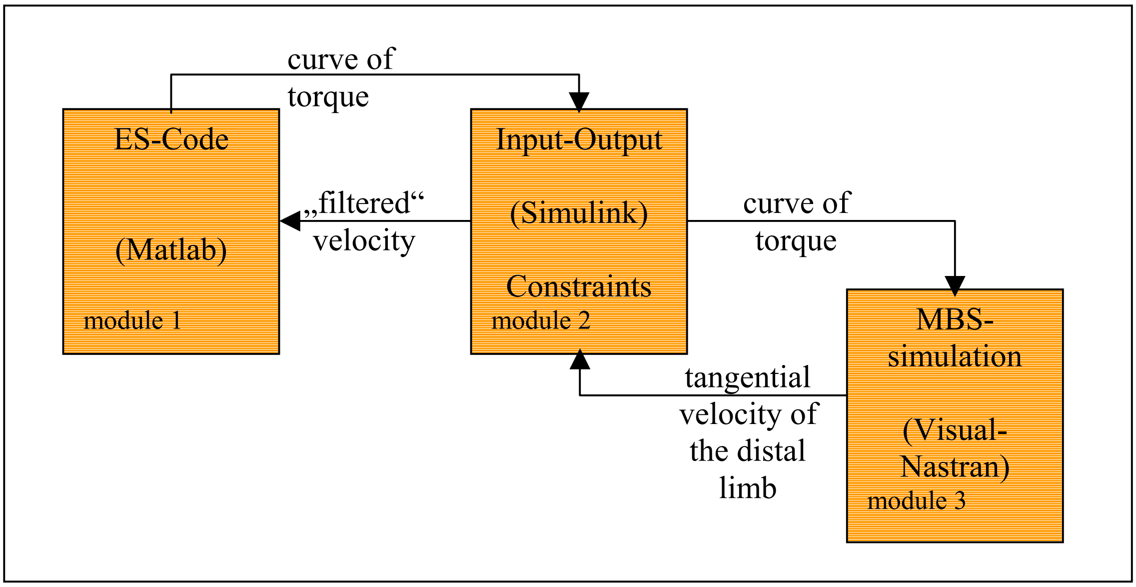

Figure 2: The construction of the system

The first module, the evolutionary strategy

In order not to go beyond the scope of this exposition I will refer to the manifold literature on operating sequences of ES an (e.g. Nissen; Schöneburg).

The used ES is a (μ,λ)-ES. The criterion to abort is the pre-set amount of the calculated generations. The main vector adaptation is an advantage of the ES. That is why an optimum will be found (faster) in high dimensional search areas.
The ES is giving only four values in a time slice, they are represented in black in figure 3. The choice of the maximum values of the torque is basing on values of isokinetic movements. A cubic spline with 15 nodal points is put over this values (red in figure 3). This represents a torque of one joint in the time slice.

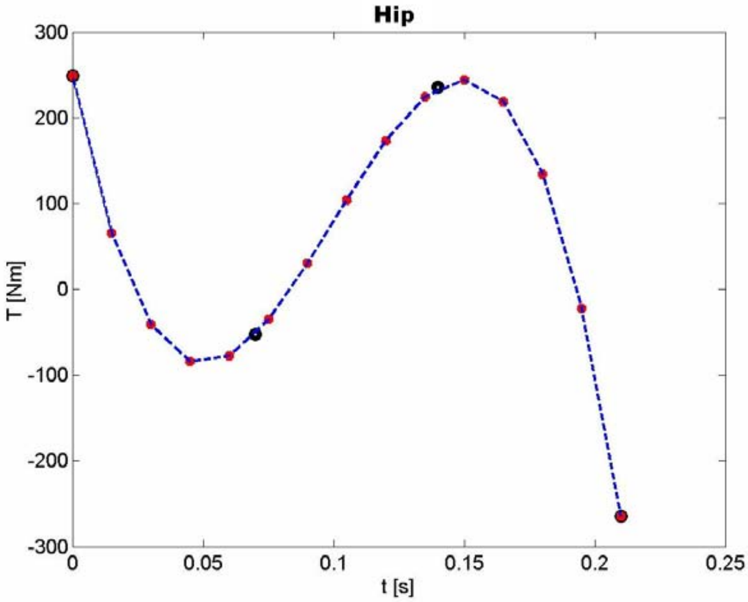

Figure 3: Torque of the hip as an example of the output of module 1

The second module, the constraint

The constraints are needed to eliminate unsuccessful throws: "window of the throw". For that purpose the fitness function "velocity of the throw" will be set in relation to the importance of the quality of the angle (φ) between the forearm and the horizontal line with a factor X.

$$\vec{v}_{Output} = X \otimes \vec{v}_{tang}.$$

Some examples of the value of the factor X (table 1). If φ = 5° the factor X = 0, because the throw would only be in the hight but without an large distance. The optimum angle is approximately (by) φ = 43°, therefore the factor X is 1. The choice of the factor X is based upon the expert knowledge of optimum throw-off angles.

angle (φ) between the forearm and the horizontal line	factor X
5°	0
43°	1
85°	0.5

Table 1: Examples of the value of the factor X

First experiences and first conclusions

To gain some experiences on effects of the differences in the selection force ($s = \frac{\mu}{\lambda}$) the values of μ and λ are changed systematically. Below there are two examples of a (5,15)-ES (figure 4) and a (30,30)-ES (figure 5).
Whereas an increase of the throwing velocity is accomplished in a (5,15)-ES after a few generation this does not happen with a (30,30)-ES. The pressure of selection is missing. Improvements are only at random.

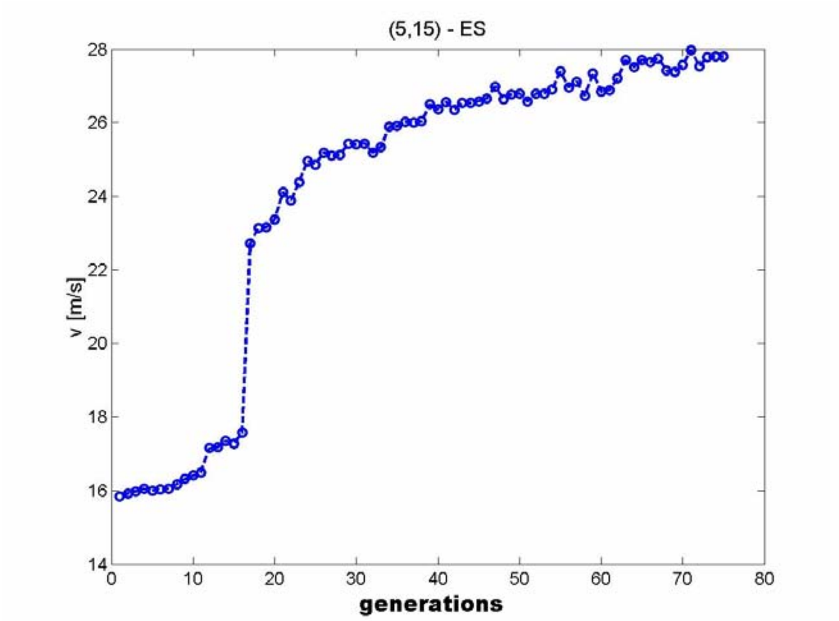

Figure 4: The throwing velocity vs. numbers of generation in a (5,15)-ES

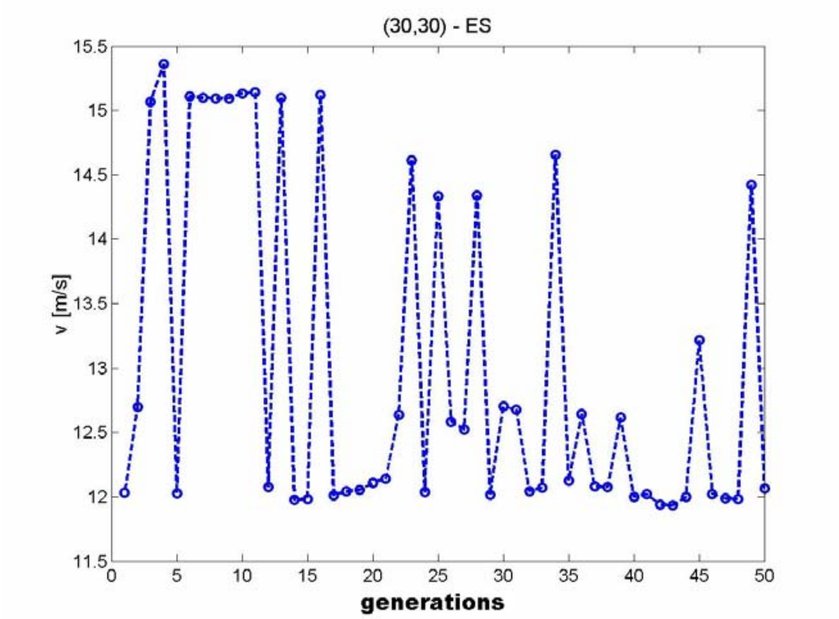

Figure 5: The throwing velocity vs. numbers of generation in a (30,30)-ES

First but not final results of an optimal run of the torque are shown in figure 6. It is calculated with a (10,30)-ES above 50 Generations. The maximum throwing velocity amounts to v = 20,892 ms^{-1}.
The positive torque of the hip in the beginning results in an acceleration of the trunk, whereas the negative torque of the elbow at the same time causes a backward movement of the forearm.
After approximately t = 0.13 s the torque of the hip becomes negative, the trunk will be decelerated. A short time before that the forearm is accelerated into the throwing direction with a positive torque of the elbow.
All the time the torque of the shoulder is negative. Therefore the shoulder will be kept all the time backwards.

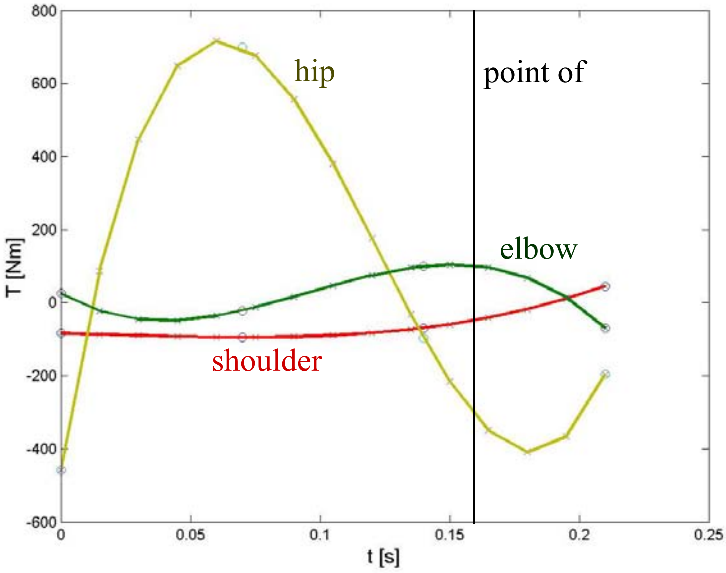

Figure 6: Curve of torque of an optimal throw. Calculated with a (10,30)-ES above 50 generations.

Movements

The optimal movement pattern of the throw which is determined by the ES is similar to the human throws. This is shown in a comparison with literature which deals with throwing movements (figure 7).
In that picture of a throw with both hands above the head it is possible to see the remaining of the forearm in a backward position while the trunk is accelerated in a forward direction. In the last but two picture the trunk is almost vertical and the forearm begins to accelerate to the front.

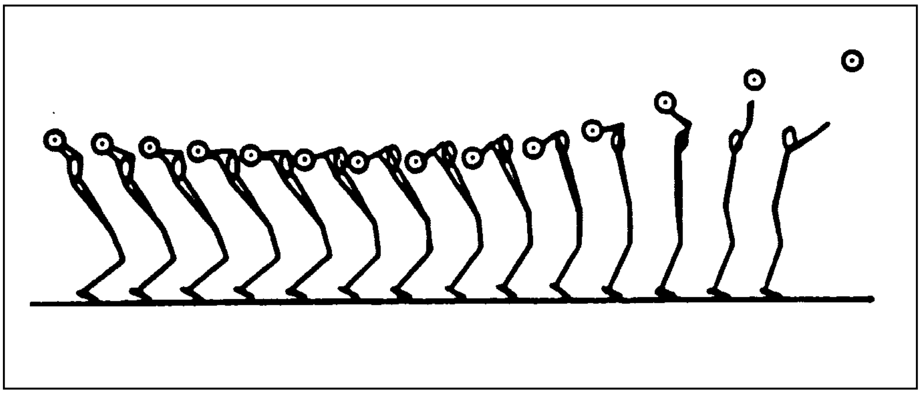

Figure 7: Kinegram of a throw with both hands above the head (Kollath 1996, 214)

In the last but one picture the forearm is almost vertical, the ball is leaving the hands.
This sequences mentioned can also be found in the ES calculated optimal movement (figure 8). It is remarkable, that the movement which is similar to the movement in figure 7 is merely calculated on the basis of maximisation of the fitness function "velocity of the throw".

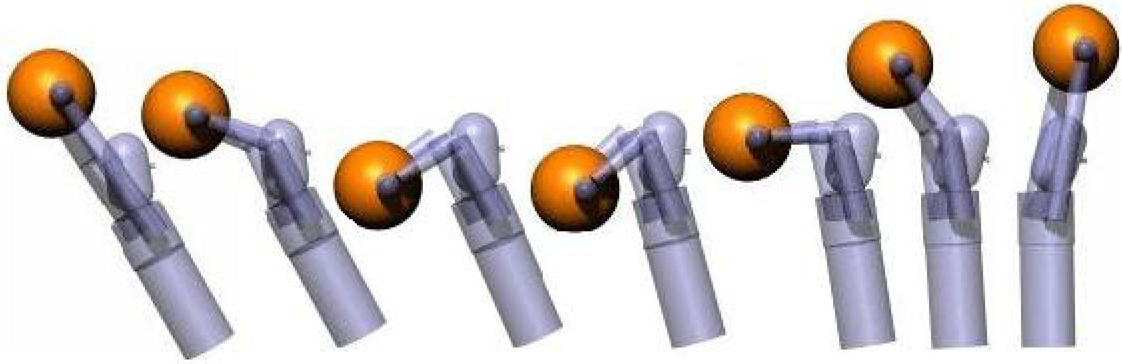

Figure 8: Kinegram of the ES calculated throw

Further experiences

Experiences which were made in the first simulations can be used in/for further research with the ES:

- The simulation in the third module, not the ES-algorithm in itself, takes too much calculating time. The simulation requires a multiple of the computer time of the ES-algorithm. The calculation of a (30,210)-ES with 100 generations needs approximately 2 ½ days for example
- The influence of the constraints (e.g. the choice of the factor X and the "window of the throw") and single ES-parameters must be further evaluated.
- The complexity of the object of research (e.g. the use of a fraction model) is to be reduced and to be held low.

Prospects

In the further process of research more sportive movements with the same problem of exploration should be explored.
Additionally a systematic variance of the parameters of mass should be made to find movement patterns that depend or don't depend on the executive person.

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On the long term behaviour of the performance-potential-metamodel PerPot

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Abstract

PerPot has been developed for modelling, simulating and optimising the interaction between load and performance in training processes in sport but can be used for modelling general physiological adaptation processes as well. The basic idea of PerPot is that a time-dependent load input feeds buffer potentials, from which a performance potential is fed by specifically delayed antagonistic flows (e.g. see Mester & Perl, 2000; Perl & Mester, 2001).

However, dealing with the special phenomenon of atrophy we learned by mathematical analyses that neither short term atrophy nor even load itself change the system's balance. So, training load in the PerPot model not really "feeds" potentials but just pump their contents around. High load rates speed up the pump. On the short run this can be helpful to increase performance. In the long run, however, it disturbs the system's balance and so can cause irreparable negative effects.

Introduction

Analyses of the functional behaviour of PerPot show the following effects, which are primarily interesting under the aspect of model dynamics but also can be discussed under the aspect of similarity to physiological phenomena (see Perl, 2001; Perl, 2002):

(a) Independent on time and load input, the internal load balance of PerPot has a constant value only depending on the initial values of the potentials. The reason is that load input does not effect substantial increments but only effects a re-distribution of the available amount of potential substance. In so far, load just plays the role of a pump. However, too intensive or fast pumping can cause that single potentials get overflows or become empty, which means a temporarily irreversible loss of stability.

(b) The quality of PerPot-simulation can be increased by adding atrophy components. Due to (a), two different types of atrophy have to be distinguished: Temporary atrophy, which does not affect the constant balance property, has mathematically to be modelled by a delayed re-flow from the performance potential PP to the response potential RP. So on the one hand the current performance is reduced by temporary atrophy. On the other hand, the increased response potential causes an initially delayed but then speeded up recovering of the performance value. Quite different, the life long atrophy, modelled as an output flow, reduces the amount of performance substantially. This effect changes the internal balance of the model and cannot be compensated by additional load.

(c) The delay parameters determine the behaviour of the model. In particular, changing these parameters changes the asymptotically reachable maximum value of the performance potential. However, changing model parameters consequently means changing the model – i.e. adapting the model to a changing system. This aspect opens a new view to the modelling

of training by coupling two PerPots: An external PerPot, which models the temporary or short term interaction between load and performance, is itself influenced by an internal PerPot, which in particular affects the delay parameter of the outer one and so can improve its long term training results substantially. For example, load input to the inner model can cause a reduction of the response delay of the outer model, which then not only increases the maximum value of performance but also speeds up the increasing process of performance – without any violation of balance. In the long run, however, speeding up the pumping process this way can cause performance reduction and serious instability of the whole system (as has been pointed out in (a)).
The presented aspects regarding atrophy and long term behaviour of PerPot show a certain analogy to that of adaptive systems like athletes. So, as already has been done with the temporary load-performance-interaction using PerPot, simulation can help to better understand and optimise long term training under the aspects of atrophy and improving parameters. Finally, aspects of life-long-training have to be discussed in order to avoid instability, break downs, or even sudden death phenomena.

Basic PerPot

Structure and dynamics

The basic concept of the performance potential-metamodel, which has been used in PerPot, is that of antagonism: Each load impulse "feeds" a strain potential as well as a response potential. These buffer potentials in turn influence the performance potential, where the response potential increases the performance potential (delayed by DR) and the strain potential reduces the performance potential (delayed by DS), of course depending on the maximum capacities and on the current states of the respectively involved potentials (see figure 1).

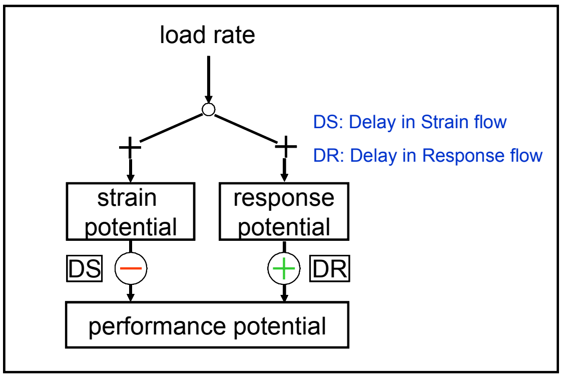

Figure 1. Antagonistic structure of the basic performance potential-metamodel.

If the delays are identical the rates compensate each other, resulting in a constant performance potential. Otherwise, the relation between the delays specifies types of balancing out, one of which is the so called super-compensation. These effects are well-known from adaptation processes.

Strain overflow

An interesting observable effect not represented in the basic structure is that of collapsing: If the load integral over a period of time becomes too high, the performance breaks down spontaneously. This effect can be modelled using the concept of overflow: Potential capacities are limited. So, if in particular the strain potential is fed over its upper limit, an overflow is produced, which reduces the performance potential immediately, i.e. with a rather small delay DSO.

Atrophy

Finally, atrophy in a first step had been modelled as flow of performance leaving the system – as is shown in figure 2, comparing the types of so far modelled system behaviour.

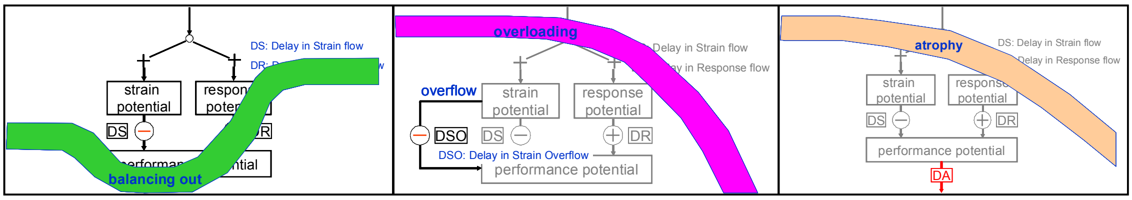

Figure 2. PerPot dynamics: Balancing out (left), overloading (middle), and long term atrophy (right).

However: This type of atrophy is not reversible and so can not be used for modelling short term atrophy effects that can be balanced by training. Deeper analysis leads to the following mathematically based result:

The modelled system of load and performance is closed – i.e. load rate just "turns the wheel" without changing the stable amount of performance producing "substance". Due to this fact, in case of reversible short term atrophy the atrophied potential has to be fed back (delayed by DA), which mathematically only can be done feeding it back to the response potential (see figure 3). (Colleagues from sport medicine ensured us that this result meets physiological expectations.)

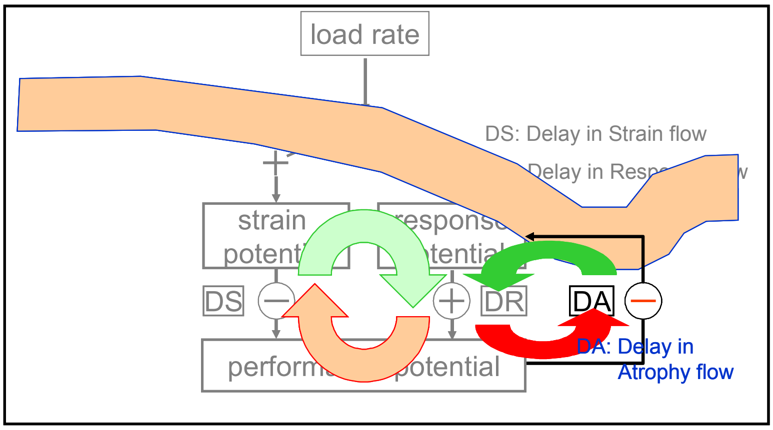

Figure 3. Atrophy as a closed loop extension of PerPot.

In figure 4 the typical effect of atrophy is shown: After reducing the load to "0", performance after a specific delay is decreasing – and than again balancing out on a low level. As can be shown according to experiences from practice, newly activating the load rate would normalize the situation rather fast.

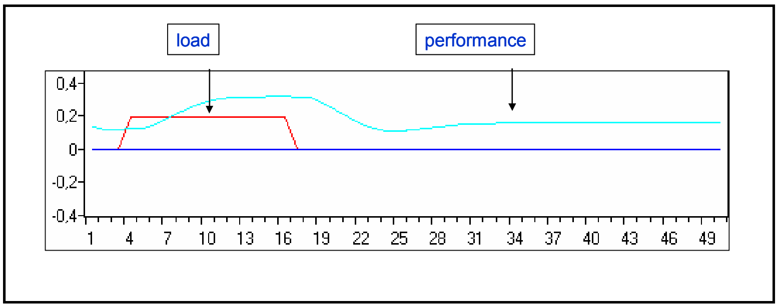

Figure 4. Atrophy of performance after reducing the load rate to "0"; delay DA=16.

The aspect of pumping performance in a closed loop by means of load is not only helpful in order to understand the phenomenon of short term atrophy. Moreover, it can help to understand the long term effects of high load training, as is dealt with in the following section.

Long term training, modelled by two-level-PerPot

Changing delay parameters

As has been pointed out in connection with atrophy, short term behaviour of a physiological adaptation system has to be kept distinct from its long term behaviour: The short term system can be thought to be closed and rather stable with regard to its parameters. Its dynamics can be described like that of a load-triggered pump, which is activating and moving available potentials. So far, the short term behaviour is modelled by PerPot – which however does not answer the question how performance potential can be increased or decreased substantially over time.
The following aspects could help to answer the question:
If the strain delay DS becomes greater compared to the response delay DR then the maximum performance potential in the long run becomes greater (see figure 5).

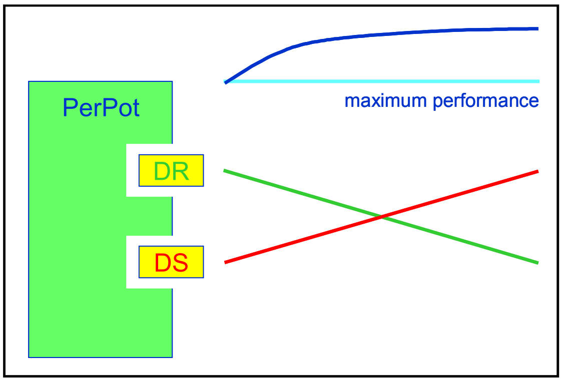

Figure 5. Increasing the maximum of performance depending on the relation between DR and DS.

The physiological interpretation of that change could be that corresponding physiological reproduction components (controlled by relatively decreasing response delay DR) become faster or increase their flow volume. So, constant delay parameters characterize the athlete's temporary condition and the effect of short term training, where changing delay parameters can be understood to be the long term effect of training, directed to improve the performance by improving the physiological training condition.
Figure 6 shows how closely the performance can be connected to the delay parameters and how weak then the interaction between load and performance can be.
(The data from figure 6 are virtually generated. For original data and specific explanations see Perl & Mester, 2001.)

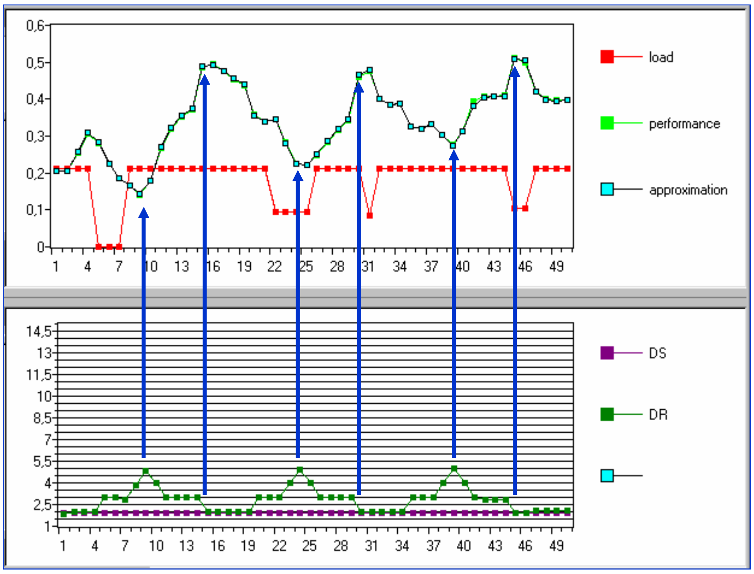

Figure 6. Influence of delay parameters to the performance maxima.

The problem however is that with increasing DS in the long run the system's balance becomes disturbed by overflow effects.
Because of this reason, PerPot can not be used to model short as well as long term effects on the same level. Instead, these two types of effect have to be distinct and modelled on different levels:

Two-level-PerPot
In order to model the interaction between long and short term behaviour, a two-level-PerPot has been developed, where the internal or long term model changes the parameters of the external or short term model: As can be seen from figure 7, the same load rate controls as well the internal model, affecting the delay parameters of the external model, and the external model itself, affecting its temporary performance.

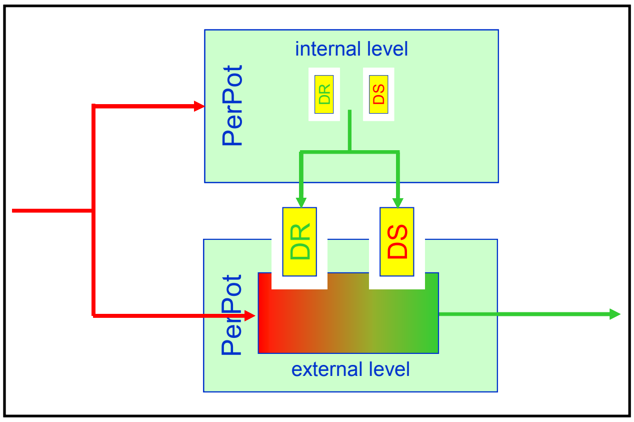

Figure 7. Load rate, controlling the internal and the external model of two-level-PerPot.

Some examples of the basic dynamics of that approach in the case of constant load are given in figure 8 and discussed below.

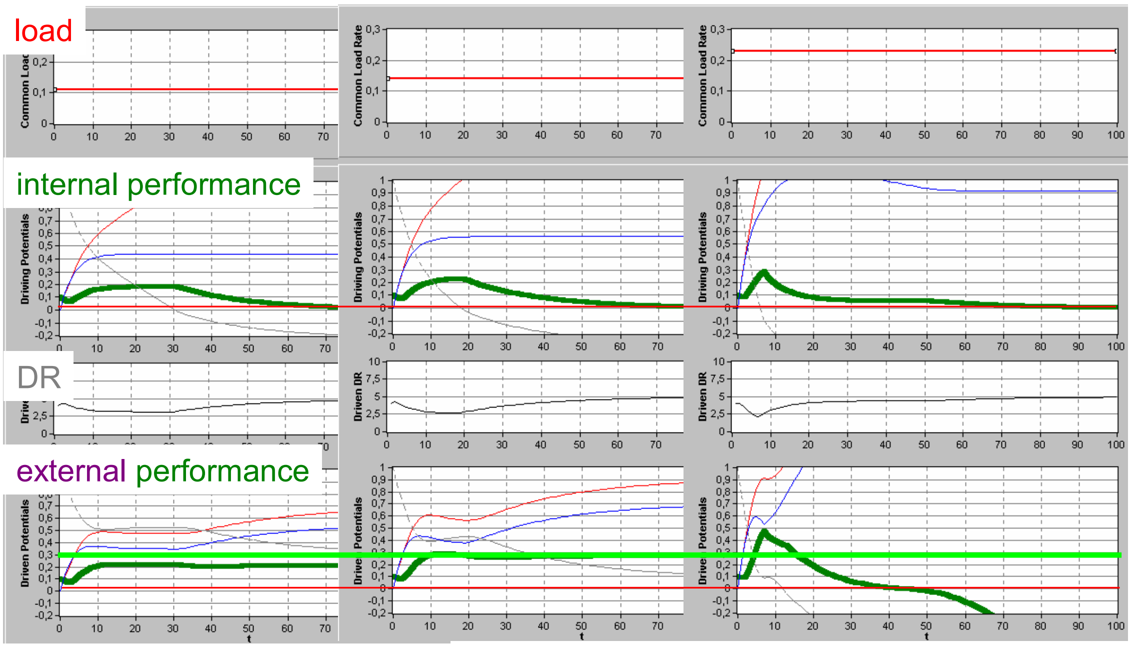

Figure 8. Basic dynamics of two-level-PerPot in case of different types of constant load.

Comparing the first and the last row shows that with increasing level of load the maximum of obtainable performance increases as well. (Take the horizontal light green line as an orientation).

The third row shows that smaller values of the response delay DR (with the interpretation of improved internal condition) are the reason for this effect.

Changing DR behaviour is the result of affecting the internal model by the load, as can be seen from the second row: With increasing load the internal performance profile also increases its maximum but decreasing the length of that maximum phase.

The DR-profile of the external model is – more or less – the mirrored performance profile of the internal model. So, higher load causes a higher but shorter maximum phase of internal performance. In turn, it causes a lower but shorter minimum phase of the external DR profile, and this finally causes a much higher but much shorter maximum phase of the external performance.

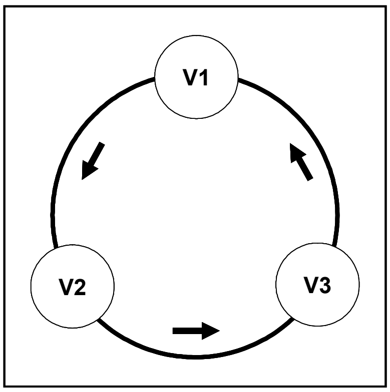

Figure 9. Pumping around in a closed loop.

As mentioned above, the characteristic behaviour "higher but shorter" of the maximum phase is a direct consequence of the pumping phenomenon of the closed PerPot-System, as is given in a different view in figures 9 and 10:

Pumping very fast from V2 to V3 can raise the level of V3 very much and very quickly. If however the flow from V1 to V2 is slow then V2 as quickly becomes nearly empty, and also the level of V3 quickly becomes low because of the flow from V3 back to V1.

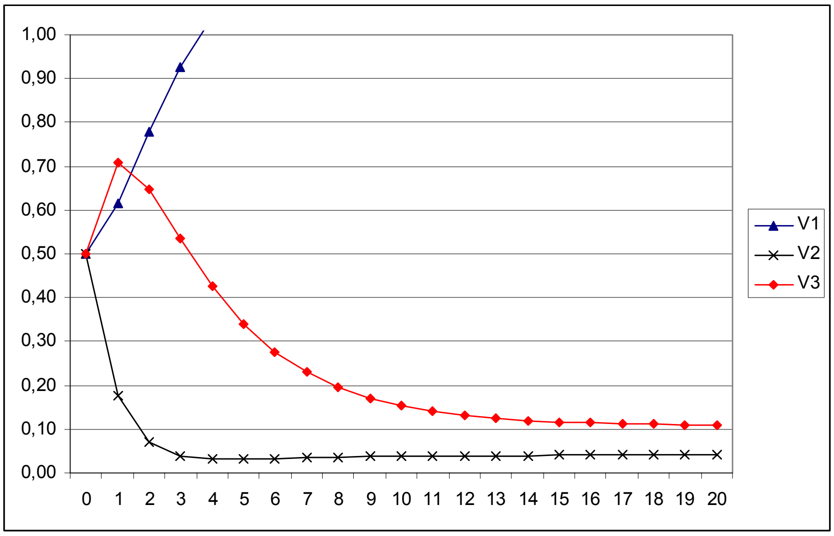

Figure 10. Dynamics of pumping around in a closed loop.

So far, the situation becomes bad but not disastrous. If however the overload of V1 causes an overflow as is modelled in PerPot then the system collapses if pumping is continued in the critical situation (see figure 11).

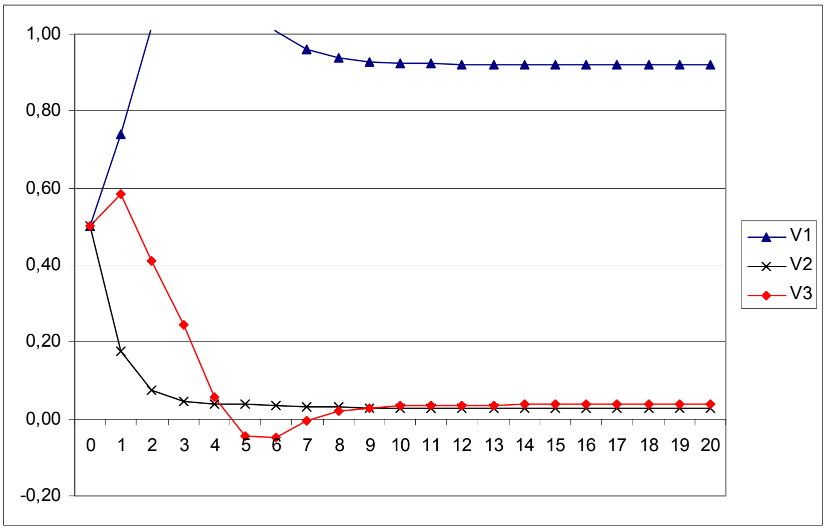

Figure 11. Collapse caused by overflow.

This effect is quite similar to what we got in the third column of the external performance in figure 8: Small DR-values caused fast pumping and so produced not only a high but short maximum but also a collapse.

Interpreting the time scale as the life time the result means that an intensive training in the youth can increase the performance extremely but also can imply the hidden danger of an unexpected break down long time later.

The problem is how to optimize the long term training load in order to stabilize long term performance and avoid break downs. Figure 12 demonstrates how two-level-PerPot might give an answer:

The left column shows one very common scenario: During a period of time in the youth the load values are very high, causing a high (but not necessarily constant) performance. Stopping training completely then leads to a reduction of the stable performance on a low level.
The middle column shows what happens (in the model) if training is not stopped but continued, maybe with even increased load: The internal system becomes "empty" (i.e. there is no organic reserve any more) and the external system collapses. In the special case demonstrated here, this happens without improving the performance at any time.
Finally, the right column demonstrates that already a small reduction of the load level can stabilize the performance on a very high level (horizontal light green line) without reducing the maximum performance (horizontal violet line).

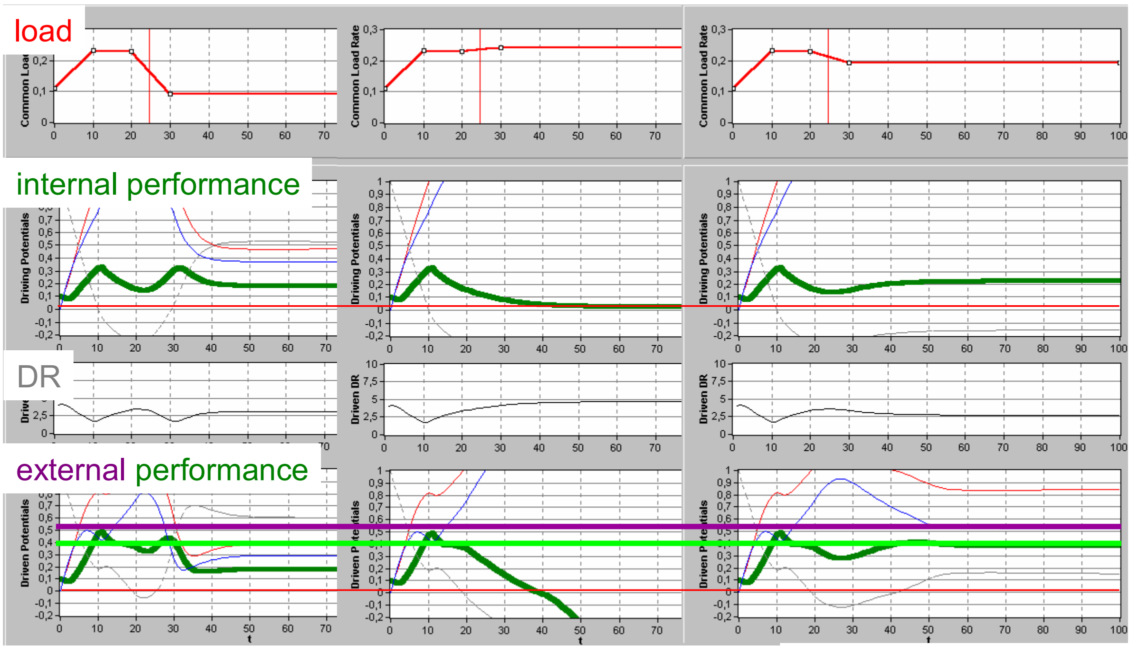

Figure 12. Optimizing long term training in order to stabilize long term performance

Discussion and outlook

The two-level-PerPot seems to be able to simulate an often-discussed phenomenon – namely that high training load over a long time on the one hand can keep fit but on the other hand can cause spontaneous brake downs.
Of course, it is just a model and we do not have any practical experience with it. The idea was just to find out how "parameter training" – i.e. the adaptation of delay parameters – could be used for better understanding the long term training process.
From a structural and qualitative point of view the results are encouraging:
First, the decomposition into an internal ("organic") level that controls the external level of temporary performance seems to make sense: Training on the one hand influences temporary performance. But on the other hand, this effect in the long run depends strongly on the organic capacity, which is influenced by the same training.
Second, the fluctuations of delay parameters that can be observed in the analyses of original load-performance-data become more transparent and understandable if the temporary PerPot is imbedded in a long term controlling environment.
There are, however, a couple of questions that have not been answered yet:
The first question deals with the absolute values of time units: The PerPot "time" scale is independent of any particular interpretation of "time". So the interpretation of the time units in

the two-level-model as to be "years" is rather arbitrary. If such an absolute scale is needed it has to be found by calibration using original data.
The second question is somewhat more complicate: The idea of two-level-PerPot is based on the pumping-result, i.e. that the balance of a PerPot-system is not changed by load rates and so is constant over time. In the interpretation of "organic capacity" this means that this capacity is only reduced by irreversible long term atrophy. This could be in correspondence with ideas of "vital energy". But then the question is whether the scale of the long term performance values of a person is independent of or related to his age: Obviously, at least in the first phase of growing up the absolute performance values depend on the person's age.
In turn, it seems to be very unlikely that a person is able to increase his load amount with increasing age, as has been modelled in figure 12 in the second column. And also the situation in column 3 does not look very realistic.
One (however rather speculative) idea to answer those questions could be to assume something like an "(organic) capacity function" that is not constant but age-depending, controlled by a "capacity controlling function" (see figure 13):

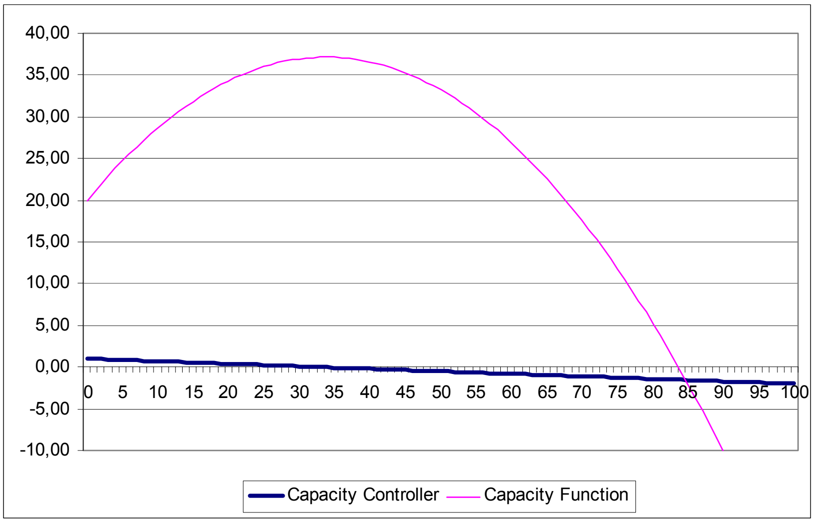

Figure 13. Non-constant capacity function depending on a linear capacity controller.

In this very first approach, the capacity controller is modelled by a linearly decreasing function (which is meant to specifically depend on the respective person):
In the first phase, i.e. as long as its values are positive, it plays the role of a generator and so characterizes the decreasing increments of the capacity function, starting with an initial birth value.
In the second phase, i.e. becoming increasingly negative, it plays the role of atrophy, continuously and irreversibly reducing the capacity.
(One interpretation of this "capacity" could be the cell multiplication ability.)
What we are going to do next is to imbed the two-level-PerPot in the frame of age-depending maximum capacity values given by the linear capacity controller.
Even if it does not seem to be realistic to validate such a generalized model it nevertheless might be helpful for a better understanding of system structures and dynamics phenomena. So, as already mentioned in the introduction, modelling and simulation at least might help to better understand and optimize long term training in order to avoid instability and break downs.

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Social-scientific modelling supporting theory development: A Model of socioepidemiology of success in top-level sport

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Abstract

In recent past, the connection between aspects of top level athletes' careers and success in top-level sport range was focussed by a sociological based theory of training in sports. Several studies showed, that simply structured connections between training in top level sports and success are far from being able to explain the emergence of success in sport in collectives from processes of individual top level athletes' careers. Especially the discontinuities in long during ingates of sport careers (e.g. Güllich et al. 2001) have led to the development of a "socio-epidemiology of athletic success" which tries to derive the success a top level athlete reaches at the climax of his or her career from the fact, that these athletes missed carreer-terminating critical events in other segments of life (e.g. school). Basing on this first draft, an actor based divided intelligence-model was defined in order to explain effects in collectives from individual data. To do this, it was necessary to integrate social aspects, affecting training and careers in sport and several biological aspects of aging, affecting training and careers as well. This led to an interdisciplinary character of the model as well as to the necessity to extend instruments of social-scientific modelling.

Starting point and objectives of modeling

The system of supporting top level athletes in Germany is structured rigidly, basing on the assumption, that successful sportsmen (and -women [in the following: „Verbum hoc ‚si quis' tam masculos quam feminas complectitur"; Corpus Iuris Civilis]) deal with the same kind of sport over long periods of time, supervised in a supporting system for top-level athletes' promotion and that with a growing period of training a kind of sport, success grows as well. The results of retrospective analysis of connections between top level athletes' careers and success in sport published recently (cf. Emrich & Pitsch 1998, Güllich et al. 2000, Pitsch et al. 2001, Emrich & Pitsch 2002, Güllich et al. 2001) show,

- that the period of time in training a kind of sport correlates if ever only weakly with success in sport and correlates partially negative,
- that under top level athletes one can find many late beginners and people who switched from one kind of sport to another,
- that the promotion of young and top level athletes in Germany shows a high level of annually fluctuation and
- that discontinuities in supporting athletes could not be shown to have a negativ effect on success in sport

To explain these effects, a socio-epidemiological model of success in sport under the conditions of the actual structures of the top-level athletes' supporting system and under actual socio-structural conditions was developed. This aimed especially on the attempt to explain the discrepancy between the untested antecedens-conditions for the structures of the supporting system and the empirically shown effects at the level of the acting people within that system. Even more specific, the aims of modelling this system were

Firstly to derive the structures of athletes' behaviour from aspects of the development of performance in sport over time as well as from the structures of the promotion-system in interaction with opportunities and restrictions that are consequences of socio-structural conditions. Thus, this is the attempt to derive collective effects from the restrictions of behaviour of individual agents

Secondly, the aim of modelling is the construction of a base for discussing the question of controllability of the supporting system for top level athletes in Germany and, if it can be controlled, which manner of controlling actions has which intended and has which unintended social effects.

The socio-epidemiological model of success in sport was developed as a social-scientific, multi-agent based simulation model because of several reasons: Assumed correlations between the period of time and the arrangement of athletes' careers on the one hand and success in sport on the other hand could be more simply modelled in form of linear regression models or of LISREL-models. Looking at longer lasting periods of careers, the assumption of linearity can however only be held at few parameters. So, linear structured relationships cannot be used to model the subject of interest. Besides this, career-affecting events like the beginning of training in sport at all and in a specific kind of sport, beginning of schooling and switches to and between occupational career periods cannot be modelled as correlations. This kind of career-affecting events deal with the question, if a special agent is part of the population of athletes, training the kind of sport which is modelled and if the agent is part of the pool of sportsmen who is possibly to be supported in the future.

Social-scientific multi-agent-based simulations can be seen as an access to the modelling of dynamics of social collectives or aggregates, whereas the variables for modelling are measured exclusively at the level of individual agents. The models exist only of autonomously behaving agents. System dynamics at collectives' or aggregates' level thus is the result of rule-based interactions between agents under (also modelled) restrictions, set by the environment. As Brassel et al. (2000) mention, agent-based models can be classified with respect to the modelled abilities of the agents as existing of simply reacting, intentional or social agents. With reacting agents, these models corresponds to neural networks where activation rules are interpreted in concern of the meaning of the activation rule theoretically. In the case of intentional agents, these have rules for decisions between several action strategies with different weights for selection under differing conditions. In the ideal case of social agents, the agents themselves are modelled as having models of other agents' behaviour, thus being able to plan their own behaviour with respect to the expected behaviour of other agents.

Typical examples for the utilization of agent based models are e.g.:

- the emergence of coalitions between egoistic agents (z. B. Pistolesi et al. 1997).
- sexual attraction among virtual agents (Hemelrijk 2001)
- the behaviour of voters with imperfect information in Multiparty systems (Lomborg 1997).
- the behaviour of perfectly rational and bounded rational agents in organizations (Dal Forno und Merlone 2002).

A view of current works on this field gives the journal of artificial societies and social simulation (http://jasss.soc.surrey.ac.uk/).

Structures of the model of the socio-epidemiology of athletic success

In the basic structure of the model represented in figure 1, the close connection between on the one hand materially physically clear based condition factors of athletic success and on the other hand social general conditions and condition factors is shown. In the upper and right part of the illustration, one can recognize the form of modelling the dependence of athletic performance on the physical factors talent, motor development and specific and non-specific training. These three condition factors lead to an individually determined athletic performance for the agent, which one is in the course of a model part "competition" coded into another variable, called “athletic success”. In the lower and middle part, one recognizes the form in that career affecting and determining events as factors influencing the sporting career and success evolution find entry into the model. The mentioned career influencing events should only be understood here as examples. On the one hand, these events influence the variable specific and non-specific training for the modelled kind of sport directly, influence on the other hand, but also the question whether the agent participates in the competition system in the modelled kind of sport. Dependent of it shows itself whether an athletic performance and therefore an athletic success level in this kind of sport can be assigned to this agent. Rating the agent into the supporting system in turn results from the determined athletic success level, what itself again can be effective as a career influencing event as the rating may change.

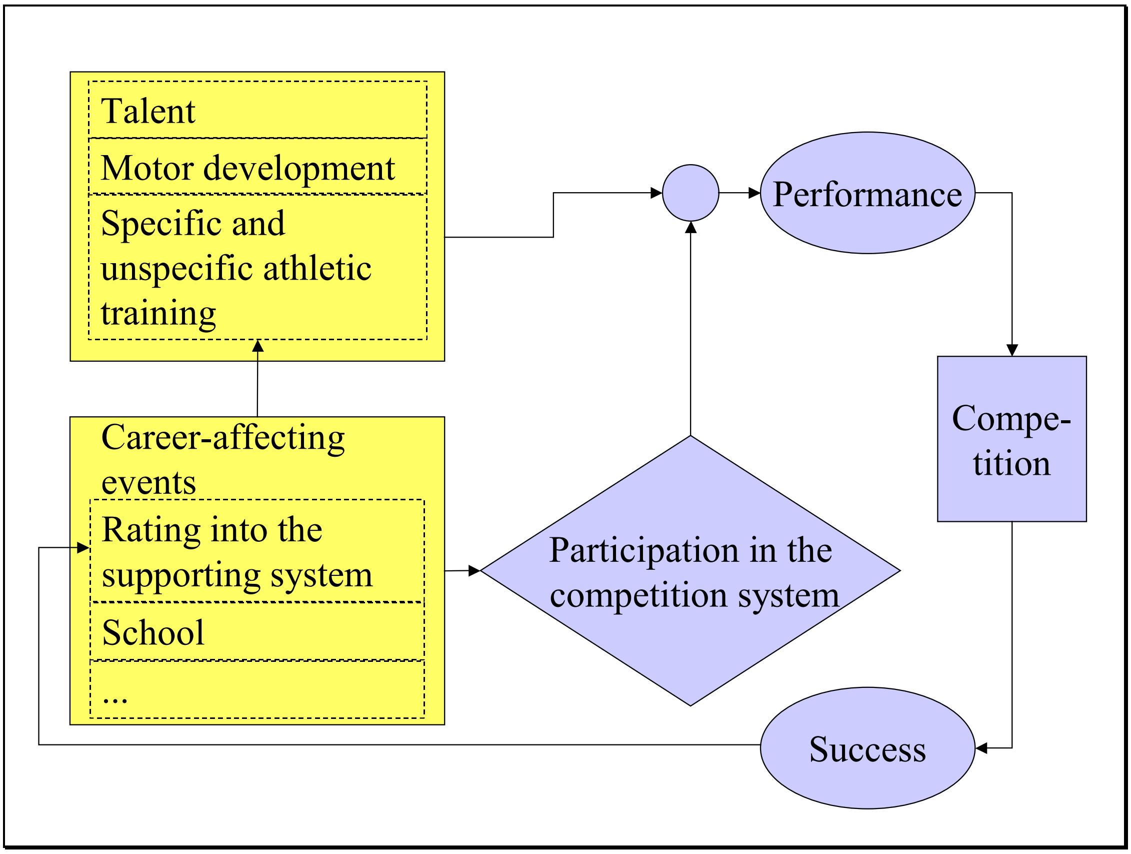

Figure 1. Basic structure of the model of the socio-epidemiology of athletic success

As most important shortenings and abstractions, the following aspects are to be considered during the consideration of the model:

- A kind of sport is modelled with a strong connection between athletic performance and athletic success. One can for instance imagine an event like swimming, track and field events, cross-country skiing or rowing as an example here. For the parameterization of the model serve later data that were raised from squad athletes and other athletes in track and field events.
- The model refers to a sex uniform population of agents. Modelling two sexes would simply have duplicated the number of the simulation runs, as in the fewest kinds of

sport competitions with female and male athletes occur on an athletic level where rating into a high level athletes' supporting system is performed.

- A stable population is modelled without mortality before the maximum performance age with an approximate uniform distribution over all age stages.
- The model is formulated as a discreet model in time at the least unit "year".
- The agents are characterized through a homogeneous maximum performance age (26 years).
- Neither contents of training nor the amount of training load or the training load intensity are considered in detail but the specific and non-specific training is considered by the duration of this training in years.

The modelled agents are characterized through three particular age variables, indeed, their age at the beginning of the simulation, their entrance age into sport and their entrance age into the modelled kind of sport. The age is implemented as a rectangularly distributed random variable over the modelled period of age; modelling the entrance age into the modelled kind of sport and the entrance age into sport followed the known distributions of this age variables with squad athletes.

In the field of the physical, performance determining factors, the agents are characterized by an individual athletic performance in the maximum performance age, deriving from talent as well as by the individual deviation from a middle motor development curve in the form of an accelleratedness and/or retardedness until the maximum performance age, and - analogously but independent of it - at the period of time after the maximum performance age. In addition, the agents are characterized by the strength and direction of the individual athletic achievement motive which is also implemented as a normally distributed random variable. The structure of the model part “career influencing events” is shown in fig. 2. The individual event risk for every modelled career influencing event is computed from the variables age, state of the social career as well as specific and non-specific training age and athletic performance. From effect of a random number generator, one then decides for every individual agent whether the event in the respective simulation step occurs for this agent or not. Career influencing events on the one hand, are modelled as deriving from the field of sports and therefore being related directly to the athletes' careers, on the other hand modelled in the fields of not sport related events. Events in the training environment, injuries, stagnation in performance and/or in success as well as deviating behaviour belong to the events related to sport directly. As not sport related events, events are modelled in the fields school, vocational training, study, occupation as well as family.

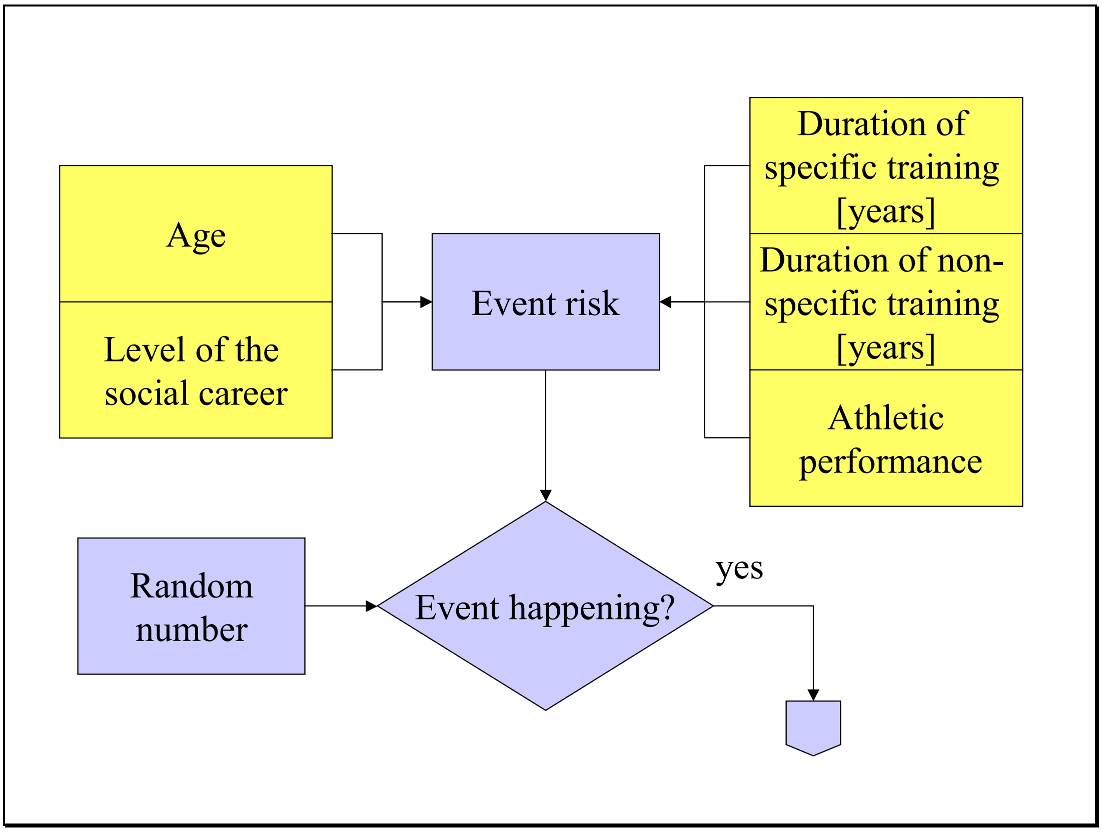

Figure 2. Structure of the part model „career-affecting events"

The effect of the event as breaking off an athletic career is modelled according to modelling the entry of the career influencing events. The event seems career ending depending on the result of a simulated decision on the basis of theory of the achievement motivation, more particular within the framework of the risk choice model (Atkinson 1957). Fig. 3 gives an insight into the structure of the decision algorithm of the risk choice model as implemented for the simulations. In the case of incidence of career affecting events is for every agent on the basis of the performances of his 20 "neighbours" on the success rank scale decided on his further remaining in top level sport career**.** Decisive for this on the one hand, is the agent's assessment with regard to the event risks for increasing and stagnating success on the other hand the strength and direction of his achievement motive.

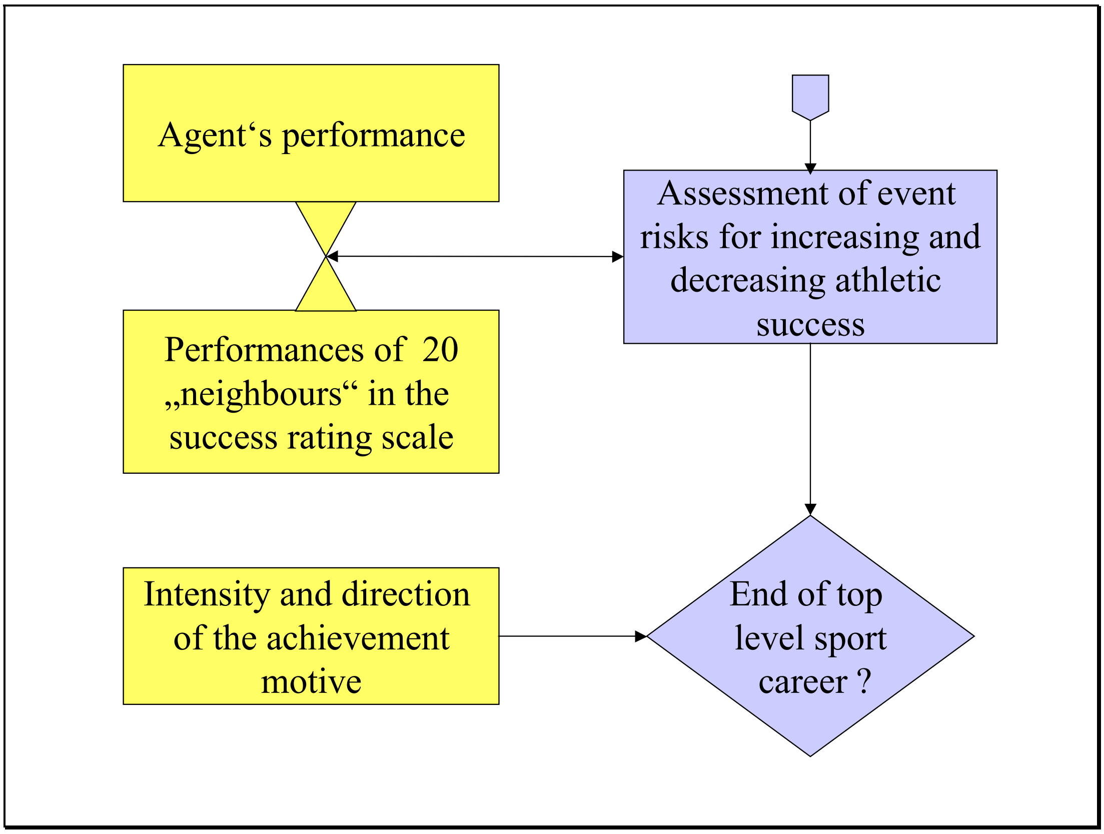

Figure 3. Decision in the risk choice model as implemented in the model of socio-epidemiology of athletic success

The simulation runs

The course of simulation runs with this described model is illustrated in figure 4. After the construction of a population, ageing this population occurs in every simulation step by in each case a year. The determination of the number of too old agents is at first required for that. Those are removed from the population and replaced through the same number of new (born) agents with individual data assigned in each case again for the variables talent and the entrance ages into sport and the modelled kind of sport. In the second step, the part of the sport acting agents is determined in the modelled kind of sport. For this purpose, it is found out which agents have exceeded their specific entrance age. For these agents is simulated whether a career influencing event occurred in the present simulation step In the risk choice model, the evaluation of this event is then carried out as career ending in this simulation step. For the residual sport acting agents in the modelled kind of sport are determined the athletic performance and dependent of it athletic success. On the basis of success, the status of the agent as a squad athlete is determined. After that a new simulation step is in turn initiated in the form of ageing by a year the population. Breaking off criterion for simulation is the number of the simulation steps.

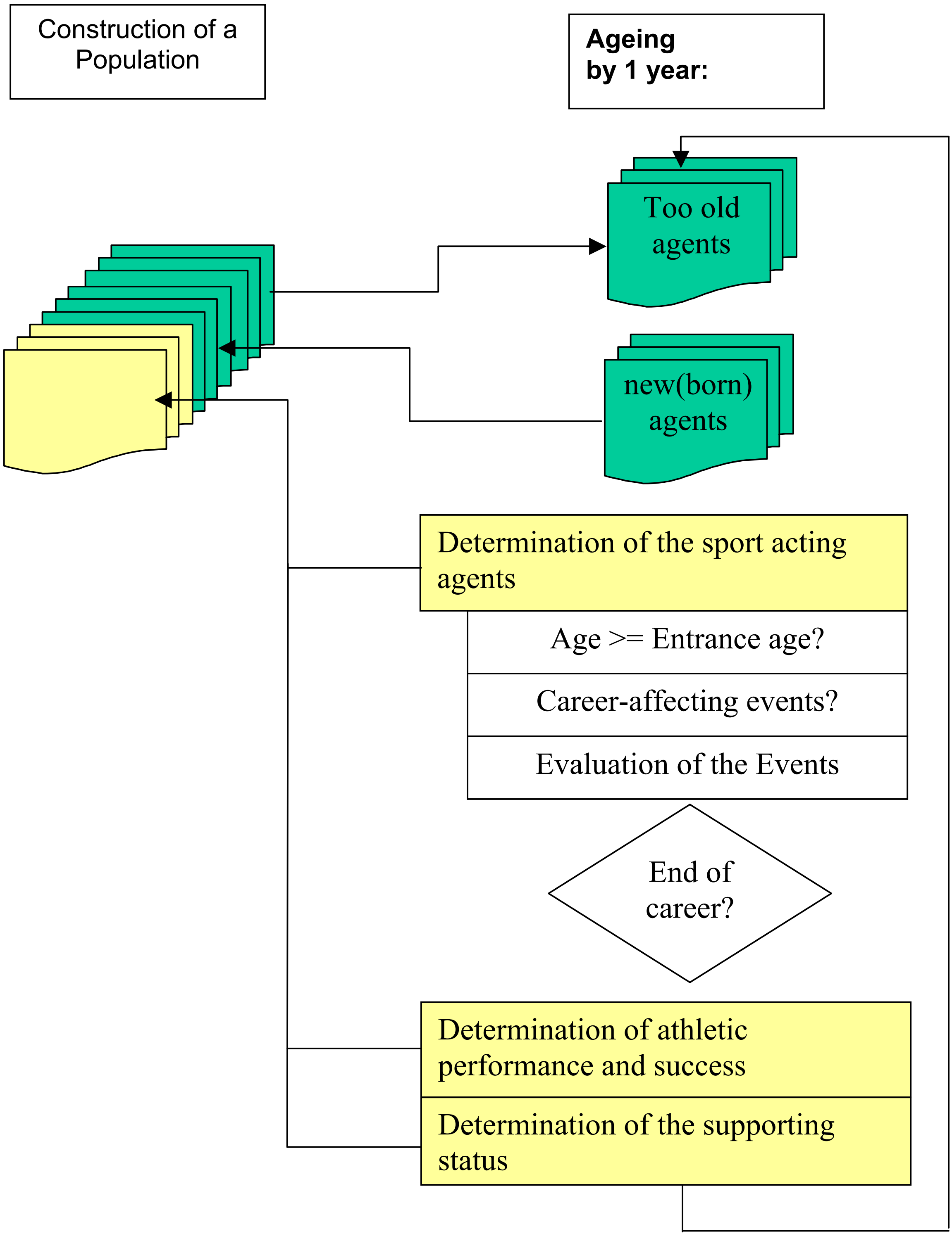

Figure 4. Structure of a simulation step

The model was initially parameterized on the basis of the present sport scientific findings to the individual fields. Target variables for model inspection and model revision are:

- the distribution of age in the several squads,
- the distribution of the careers of squad athletes with respect to the aspects of continuous and not continuous careers
- the distribution of careers ascending continuously and ascending non-continuously

which shall be reproduced in the simulation runs in accordance with the known data from parts of the population of squad athletes. The part of the early and late beginners as well as the direction and power of correlations between the process of sport careers and athletic success are further target variables for the model inspection and revision.

After the ability to run of the model as well as the suitability of the developed algorithms for simulating the accepted connections could be checked in a preliminary version, this model is currently implemented in C++ in a LINUX-environment. Objective of this new implementation is to be able to carry out the simulations, which cost very much time also in a large multi computer environments at the Johann Wolfgang Goethe-Universitiät Frankfurt.

Intended and non-intended results of the formulation of this model

The necessity of the formulation of particular and parametrizable connection and effect statements within the framework of the formulation of a such model was already sometimes mentioned as a great advantage of this means in social sciences (e.g. Schnell 1990, Gilbert & Troitzsch 1999, 5f.), in which otherwise often complex connection assumptions may be expressed in a rather slightly formalized manner. In addition, further effects appeared in the investigation process. The model designers combine with the intended simulations also the programmatic effect that the estimation of the influence height of the different model parts - the physical and the socio-economic model - help to identify promising future further question formulations as well as promising variables for the excitation of effect of the supporting systems in top level sport. Over the field of the sociological modelling in sport represented here, this model also shows aspects interesting for other fields of sociological modelling. Integration a social and a physical part-model has relevancy for all fields in which human action is examined in long-term time perspectives and in which physical development is relevant. Such fields e.g. are the analysis of the evolution of media related leisure time interests of adolescents considering "concurrent pleasures" as well as modifications of health related interest and possibilities of older people. This special case shows, that a specific form of computer science like computer science in sport, which can be seen as a „Forum für metatheoretische Beiträge zur Sportwissenschaft“ (Lames 1997, 229 ff.) does not only support the development of disciplinary and inter-disciplinary theories of short and of middle range in this specific field of sport sciences but does also support the advancement of instruments in other (here especially: social-scientific) areas.

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Concepts for the development of multimedia for education

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Abstract

Development of multimedia products should be a structured process, particularly when science is involved. In this contribution, the advantages and disadvantages of three different concepts for developing multimedia are discussed:

- Software Engineering (SE)
- New Media Engineering (NME)
- Systematic Instructional Design (SID)

The purpose of this contribution is to compare these three concepts concerning their viability and adaptability for developing multimedia products for educational goals.

SE divides the development process into specific phases, e.g., planning, definition, sketch, implementation, introduction, and maintenance.

NME comprises also six development phases: initialisation, basic concept, fine concept, realisation, introduction, and use. The first five phases result in a special milestone, respectively: disposition, treatment, multimedia script, test product, and final product.

The main focus of SID is to take into consideration didactics, including didactics of media application and psychology of learning and cognition. SID comprises three main phases: analysis and planning, development and production, evaluation, revision, and using. These main phases are further divided into substeps.

Each of the three concepts has specific strengths and weaknesses. Therefore, the best strategy is to combine the three concepts to ensure structure, specificity, transparency, and interdisciplinarity.

Introduction

As is the case with any software development, the development of multimedia learning programs or environments also has to be systematic. There are numerous reasons for a methodical and systematic development (e.g., Balzert, 2000):

- Multimedia products are becoming increasingly complex. Concepts for systematic development help to establish a clear, manageable procedure.
- The quality demands on multimedia products are steadily increasing. The several parts of the ISO norm 9241, e.g., specify specific demands on hardware, software, dialogue, and usability. Therefore quality management has become an obligatory part of every multimedia development project.
- In order to keep a project within the proposed financial and temporal limits, the application of systematic development concepts is also required.
- Particularly in scientific contexts, it is a condicio sine qua non that the development of multimedia learning programs and environments shows a maximum of transparency. All the decisions and steps should be exactly documented and justified, so that everyone who is engaged in the development can easily understand and reproduce the procedure.

The purpose of this contribution is to discuss the application of development concepts. In a first step, three concepts are introduced shortly in order to integrate them into a summarised concept.
The following demands are serving as criteria for evaluation of the concepts:
- The development process should be appropriately structured (structure).
- The concept should be particularly suited for the development task at hand (specificity). The concept should suggest respective goals, methods, guidelines, tools, etc. for the multimedia development.
- By means of a preferably complete documentation of the development process the concept should guarantee as much transparency as possible.

Software Engineering or software technique

Multimedia learning programs can be considered a specific type of software that has to serve a particular purpose. Therefore, it is reasonable to deal with concepts of Software Engineering (SE) or software technique, if questions of systematic development are concerned.

Table 1. Stages and documents of the software technique or SE concept

Phase	Documentation
Planning	General requirements specification
	Glossary
	Project calculation/ plan
Definition	Requirements specification
	Glossary
	Model of the product
	Interface prototype or pilot model
	User manual
Sketch	Software architecture
	Components of the system
Implementation	Source and object code, documentation
	Test protocol, verification documents
Introduction	Installed product
	Documentation of the whole product
	Handover certificate
	Introduction protocol
	Archived product
Maintenance	Modified product
	Documentation of major modifications

According to Balzert (2000), the development process can be divided into six phases (see Table 1):
- Planning
- Definition
- Sketch
- Implementation
- Introduction
- Maintenance

Due to the purpose of this contribution, the first four phases are of particular interest.

Planning

The purpose of the planning phase is to decide whether to initiate a development or not. The most important activities comprise the selection of the product, the pre-examination of the product (e.g., specifying the main requirements), and testing the practicability.

The results of this phase are documented in the general requirements specification, the glossary, and the project plan. The general requirement specification is the most important document; in this document goals, application, overview, functions, data, performance (e.g., time and precision), quality demands, possible supplements, and further demands of the product are documented.

Definition

The purpose of the definition phase is to establish a complete, clear, consistent, and unequivocal model of the product.

The most important activities comprise the determination, description, analysis, modelling, simulation, and animation of the product demands. This phase is to be considered an iterative process that has to be cycled repeatedly until a complete model of the product is established. The results of this phase are documented in the glossary, the product model, the requirements specification, the graphical user interface (GUI) prototype, and the user manual.

Sketch

The purpose of this phase is to establish a software that solves the problem, i.e., that fulfils the specified requirements properly.

The respective activities comprise the clarification of the constraints (e.g., application conditions, application platforms, and quality demands) and the sketch of the software architecture (e.g., services, network distribution, expert system, data handling, GUI, and help functions). The results are documented in the software architecture and the components of the system.

Implementation

The purpose of this phase is to actually realise the specified performance by means of the program.

In this phase, data structures and algorithms are developed, the program is structured, and problem solutions and implementation decisions are realised. Further activities comprise the transformation of the constructs into the programming language, the determination of the time and memory requirements, and the test and verification of the developed program.

There are specific tools for the development of multimedia (see Table 2; for a discussion and examples, see Freibichler, 1997; Wiemeyer, 2001): page-based methods, icon-based methods, time-axis-based methods, and object-oriented methods.

Using a *page-oriented tool*, text and other media are arranged in a structured way (hypertext, hypermedia). This method allows simple and intuitive programming. For more sophisticated and complex interactive applications, programming experience is required, and with increasing complexity, problems of keeping clearness arise.

Using an *icon-oriented tool*, multimedia developers drag and drop icons and arrange media elements to a complex system. This method allows a visual and intuitive way of multimedia building. Developers can concentrate on aspects of content and design. On the other hand, a great effort and programming experience is required in order to produce complex and flexible systems.

Table 2. Four types of methods for developing multimedia (Freibichler, 1997)

Basic unit/ orientation	Advantages	Disadvantages
Page (Hypermedia)	Simple, intuitive programming Complex associative networks ⇒Hypermedia applications	Programming experience required Lacking clearness (complex systems)
Icon	Visual, intuitive overview of the system Emphasis on content and design ⇒Tutorials, interactive applications	Great effort when producing complex, flexible systems Problems with complex networks
Time-axis	Film or theatre metaphor ⇒Complex, attractive animations ⇒Hypermedia applications	Time for training and acquiring professional know-how required
Object	Universal application ⇒All types of multimedia systems ⇒Interactive simulations	Time for training and professional know-how required

Applying a *time-axis-oriented method*, the development is based on the film or theatre metaphor. There is a stage, a screenplay, and a cast of characters. This method allows the development of complex and attractive multimedia systems. However, in order to exploit full interactivity, professional know-how is required.

The most universal method is the application of *object-oriented tools*. Any kind of multimedia may be developed using this concept. On the other hand, professional knowledge is required in order to build complex and flexible multimedia systems with full interactivity.

From Table 2, we can clearly see that the more flexible the system is the more time for training on the tool is required. The best strategy is to combine the advantages of the particular tools: developing simple animations with time-axis oriented tools, programming interactive simulations with object-oriented tools, and integrating them by means of page- or icon-oriented tools.

The results of this phase are documented in the source code (including documentation), object code, test protocol, and verification documents.

Critical appraisal

Overall, the SE concept is an extraordinarily elaborated concept that offers numerous options for the respective development phases. Furthermore, it ensures high transparency, because the phases and their results have to be documented in detail. However, the development effort is comparably high. For multimedia development purposes this model has to be adapted, because this concept does not address questions of learning, perception, and didactics.

New Media Engineering

This concept has been arranged specifically for the development of multimedia. The New Media Engineering (NME) concept, proposed by Franz and Franz (1998), is very similar to the SE concept. It also distinguishes six phases (see Table 3):

- Initialisation
- Basic concept
- Fine concept

- Realisation
- Introduction
- Using

In this contribution, only the first five phases are introduced, because in these phases the main development activities are performed.

Table 3. Phases and documents of the NME model

Phase	**Documentation**
Initialisation	Disposition (exposé)
Basic concept	Treatment (raw script)
Fine concept	Multimedia script
Realisation	Test product
Introduction	Final product
Using	–

Initialisation

Similar to the SE model, the purpose of this phase is the development decision.

In this phase, goals and target group are determined, efforts and costs are estimated, market chances and needs are analysed, and constraints (e.g., financial and personal resources, temporal constraints, technological constraints) are defined. Milestone of this phase is the disposition (exposé) containing the specification of the idea of the product, the goal specifications, the structure of the topics, and the constraints.

Basic concept

In this phase, the "plan view" of the multimedia product is established. Besides planning activities (phases, quality management), the components *goals, partial goals, provision, processing* and *evaluation of information, topic tree* and *verbal description, storyboard* (visual description), and *interaction diagrams* are developed. Technical preconditions are determined, and first prototypes are produced. Furthermore, a revised cost-profit estimate and a practicability analysis are performed. The treatment (raw script) is the milestone of this phase.

Fine concept

The purpose of this phase is to plan the multimedia production in detail.

The auditory and visual media are planned, and interactions and storyboard are developed. Furthermore, the production process is exactly planned. Very important activities pertain to economic and commercial aspects: practicability analysis, budget plan, proof of efficiency, marketing, sale, and advertisement. The multimedia script is the milestone of this phase.

Realisation

In this phase, the multimedia program is actually produced. Besides revised planning of the organisation, practicability analysis, adaptation of the budget plan, and adaptation of the schedule, the production is performed and processed. Parts of the product and the whole product are tested, before the final acceptance, mastering, and production of a small amount of samples takes place. In this phase, the product documentation is established. This phase results in a multimedia test product that is ready for introduction.

Introduction

Purpose of this phase is the testing and modification of the product, depending on the results of the beta test.

In this beta test, functionality, usability, and effects on the target group are examined. If deficits are discovered, the product is modified in order to be multiplied and introduced to the market. In this phase, marketing and public relations activities are performed. The final product is the milestone of this phase.

Critical appraisal

The activities of the different phases clearly show that the NME model is designed for commercial multimedia productions. Commercial and economic issues are as important as aspects of content and presentation. As compared to the SE model, the NME model takes much more into account the specific requirements of a multimedia development; but it does not consider the requirements of multimedia learning programs and environments. This concept also requires extensive documentation of the development phases.

Systematic instructional design

Systematic instructional design (SID) divides the development process of multimedia into three phases (see Figure 1):

- Analysis and planning
- Development and production
- Evaluation, application and revision

When analysing and planning instructional media, the following activities are performed:

- Definition of the learning goals
- Identification of the learners' characteristics
- Selection and preparation of the learning stuff
- Planning of instructional method and media
- Development of the instructional units and production

During and after this process, formative and summative evaluations are performed in order to test the product with single learners or learning groups and to revise the product if required.

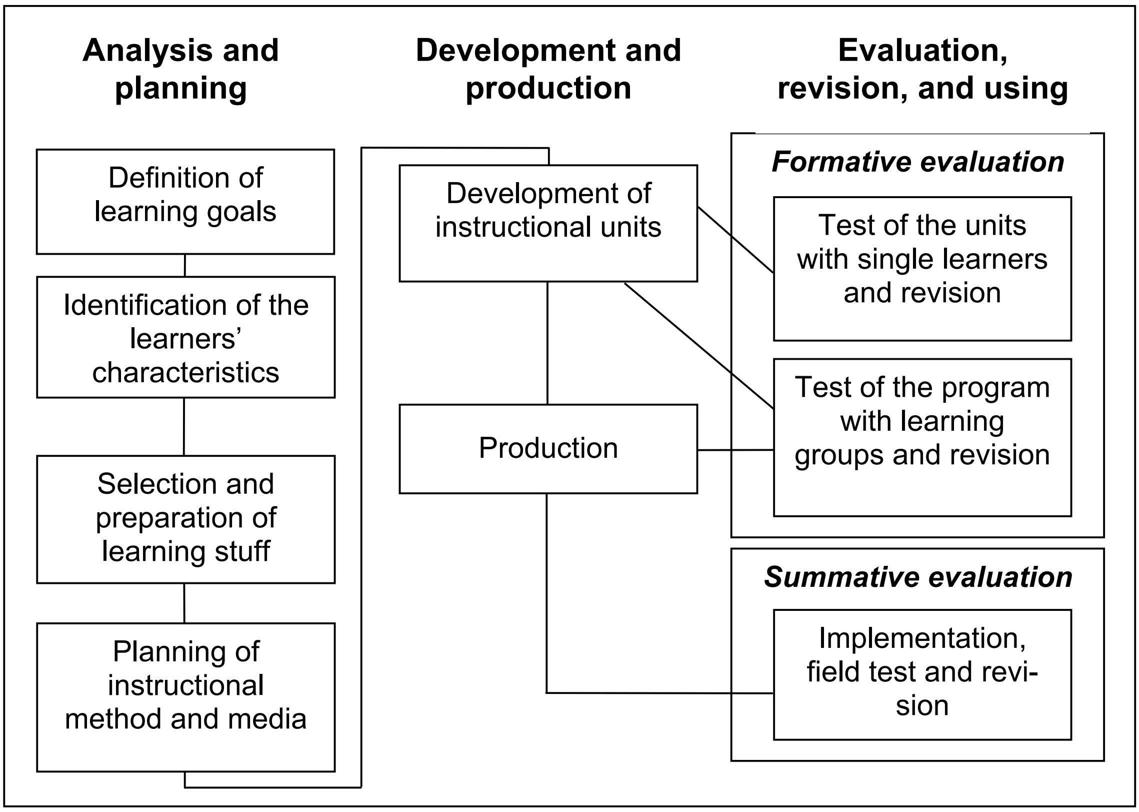

Figure 1. Development phases of SID (according to Issing, 1997; from: Wiemeyer, 2001, p.45)

More than 50 different theories and approaches offer for instructional design (Kearsley, 2001a; Wiemeyer, 2001). Among these theories, there are some specific didactic concepts that seem to be particularly relevant and useful for multimedia instruction (e.g., Kaiser, 1999; Siemon, 1998):

- *Component display theory* (Merrill, 1988)
  Component display theory classifies learning contents according to four different categories: facts, concepts, principles, and procedures. The level of performance is differentiated into remembering, using, and finding contents. Based on these two dimensions, a *content-performance-level matrix* can be established (see Table 4). Furthermore, primary and secondary presentation forms are distinguished (Kearsley, 2001b), i.e., generic or concrete explanations or questions like rules, examples, recall, and practice (primary), or different types of coding strategies like prerequisites, objectives, helps, and mnemonics (secondary). Within a *design matrix,* primary presentation forms and learning contents can be assigned to each other.
- *Anchored instruction* (Brandford et al., 1990)
  By means of a video display of the respective case, a concrete problem is presented to the learner in order to establish an anchor or focus. This focus on the one hand enhances learning motivation and on the other conveys, as compared to texts and static pictures, a much more comprehensive and informative source for a problem solution to the learner. The authors specify a total of seven design principles that pertain to form, content, and didactics.
- *Cognitive apprenticeship* (Collins, Brown & Newman, 1989)
  In order to convey an appropriate solution to the learner, the authors suggest to use the knowledge and experience of experts. The purpose is to teach cognitive and meta-cognitive problem solving strategies of experts in exactly those contexts where they are actually applied. As a first step, the problem solving procedure of an expert is demonstrated and explained. As a second step, comparable problems have to be solved. The proponents of this approach also suggest design parameters pertaining to content, teaching methods, sequence of learning tasks, and social learning context.
- *Goal-based scenarios* (Schank, 1993/94a and b)
  The purpose of this approach is to support goal-oriented, intrinsically motivated learning in realistic contexts. The core concept is the demand to solve a problem independently in a context that should be as realistic as possible. The authors specify seven design principles, e.g., authenticity, controllability, and individual level of aspiration. Goal-based scenarios should contain four components: the mission (goals for action), the mission focus (activities in order to achieve the goals), a motivating cover story, and activities that are specific for the respective scenario.

Table 4. Example of a *content-performance-level matrix* for soccer according to Merrill (1988)

Performance level	**Learning contents** **Facts**	**Concepts**	**Principles**	**Procedures**
Remember	size of the field	offensive tactics	attacking rules	feint
Use	-	offensive tactics	attacking rules	feint
Find	-	offensive tactics	attacking rules	feint

Particularly the last three concepts clearly show constructivistic characteristics, whereas component display theory is primarily a cognitive concept.

Critical appraisal

The SID concept is clearly appropriate for the development of multimedia learning programs and environments, but it also has some possible shortcomings (Issing, 1997, p.215):

development of instructions is very time-consuming, there is a danger to perform the development process as a linear procedure, and the concept may lack flexibility. Some of these shortcomings may be overcome by arranging the development as an iterative process that includes several cycles of production, evaluation and revision. Furthermore, issues of presentation and technology are clearly neglected in favour of content, instruction, and didactics. Details concerning the documentation cannot be found.

Solution: Integrating the strengths of the three concepts

The presentation and critical discussion of the three development concepts has revealed that every concept has its specific strengths and weaknesses. On the one hand, the specificity of the concepts for the development of multimedia learning material increases from SE models to SID models. On the other hand, the concepts become increasingly sophisticated in the order SID, NME, and SE. Each concept focuses specific issues. Therefore, an integration of the three concepts is suggested in order to exploit the strengths and to avoid the shortcomings. The purpose of this integration is to preserve, at the same time, specificity, transparency, and elaborateness. Table 5 contains the suggested integrated concept.

Table 5. Integration of the three concepts for the development of multimedia learning software

Phase	Documentation
Analysis/ planning	Goals (learning goals etc.) Coarse analysis of the learning stuff Didactics, teaching methods, learning theory Conditions of application Main functions and performance of the product Quality requirements Practicability analysis
Definition	Precise and concrete demands concerning – learners – learning stuff: visual and verbal description – didactics, teaching methods, learning theory – function and performance – technology – graphic user interface (GUI) – presentations Non-functional demands (norms, safety etc.)
Sketch	Multimedia architecture Components of the multimedia system
Production and formative/ summative evaluation	Multimedia product or parts Test protocols Evaluation plans and protocols
Introduction and formative/ summative evaluation	Multimedia product Documentation of the multimedia product User manual Evaluation plans and protocols
Maintenance	Reports about experiences Evaluation plans and protocols Modifications of the multimedia product (removing errors, updating)

By means of this integration, three purposes can be pursued:

- Aspects of software technology, multimedia specificity, and didactics are equally taken into account.
- Decisions concerning all aspects are well documented in order to ensure a high level of transparency.
- Aspects of formative and summative evaluation are taken into account in the respective development phases. The results can be used to modify the product if required.

Conclusions

Multimedia development has to be systematic in order to meet several requirements. In this contribution, three concepts for the systematic development of multimedia have been explained and discussed: software engineering or software technique models, new media engineering models, and systematic instructional design. Because the three concepts focus on specific aspects, they differ considerably. In order to ensure transparency, specificity, and interdisciplinarity, an integration of the three concepts may be useful.
Adopting systematic methods requires much effort, but this effort will pay off.

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Evaluation of multimedia programs in sport science education

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Abstract

When developing multimedia as an educational tool, formative and summative evaluations should be applied. Among other aspects, these evaluations can pertain to the extent and way of use, the learning contents and their formal presentation, the learning results, the acceptability, and the usability of the multimedia tool. Furthermore, effectivity and efficiency of the multimedia program can be examined.

Several qualitative and quantitative tools can be applied, e.g., expert evaluation according to specific models of cognition, perception and action, discussions and interviews with users, observation of users in real-life or laboratory situations, heuristic evaluation, using paper or electronic prototypes, or scenario techniques.

Three multimedia tools for education are currently developed:

- Program *EidS* for introduction to studying sport sciences.
- Program *BWS-CBT* for introduction to movement science.
- Program *BioPrinz* for introduction to the principles of biomechanics.

During the development process the following research methods have been applied:

- thinking aloud
- qualitative interviews
- three questionnaires (*ISO norm 9241/10* and *Isometrics*^{L} questionnaires, self-developed multimedia questionnaire)
- logs documenting the experiences with the actual use of the program

The results of the evaluations clearly confirm the efficiency of qualitative methods as means for formative evaluation.

Introduction

Evaluation is the systematic collection of all kinds of data in order to test and to improve a product or a procedure (Bortz, & Döring, 1995, p.614). Evaluation of multimedia learning programs or environments is useful at any stage of the development process. Evaluation has many possible benefits, e.g., conveying a reliable and detailed impression of the strengths and weaknesses of a multimedia product or prototype when being actually applied for learning. There are many different criteria for evaluation, e.g., performance scores, learning duration, behaviour, or attitudes of the users. On the other hand, evaluation requires much effort. This may be one of the reasons that multimedia developers seem to be reluctant to subject their products and prototypes to evaluations.

There are different forms, purposes, techniques, and models of evaluation (Fricke, 1997). The purpose of this contribution is to deal with methods for formative evaluation, i.e., evaluation that is applied during the development process. As a first step, the various techniques of formative evaluation are shortly introduced. Then the application of selected methods of formative evaluation on the development of multimedia learning programs in sport is demonstrated.

Formative evaluation – Methods

In general, there are two sources of information for evaluation: experts of multimedia-related issues, e.g., learning theory, software design, or didactics, and the users themselves. The most important data types are written, oral, and behavioural data.
Wandmacher (2000) suggests the following methods for formative evaluation:
- expert evaluation
- heuristic evaluation by several experts
- heuristic evaluation, using paper mockups or electronic prototypes
- discussions and interviews with users
- evaluation questionnaires
- observation of users
- scenario techniques

Experts can evaluate multimedia products according to specific criteria, e.g., models of cognition, perception, action, learning, and didactics. Experts can also perform heuristic evaluation, i.e., several experts representing different scientific disciplines or research areas independently look for shortcomings of the multimedia product, e.g., dialogue design, graphic design, language, or memory load. Heuristic evaluation techniques can also use paper mockups or electronic prototypes; here, possible users are confronted with a raw model of the multimedia product. Another technique is to discuss selected issues with possible users or to interview users. On the other hand, evaluation questionnaires can be applied in order to get written information about the multimedia product or prototype.
Another way is to observe users when applying the multimedia program in real-life or laboratory settings. A specific way to observe users are scenario techniques, i.e., defining special contexts where the multimedia software is used.

Multimedia learning programs in Darmstadt – three examples

In the institute of sport science in Darmstadt, besides some other projects, three multimedia tools for education are currently developed:
- Program *EidS* for introduction to studying sport science.
- Program *BWS-CBT* for introduction to movement science.
- Program *BioPrinz* for introduction to the principles of biomechanics.

The multimedia learning program *EidS* was developed by Sturm (2001). The main purpose of this program is to support the basic course "Introduction to studying sport science". The program consists of six chapters (introduction, contents, scientific methods, topics for student presentations, useful stuff, and test).
The multimedia program *BWS-CBT* serves to support the lecture "Basics of movement science". This program consists of six chapters:
- Isn't movement science useless?
- Basic concepts of movement science
- Movement between form and function
- Movement from a biomechanical perspective
- Neurophysiological and psychological models of movement
- Knowledge and motor learning

All chapters are divided into 6 sections: overview, learning goals, initial questions, transparencies, tasks, and references.

The purpose of the program *BioPrinz* is to support the basic course "introduction to the biomechanics of sport". This program deals with the biomechanical principles of movements. Version 1 consists of two parts: principles and movement techniques. Part 1 comprises one introductory and five further chapters, each chapter dealing with one principle, e.g., principle of initial force. The chapters of the first part are divided into ten sections (introduction, examples, animations, definitions, tasks, exercises, quiz, references, glossary, and links). Part 2 consists of three chapters: running, upstart on the horizontal bar, and swimming.
In version 2, the structure has been changed. In part 1, the five chapters dealing with the principles consist only of seven sections: Overview, examples, simulations, definitions, tasks, exercises, and quiz. The sections *references, glossary,* and *links* have been summarised because of many redundancies. These three sections now constitute the second part of the program. The sport examples have been removed.

Formative evaluation – methods applied for evaluation

When evaluating the above-mentioned multimedia programs, the following methods were applied:

- *ISO norm 9241/10* questionnaire, designed by Prümper and Anft (1993; see Table 1; for test criteria, see also Prümper, 1997; Richter, 1999)
- ISO norm questionnaire *Isometrics^L*, designed by Willumeit, Hamborg, & Gediga (1997, see Table 1)
- self-developed multimedia questionnaire (8 parts: using, general acceptance, contents, form, usability, learning, attitude, further remarks; total: 52 items)
- self-developed log (4 items: date, time, sections and contents, remarks)
- thinking aloud
- qualitative interviews (two versions with different questions)

Table 1. Comparison of the two ISO questionnaires

Category	**ISO norm 9241/10 (7-point scale[a])**	**Isometrics^L (two 5-point scales; open items[b])**
Suitability for the task	5 items	15 items
Self-descriptiveness	5 items	12 items
Controllability	5 items	11 items
Conformity with user expectations	5 items	15 items
Error tolerance	5 items	8 items
Suitability for individualisation	5 items	6 items
Suitability for learning	5 items	8 items
User characteristics	8 items	-
Total ISO items	**35 items**	**75 items**

[a] The scale ranges from "---" to "+++".
[b] For every item degree of agreement and significance is rated on a 5-point scale (agreement: *wrong* to *very right*; significance: *not important* to *very important*), and exceptions to the general rating can be added.

The subjects had to complete the ISO norm and multimedia questionnaires at the end of the period of using the multimedia program. During this period, they had to keep a log.
Furthermore, the subjects were asked to come to the institute for one session. The respective program was started, and the subjects had to work on a selected chapter. During this work they were encouraged to think aloud, i.e., to tell all the thoughts they were aware of. After this session, the qualitative interviews were performed.

Formative evaluation – a comparison of the three programs

Because similar questionnaires for ISO norm 9241/10 assessment and general evaluation were applied, these two features can be compared.

ISO norm 9241/10 – generic dialogue principles

Concerning the ISO norm 9241/10, two different questionnaires were applied. Because the questionnaires offered different point scales (*ISO norm 9241/10*: seven points; *Isometrics*^{L}: five points), the data were normalised. The results are presented in Figure 1.

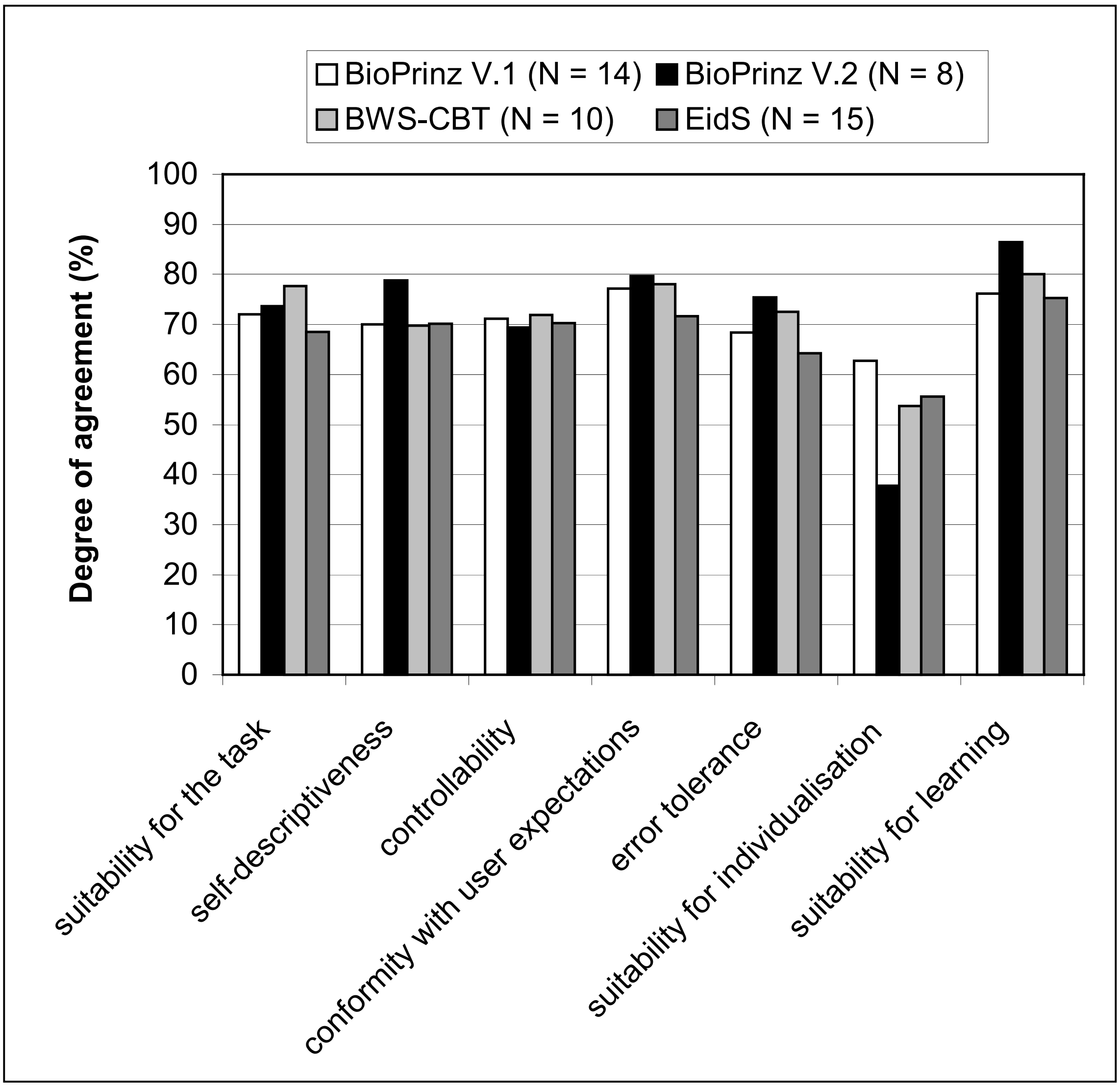

Figure 1. ISO norm results for the three multimedia programs

As can be seen in Figure 1, dialogue quality showed agreements between 68 and 86 per cent (with the exception of *suitability for individualisation*). The multimedia program *BioPrinz V.2*, which is the only software that has been tested twice and revised based on the first evaluation, got the best scores concerning self-descriptiveness, conformity with user expectations, error tolerance, and suitability for learning. Scores concerning the item *suitability for individualisation* were relatively low, because the programs offer very few opportunities to adapt them according to individual needs.

Navigation

Subjects were also asked, which means of navigation they used. In Fig. 2, the two multimedia programs *BioPrinz* and *BWS-CBT* are compared (Data for the program *EidS* have been omitted, because a slightly different questionnaire was applied).

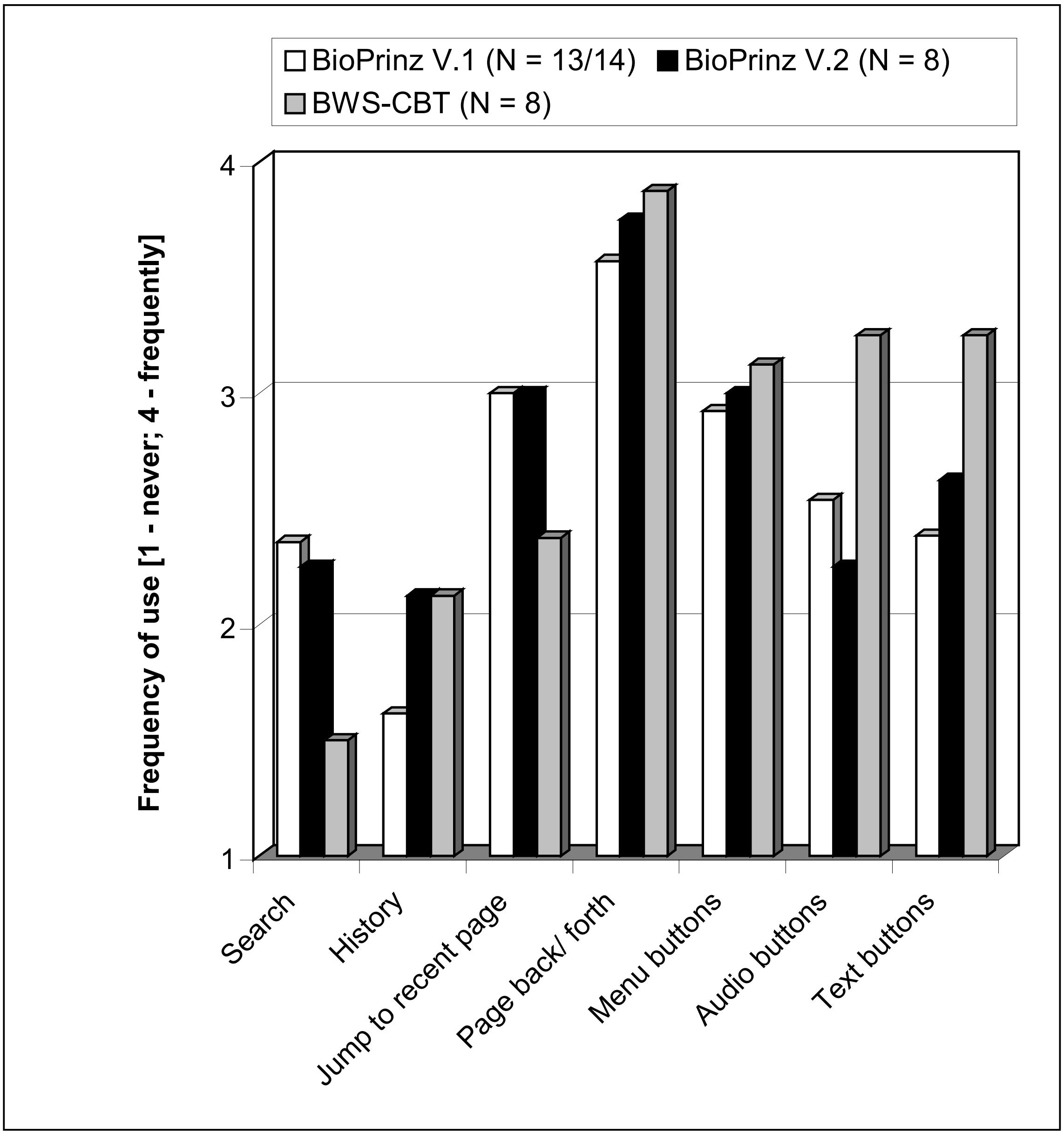

Figure 2. Frequency of use of different navigation options

A preference of the subjects for linear navigation was clearly visible: The *page back/ forth* button was used most frequently.

On the other hand, specific features of the respective program could also be detected: Whereas users of the program *BioPrinz* activated the *search* and *Jump to recent page* functions more often as compared to the users of the program *BWS-CBT*, the users of *BWS-CBT* activated the *audio* and *text* buttons more often. The latter finding can be explained by the fact that the *BWS-CBT* program has much more audio and text buttons. The former result may be due to the fact, that the users of the program *BioPrinz* were exclusively students who attended the diploma course of study with special emphasis of computer science; therefore, they may be more accustomed to these functions that are typical for standard internet browsers.

Day and time of use

Because the data concerning day and time of use were very similar for the different programs, they were summarised.

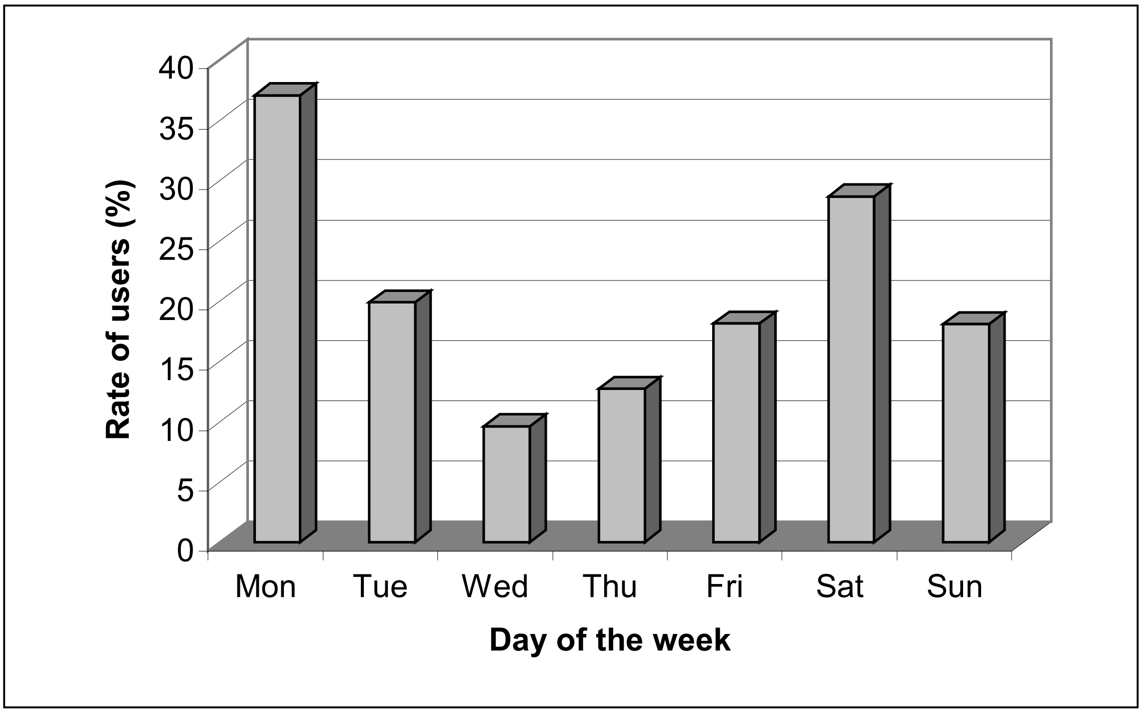

Figure 3. Preferred day of the week for using multimedia programs (*N* = 42)

Monday was clearly the preferred day of use (see Figure 3). About 37 per cent of the students used the program on this day. After a minimum on Wednesday, frequency of use gradually increased. On Saturday, about 28 per cent of the students used the program. Rate of users was comparable on Tuesday, Friday, and Sunday (19.9, 18.1, and 18.1 per cent, respectively). Overall, there was a clear preference for the beginning and the end of the week.

As can be seen in Figure 4, the rate of users increased from 9 o'clock to 20 o'clock. About 66 per cent of the users worked with the programs between 16 and 20 o'clock. One main reason for this result is the fact that the students had to attend their normal lectures and course program during the term.

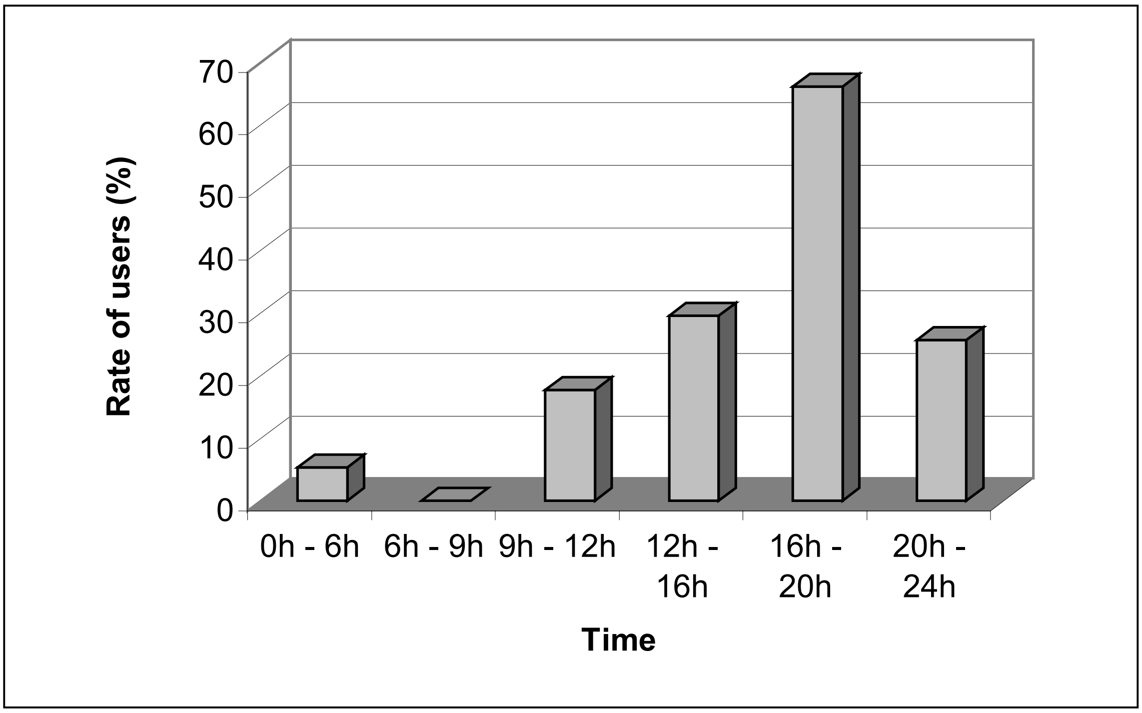

Figure 4. Preferred time for using multimedia programs (N = 42)

Formative evaluation – qualitative methods

Whereas quantitative research methods only provide very general information concerning the respective multimedia program, qualitative methods can be used to get more detailed information. This kind of information is essential for formative evaluation in order to improve the program. In this section, the application of qualitative methods for the formative evaluation of the program *BioPrinz* is demonstrated.

Thinking aloud

During the first evaluation cycle of the program *BioPrinz*, the sample of 12 students were asked to think aloud when working with the program (for details, see Walter, 2002). The students had to work on the chapter *Coordination of partial momenta* for about 20 minutes. During this session, the students were encouraged to tell everything that came to their mind concerning orientation, navigation, and screen design. The statements were written down for later analysis. Statements were categorised as "positive", if the students praised the respective feature of the program. Statements were categorised as "negative", if the students criticised the feature or suggested possible improvements.

Qualitative content analysis, i.e., summary technique (Mayring, 1993), revealed the following categories:

- *Orientation*
  Eleven students gave positive comments concerning title page, menu, glossary, and screen design. Only two negative comments could be found.
- *Navigation*
  Concerning navigation, five students gave mainly positive comments, whereas four comments were predominantly negative. The negative comments focused on the links to the glossary (8 students) and the video control (3 students).
- *Contents*
  Ten students gave positive comments concerning the contents. In general, all parts of the program were clear and understandable, particularly selected animations (video sequence of the high jump and javelin throw). Negative comments focused on more help needed in case of comprehension problems (e.g., when working at the exercises or the quiz).

- *Formal aspects*
  Eight students gave positive comments concerning this category. Only two negative comments were found, i.e., missing tool-tips and visibility of one video start button.
- *Meta-cognitions*
  All the comments concerning meta-cognitions were positive. Examples, quiz, tasks, and design were considered positive for deliberate learning, motivation, and attention.

Therefore, from the analysis of thinking aloud, very concrete aspects were derived that had to be improved.

Qualitative Interviews

During both evaluation cycles of the program *BioPrinz*, students were interviewed based on a specific scheme: Concerning the first version, the sample of 12 students were asked for comments on help functions, orientation, navigation, screen design, colour application, navigation bar, and missing navigation functions. The interviews took place after having worked with the program for about 20 minutes.

Statements concerning the different categories were predominantly positive:

- Help functions were considered sufficient and self-descriptive (11 students).
- Orientation was good (10 students); the students applied different means in order to maintain orientation, e.g., right mouse button, overview, chapter index, and menu. One student criticised that the program contained too many sections.
- Navigation was simple and unequivocal (all students).
- Screen design was considered comfortable, not too colourful, and well-designed (all students).
- Eleven students gave positive statements concerning the application of colour. One student stated that the background was too dark.
- The navigation bar was clear and self-descriptive (9 students). Two negative statements pertained to missing tool-tips and the difficult discrimination of two very similar buttons.
- Eleven students did not miss any navigation function. One student missed a print function.

After the first revision, a sample of 7 students were interviewed. After they had worked with the program for about 20 minutes, the students were asked for comments on the most positive and negative features of the program. The answers were written down for further analysis. Furthermore, qualitative statements were also derived from the open items of the questionnaire *Isometrics*^{L}. Table 2 shows the results.

Overall, positive and negative statements are nearly balanced (18 positive versus 16 negative statements).

Exclusively positive statements pertain to the interactivity and usability of the program. The students praise the interactive features of the program (e.g., tasks, questions, and quiz), and they state that the program is a useful and motivating supplement of the course.

Table 2. Results of the qualitative analysis of the interviews with users of the program *BioPrinz V.2* (N = 7)

Category	**Statement**		**Sum (rows)**
	Positive	**Negative**	
Content	1	4	**5**
Presentation	6	6	**12**
Navigation	4	2	**6**
Function	0	2	**2**
Interactivity	5	0	**5**
Application/ use	2	0	**2**
Rest	0	2	**2**
Sum (columns)	**18**	**16**	**34**

Concerning content, the reference list was praised, whereas criticism focused on structure and variety of topics, and quiz support. If they did not know the answer, the students wanted more support.
The presentational structure was on the one hand praised, but also criticised, e.g., the missing adaptability of frame size, the design, and the dominance of text.
Concerning navigation, positive statements pertained to the numerous navigation functions. Criticism focused on availability of the main menu and the links to the references.
The students missed two functions, i.e., automatic end of the simulation and a copy function for selected contents.
One further statement deals with the great effort for a comparably small section of biomechanics, and one student recommended to put the learning program on the www, using HTML and Java.
The students rarely took the opportunity to fill the open items of questionnaire *Isometrics*^{L}. The respective statements of the students pertain to the categories content, presentation, navigation, function, and learning. They confirm the statements of the qualitative interviews. Again, positive and negative statements are nearly balanced.
Overall, the qualitative analysis of the second version shows that the problems with the first version have been removed, but new problems have appeared. These problems are predominantly due to the change of structure.

Conclusions

In this contribution, the various methods of formative evaluation have been introduced. Multimedia programs can be evaluated by experts or users. Verbal, written, or behavioural data can be acquired.
Furthermore, the application of formative evaluation to the development of three multimedia learning programs has been demonstrated.
Application of comparably formal instruments, i.e., standardised questionnaires, revealed interesting information concerning general features and the use of the programs. However, this information is too general to be useful for the concrete improvement of the programs.
Application of qualitative methods, i.e., qualitative interviews and thinking aloud, and open items of the questionnaires, revealed more detailed and concrete information in order to improve the programs. Many important statements of the students concerning content, form, design, navigation, function, meta-cognitions, application, and learning were recorded that are a valuable and precise source of information for improving the programs.
Therefore, reluctance to perform formative evaluations should be replaced by the deliberate application of proper methods, particularly qualitative methods.

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e-Learning Experiments – the software RACE and the general design

Ulrike Rockmann, Stefan Thielke & Miriam Seyda

Summary

The article introduces to the hypermedia learning-software RACE. RACE was developed within the framework of the research project “New Learning Technologies” (1994-2002) in order to carry out e-learning experiments (supported by the German Federal Institute for Sport Science BISp VF 0407/13/01/2001). Additionally, the general basic research design is described. All investigations that used RACE as software, were based on this design. The specific research questions, special design variations, and results are presented in detail in the articles by ROCKMANN, THIELKE & SEYDA in this journal.

Intention of the research project

Thousands of people – teachers, researches, students, and politicians – share the powerful vision that e-learning is “something good”. Different people have this opinion for different reasons. Among other things, financial and infrastructural arguments as well as the chance for the integration of disadvantaged persons can be mentioned. From the psychological viewpoint, the content-related and learner-related aspects interest us in particular. Therefore, the experiments which have been carried out since 1995, focus on

- the technology-dependent new possibilities to process and present learning contents as well as the consequences for the learning process and the learning effects and
- the experience that the subjects need in order to be able to use the new learning medium type maximally effectively.

Definition of the term: e-learning-product

The research activities aim, among other things, to make some statements about the design of e-learning-products (eLp). Therefore, first of all, it must be specified what is supposed to be meant by the term *e-learning-product*.

1. eL-products require access to a computer.
2. Because eL-products are learning media, psychological, pedagogic and didactic aspects must be considered for their design and the implementation. eL-products make more or less use of features that are available through hard- and software technology, like interactivity, adaptability, flexibility, etc.
3. eL-products are software, thus many international and national laws, standards and rules must be fulfilled, such as ISO 9241, employee laws, safety regulations for the protection of personal data etc. (BIERHAHN, 2002; ROCKMANN, 2002).
4. eL-products can be used online and/or offline, thus the term also includes the classical CBT products.

5. eL-products can have very different sizes. Isolated from the whole context it is hardly possible to determine what a smallest reasonable learning unit is. SCORM[1] defines so-called sharable content objects (SCO). These objects have a certain compactness and completeness, and can be combined with other SCOs into units, lessons and courses. In our context, the smallest unit declared as independent is classified as an eL-product.

The general research line

In the field of learning media research two fundamental approaches can be identified: the inter-media and the intra-media approach. The intra-media approach is concerned with questions of how the technical potentials of a medium should be used, so that the learners benefit optimally. In the case of video instruction, for instance, it can be examined how to use the features zoom, presentation speed, and perspective alternation.

The inter-media approach (synonym: cross-media approach) compares the learning effects that occur through the use of media based on different technology. On account of the different technology, the media transport different information to the learner. It is, for example, a difference when you see a video that shows a movement or when you read a text that describes the movement. Therefore a comparison of the learning effects only makes sense, if the information that is submitted to the learner by each medium is equivalent with regard to the learning tests. In other words, each of the media must provide all the information needed for the successful completion of the learning test.
The findings of both approaches are important for the eL-research and can be used for the design of the products. But the eL-research is methodologically confronted with a variable situation caused by computer technology. If the effectiveness of two videos is compared, the two videos always remain the same for all observers. This is different with eL-products. If the product allows the user to vary parameters, like for instance the content sequence, than the product does not stay constant. This means that every learner generates an own variation of the product – a process that is definitely desired in the face of the demand for flexible adaptation to user needs.
Strictly speaking, this means that in the case of eL-products the learning effects of n-variations of one product are compared with the effects of m-variations of the other product. This circumstance and the fact that the products themselves are designed as multi/hypermedia applications underline that the intra-media approach should not be assigned to the comparison of two eL-products. Consequently, the information equivalence is a necessary precondition for the comparison of eL-products.
Additionally, for valid interpretation of the learning effects, it is necessary to record what parts of the learning material were used by the subjects. Otherwise it could happen that some subjects do not choose special topics and fail the test. This failure has to be interpreted in another way as the failure of subjects who worked on these topics during the learning session.

RACE – learning regatta sailing

RACE is a hypermedia software that is constructed for learning facts about the rules and tactical aspects of regatta sailing and applying them in special situations. The hypermedia software is developed with Macromedia Director 4.0-8.5.

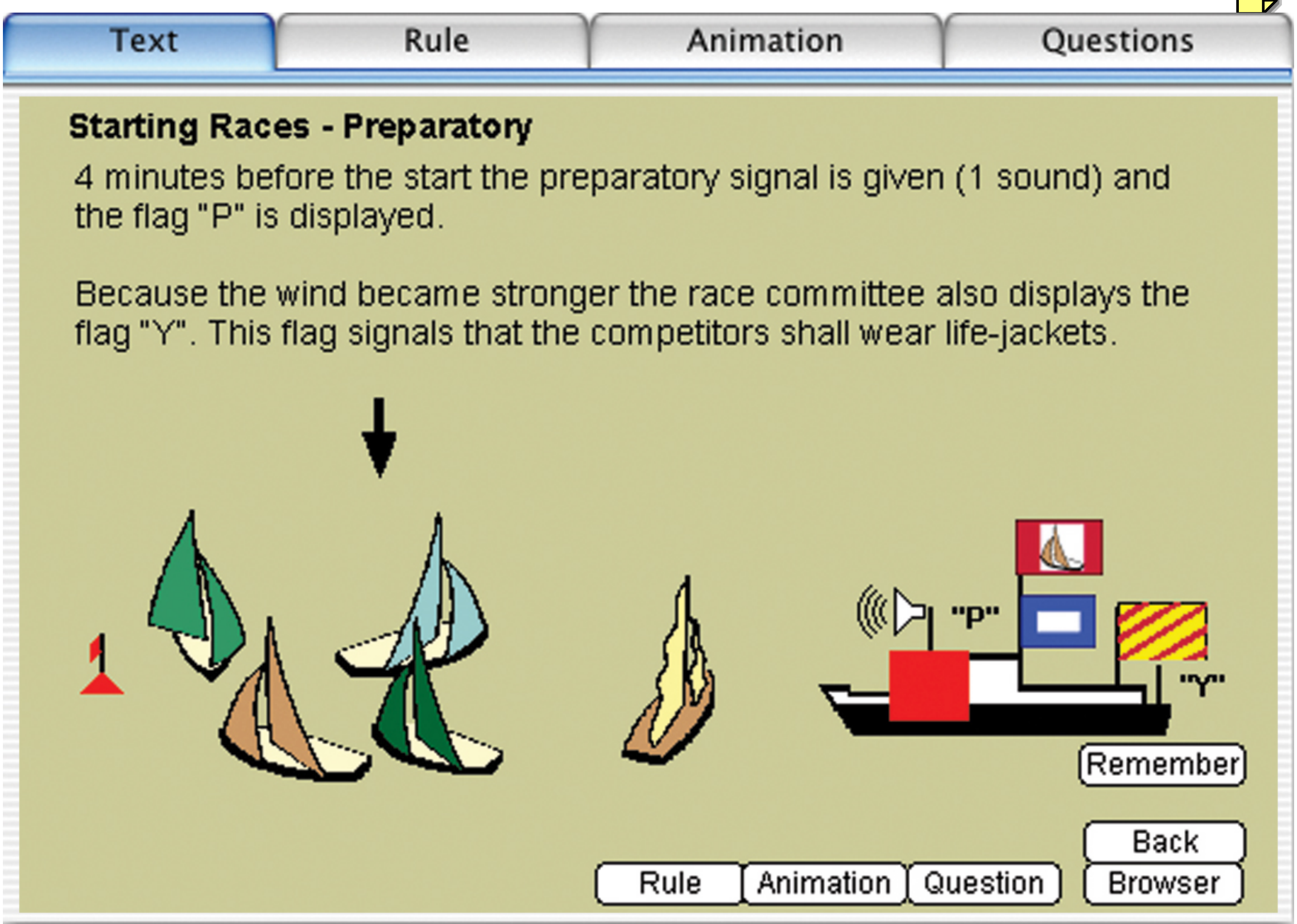
[1] SCORM – sharable content object reference model – is a product of the U.S. Government's initiative in Advanced Distributed Learning (ADL).

Since the intention is that the learners should use RACE in an individual manner and adapt it to their needs, the free navigation version of RACE is implemented with as little structure and as few guiding elements as possible. By doing this we wanted to exclude, so far as possible, the possibility that the structure of RACE inducts a special form of use and prevents the users from adapting individually (see pilot study ROCKMANN & BUTZ, 1997). The attempt was made to avoid all key stimuli that subjects learned through the use other media, especially the textbook. Therefore, for instance, no table of contents is available.

Figure 1: Menu bar

The menu bar (figure 1) allows the users the normal file operations like saving the user data, opening and closing the pool-browser-windows, generating listings, choosing the navigation mode and the level of complexity, printing, generating statistics concerning the use of the program and the test results.
The content is accessible through four information equivalent pools. That means that the subjects can access all information needed to answer all test questions even if they only use one of the pools. The major theoretical idea behind this design is that the program should support different coding preferences of the learner. Apart from regular texts (original racing rules of sailing 1999-2002) the user can refer to explanatory texts with pictures (see index card *text-picture*), animations with spoken text and exercises (see index card *question*). The pools are linked by hotlinks, which offer the possibility of a quick and thematically orientated change of windows (text-picture card: buttons rule, animation button). The content of the pools is accessible via the browser windows. The user can generate browser lists with regard to certain thematic aspects or use the full text search.

The text-picture cards are constructed taking the semantic discrepancy hypothesis (BOCK 1983) into account. This hypothesis postulates that the usage of two coding forms – text and picture – only makes sense if the users can extract information out of pictures that they can not extract out of the text and the other way around. The text of the index card *text* says something about the flag "P" und "Y". The picture shows in addition how these flags look.



The index card *question* shows a typical question card. The multiple choice format was chosen since an analysis of research findings showed that the format is better than its reputation (ROCKMANN, 1998). Some design aspects have to be taken into account, for instance there should be more than 3 answer alternatives, an answer alternative should not be the direct negation of another, etc.

The MC-format is attractive since it offers the possibility of immediate feedback to the learners by the software. The two buttons – correction and feedback – are displayed immediately when the subject marks an answer alternative. The button *correction* only provides the information whether or not the selected answer is correct. The *feedback* button displays check marks placed at the correct answers and crosses at the wrong ones. Additionally, a hint is shown, to offer the chance that the subjects can verify the considerations that led to their decision.

The same questions are also used to measure the learning effects (MC-tests). For the tests the answer alternatives are randomized to avoid answering based on the visual recognition of a marking pattern.

In the protocol file all user interactions with RACE are saved. The mouse moves, the clicks on buttons, the selection of answer alternatives etc. are written with the current time into the file. These data are used to describe learner performance.

If you want to take a closer look at RACE, please start the video (RACE is only available in German language, interrupt the video with *ESCAPE*). Show Video
Besides the free navigation version of RACE, a site map version was implemented. This version has no menu bar (figure 1). The site map presents the topics and topic-specific cards that are available.
The third RACE version is a printed version. No computer is needed. The cards are sorted by pools and are presented to the learners in card index boxes. All three versions are information equivalent with regard to the learning tests.

General procedure, subjects and data

Procedure: All experiments done with RACE are based on the same general procedure. The subjects had to come to the laboratory two times. The first session lasted about 3 hours, the second one about 45 minutes. The experiment started with general instructions and a questionnaire that asked for the demographical data. Then a demo version of RACE was presented and if necessary, questions concerning the software and the whole procedure were answered.

In a next step, the previous knowledge concerning the topic of regatta sailing was measured through the first multiple choice test (pretest: 33 questions). That was followed by the acquisition phase. The subjects were asked to work 60 minutes with RACE in any way they wanted. Immediately after the end of the acquisition phase the subjects had to answer the 33 multiple choice questions again (MC acquisition test).
Additionally they had to do a test under time pressure (TP acquisition test). The system presented 2 x 19 questions to the subjects – like “Is boat A or B right?” In a dynamic form a typical racing situation was shown, the movement of the boats stopped and the subjects had 3 seconds to decide whether boat A or boat B was performing right. To reduce the probability of guessing the right answer, the same situation was presented two times and only scored correct, if the subject answered both times correctly. After 4 days the subjects had to do the MC- and TP-test again (MC- and TP-retention test).

Subjects: In our experiments lasting from 1995 to 2001 23 racing experts (coaches and athletes) and 54 novices (with sailing but no racing experience) were examined.

Data: The collected data could be assigned to the four categories questionnaire, performance, interview, and test data (table 1).

Table 1. Data collected during the experiments 1995-2001

Categories	**Further information**	**Novices**		**Experts**
		n=32	n=22	n=23
Questionnaire Data				
Demographic data	age, sex, PC competence, regatta sailing expertise, e-Learning experiences, etc.	X	X	X
Learning strategy data	based on the questionnaires LIST and KSI[2]	X		X
Current motivation	State measure based on the questionnaire FAM[3]		X	
Performance Data				
Protocol file	Written through RACE, all interactions with the software (Rockmann & Thielke 2000)	X	X	X
Computer screen	Computer screen captured on video tape during the acquisition phase (used for self confrontation interview)	X	X	
Verbal statements	Recorded spontaneous statements during the acquisition phase	X	X	
Interview Data				
Standardized	**2 standardized interviews (3 questions) in the middle of the acquisition phase and at the end**	X		
Free	self confrontation interview	X		
Learning Data				
MC-Test	3 multiple choice tests (pretest, acquisition, retention test; 33 MC questions)	X	X	X
TP-Test	2 tests under time pressure (2 x 19 dynamic situations, randomized)	X	X	X
Free text	free text answer (about one page): the subjects had to write down all aspects they classify as very important topics	X		

Learning measures

Scoring: Every correctly answered multiple choice question was scored with one point (maximum 33 points = 100%). Every TP-question was presented two times. It was scored with one point, if both answers are correct, in every other case with 0 points (maximum 19 points = 100%).

Previous knowledge: Every MC-question that was answered correctly in every MC-test (pretest, acquisition test, retention test), was classified as previous knowledge. The TP-questions were not asked in the pretest because they only handled regatta specific knowledge. Therefore there was no previous TP-knowledge measure available.

Acquisition and Retention: Depending on the hypothesis to be proven, different measurements were used for the statistical analysis: the percentage of the

- current knowledge = correctly solved questions (MC%, TP%)

[2] LIST = Questionnaire developed by von WILD et al. 1992; KSI by BAUMERT 1993
[3] FAM = Questionnaire developed by RHEINBERG ET AL. 2001

- increase of knowledge = correctly solved questions minus previous knowledge (MC%I)
- stable knowledge = questions that were solved correctly in both learning tests (acquisition and retention, MC%S, TP%S)
- stable increase of knowledge = questions that were solved correctly in both learning tests (acquisition and retention) minus previous knowledge (MC%I_S)

Furthermore, several performance measures were calculated, for instance the time the subjects spend working with the four pools, the use of links, the navigation paths, the switching between pools, the number of cards used etc. Since these measures are very specifically linked to the hypothesis, the detailed discussion can be found in the articles that present the results.

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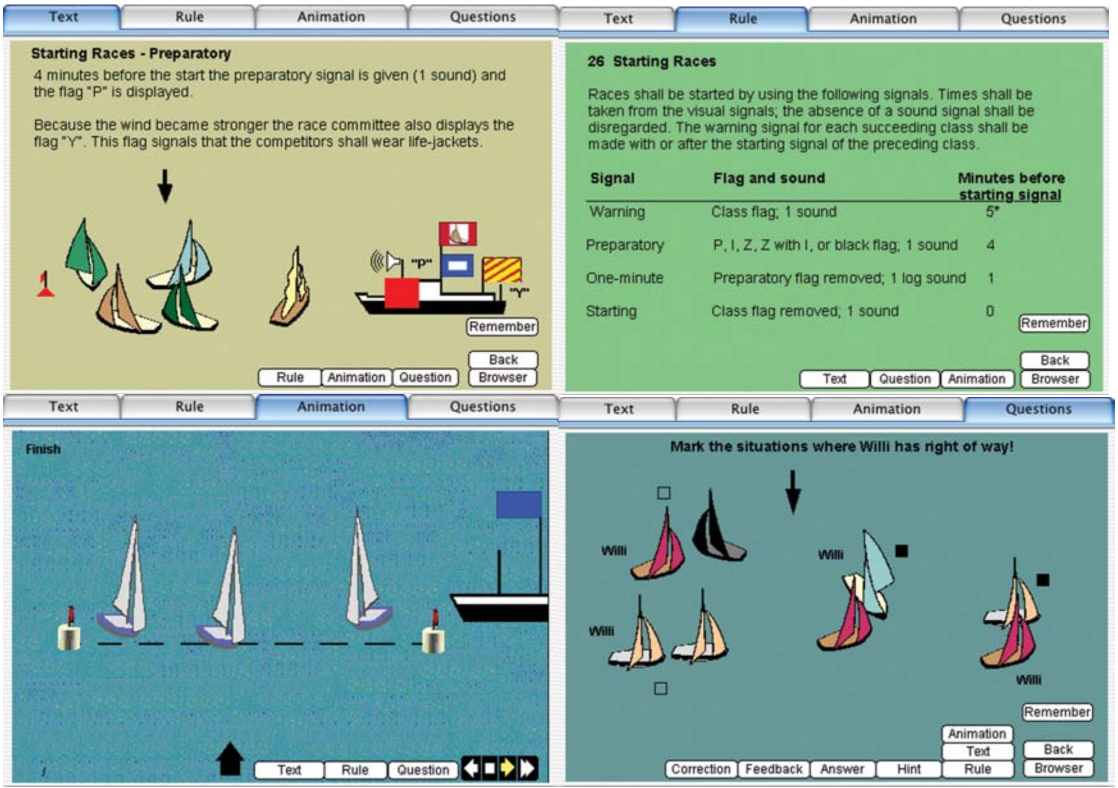

Text
Rule
Animation
Questions
Starting Races - Preparatory
4 minutes before the start the preparatory signal is given (1 sound) and the flag "P" is displayed.
Because the wind became stronger the race committee also displays the flag "Y". This flag signals that the competitors shall wear life-jackets.
"P"
"Y"
Remember
Back
Rule
Animation
Question
Browser
26 Starting Races
Races shall be started by using the following signals. Times shall be taken from the visual signals; the absence of a sound signal shall be disregarded. The warning signal for each succeeding class shall be made with or after the starting signal of the preceding class.
Signal
Flag and sound
Minutes before starting signal
Warning
Class flag; 1 sound
5*
Preparatory
P, I, Z, Z with I, or black flag; 1 sound
4
One-minute
Preparatory flag removed; 1 log sound
1
Starting
Class flag removed; 1 sound
0
Remember
Back
Text
Question
Animation
Browser
Finish
Text
Rule
Question
Mark the situations where Willi has right of way!
Willi
Willi
Willi
Willi
Remember
Animation
Text
Back
Correction
Feedback
Answer
Hint
Rule
Browser

Analysis of the learning results of experts and novices using the hypermedia software RACE

Ulrike Rockmann, Stefan Thielke & Miriam Seyda

Summary

23 racing experts (coaches and athletes) and 54 novices (with sailing but no racing experience) were examined. The sailing knowledge of the subjects was tested before they started to learn with the hypermedia program RACE (pre-test), immediately after (acquisition) and four days after (retention) the learning session. Each test was made up of two parts: a multiple choice test and a test under time pressure (TP-test; ROCKMANN, THIELKE & SEYDA 2003). The results show that experts and novices were able to learn with the hypermedia software. They used RACE in different ways and showed different learning effects[1].

Introduction

In previous publications the learning results of racing novices using the free navigation version of the hypermedia software RACE were discussed (ROCKMANN & THIELKE 2000a, b, 2002). This article now focuses on three major aspects – the effects of the different media types, computer and racing competence on the learning results.
The relevance of content-related competence for the use of e-Learning products is discussed in many articles. Main statements are that experts are not so likely to get "lost in hyperspace" (CONKLIN 1987; GAY & MAZUR 1991) and novices need more guidance, in order to reach good learning results. Therefore we want to analyze whether or not experts and novices are able to learn with RACE free navigation and whether or not the learning achievements of the novices depend on the amount of guidance (ROCKMANN et al. 2003, Chap. 4) available. Furthermore a close look is taken at the consequences of a high PC competence.

Special procedure, subjects and data

The subjects participated in the standard procedure as described in ROCKMANN et al. (2003 in this journal). The subjects were randomly assigned into two groups depending on their regatta sailing competence (see table 1). The experts were members of the German young talents sailing team. The novices had no racing experience, but held a sailing license or had equivalent knowledge.

For some analyses the subjects were classified into two groups with regard to their PC competence. Based on their answers in the demographic questionnaire, they were assigned to the category *high-PC-competence (PC-Experts)* when they had experiences as programmers, database or system administrators, website or multimedia developers etc. Subjects that had only used standard office software, like text processing, spreadsheets, email, Internet browsers, were assigned to the category *low-PC-competence (PC-Novices)*.
The factor *media type* had three levels, the software RACE free navigation, RACE site map and the paper version of RACE. All three versions are information equivalent with regard to the learning tests.

[1] This project was financed by the German Federal Institute of Sport Science (VF 0407/13/01/2001).

Table 1: Number of subjects and experimental grouping

	Learning media			
Sailing and PC competence	RACE-free navigation	RACE-site map	Paper version	Σ
Racing-Novices	31	15	8	54
PC-Experts	12	6	4	22
PC-Novices	19	9	4	32
Racing-Experts	23			23
PC-Experts	9			9
PC-Novices	14			14

Selected Results

Result 1: All subjects learned with the computer versions of RACE. Racing novices could benefit from their PC competence.

The figures 1-4 illustrate the learning effects of all subjects who used a RACE-PC version (see also table 2). The solid green line in figure 1 shows the average of the results of all novices, the blue line of all experts in the three MC-tests.
Figure 1 shows the means (% of correct answers) that the subjects achieved in the MC-pretest, acquisition and retention tests. The statistical analysis revealed that the factor *racing competence* was significant, while the experts (N = 23) were able to achieve better results than the novices (RACE free navigation + site map: N = 46) in all three tests.
Follow-up analysis reveals a significant difference between all three tests for the novices. By contrast, the results of the experts in the acquisition and retention test do not differ. This finding does not mean that no forgetting occurred in the expert group. The percentage of forgotten questions (8%) and the percentage of newly answered questions (6%) nearly equaled out. The same effect occurred for the novices, whereas the difference between forgetting (14%) and reminiscence (9.5%) was much bigger and therefore the forgetting dominated.

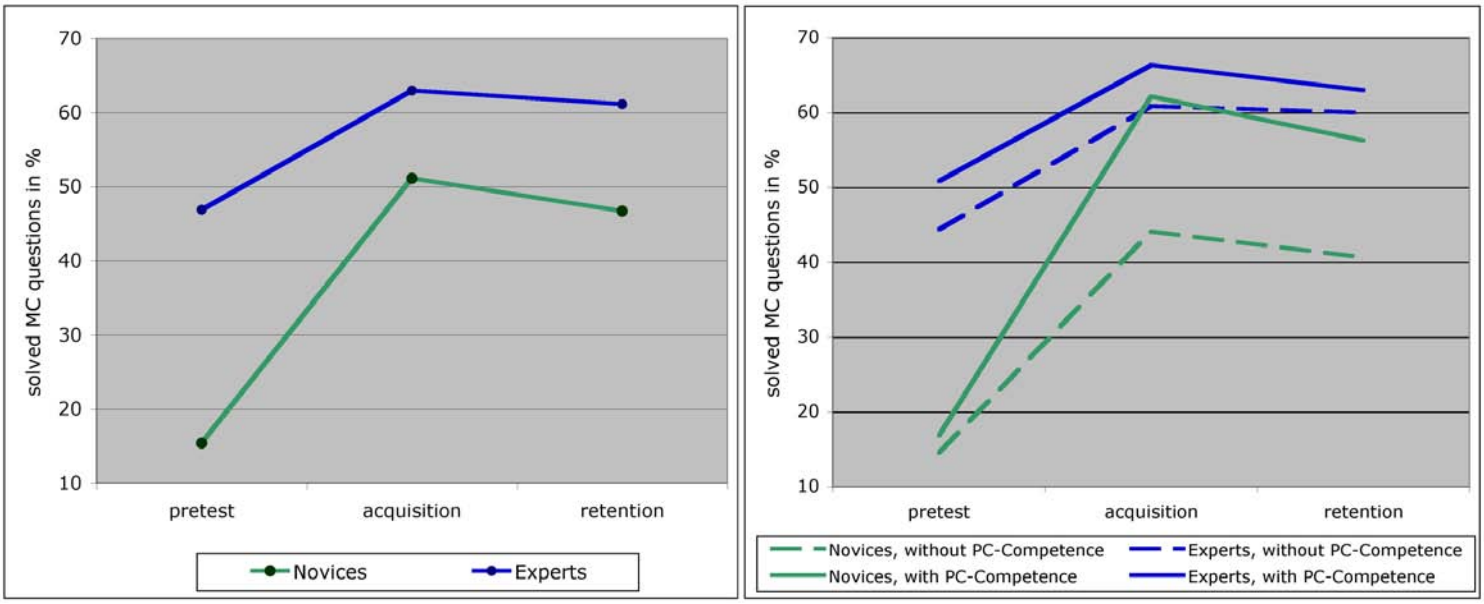


Figure 1./2. (top): MC% = correctly solved MC-questions in %

The significant interaction *time of measurement x racing x PC competence* underlines that the novices were able to benefit from their *PC competence* during the acquisition phase and were able to achieve acquisition and retention results that are comparable with those of the experts (figure 2; table 2, left).

Table 2. MANOVA results: RACE free navigation, experts vs. novices

	MC% = % of MC-questions answered correctly				*MC%I = MC% - previous knowledge*			
	df	F	p	η^2	df	F	p	η^2
Time of measurement	2	161.164	0.000	0.713	1	7.677	0.007	0.107
Time x Racing competence	2	26.183	0.000	0.287	1	1.088	0.301	0.017
Time x PC competence	2	2.701	0.071	0.040	1	1.008	0.319	0.016
Time x Racing x PC competence	2	4.456	0.013	0.064	1	0.000	0.987	0.000
Error (Time)	130				64			
Racing competence	1	30.949	0.000	0.323	1	5.937	0.018	0.085
PC competence	1	6.546	0.013	0.091	1	35.654	0.000	0.358
Racing x PC competence	1	1.116	0.295	0.017	1	11.003	0.002	0.147
Error	65				64			

Figures 3 and 4 illustrate the increase of knowledge (MC%I). The increase of knowledge for the novices was greater than the increase for the experts (figure 3, table 2, right). Again, the novices were able to benefit from their PC competence. The increase of the experts did not depend on their PC-competence.

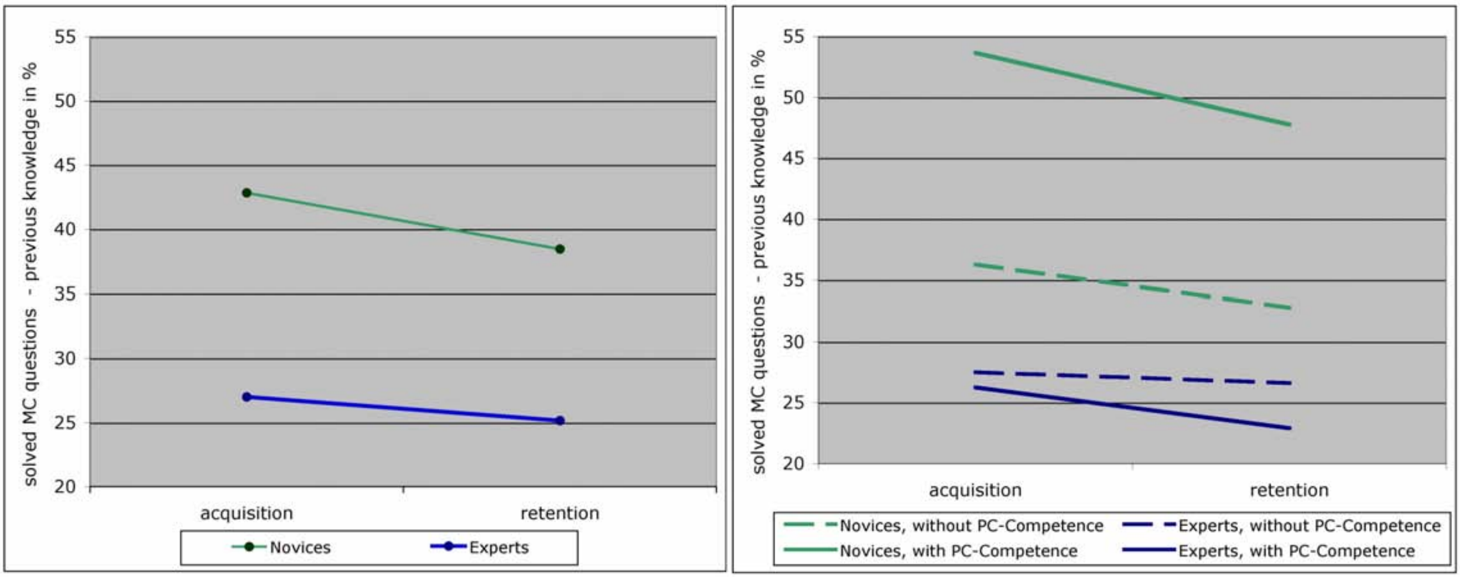


Figure 3./4. MC%I = correctly solved MC-questions in % minus the previous knowledge

A comparison of the time the subjects needed for organizing themselves in the learning surrounding showed no differences between the novices with and without PC competence ($t = 0.216$; $df = 44$; $p = 0.830$). Therefore the benefit is not related with the time spent for working with the content.

A positive correlation between the number of questions used in the acquisition phase and the increase of knowledge recorded in the acquisition test can only be shown for the racing novices (Pearson: $r = 0.44$; $n = 45$; $p = 0.003$). This effect disappears in the retention test. When the novices are divided up into subgroups with and without PC competence, with $r = 0.629$ ($n = 28$; $p < 0.000$) for the acquisition test and $r = 0.473$ ($n = 28$; $p = 0.011$) for the

retention test, only the subjects without PC competence benefit from working with the questions during the learning phase. Further, the subgroups do not differ concerning the number of questions they used (t = -0.420; df = 44; p = 0.677) and the time they spent in the question pool (t = -1.549; df = 44; p = 0.129).
The 33 MC-questions could be classified in three complexity levels (BLOOM et al. 1957) – the knowledge of terminology (B1), facts, categories etc, comprehension (B2) and application (B3). A (2 x 3 x 2 x 2) MANOVA taking the factors time of measurement, question complexity, PC and racing competence into account reveals among other things that the factor complexity is significant. Experts and novices achieved the greatest increase in learning on complexity level B1. Again, the factor PC competence was relevant for the scores of the novices on all complexity levels (figure 5). Experts achieved the better scores on all complexity levels, especially at the most complex level B3 (figure 6).

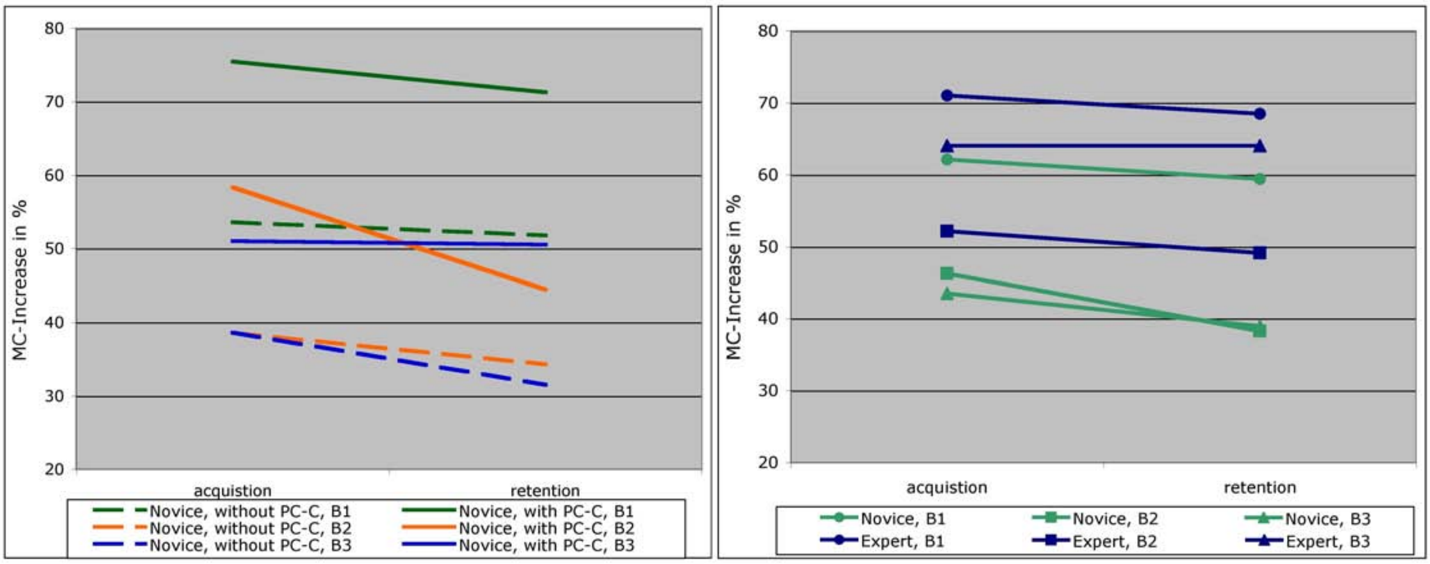


Figure 5./6. MC%I results: novices and experts categorized by complexity

Result 2: No lost in hyperspace effect: The racing novices achieved the same learning results whether they learned with RACE free navigation or with RACE sitemap.

The figures 7 and 8 illustrate that the novices (N = 46) were able to achieve the same performance and learning results independent from the RACE version they used. Again, the novices benefitted from their *PC competence,* as the MC% results and the MC%-increase show. No differences in the scores MC% and MC%I could be found with regard to question complexity.
Under the precondition that the content does not determine only one meaningful working path and the didactic concept does not have aims like generating cognitive conflicts, cognitive overhead or disorientation (MAYES ET AL. 1990), it is not detrimental for learning if the subjects have the opportunity to interactively create their own variation of the medium. Even if the subjects have no content-related expertise and no computer expertise they are able to achieve stable learning results.

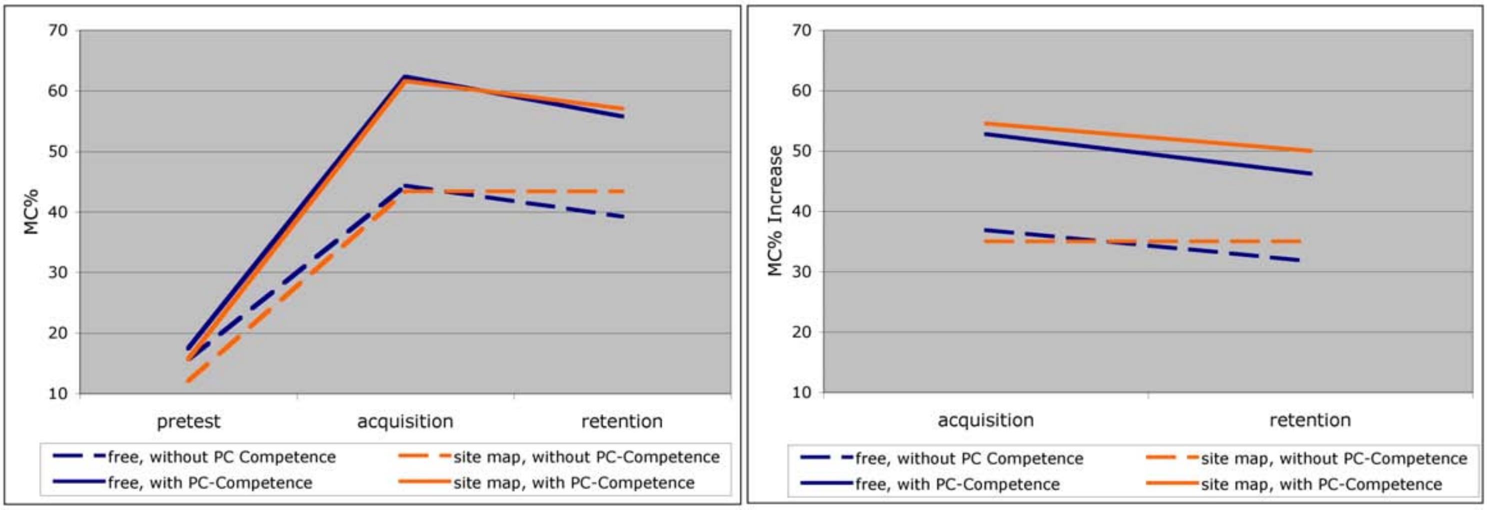


Figure 7./8. MC% and MC%I results: novices, site map and free navigation

Table 3: MANOVA results: Novices, RACE free navigation vs. site map

	MC% - Novices				*MC%I - Novices*			
	df	F	p	η^2	df	F	p	η^2
Time of measurement	2	186.494	0.000	0.816	1	5.558	0.023	0.119
Time x PC version	2	0.811	0.448	0.019	1	1.211	0.278	0.029
Time x PC competence	2	7.286	0.001	0.148	1	0.714	0.403	0.017
Time x PC competence x PC version	2	0.154	0.858	0.004	1	0.170	0.683	0.004
Error (Time)	84				41			
PC version	1	0.006	0.937	0.000	1	0.386	0.538	0.009
PC competence	1	15.142	0.000	0.265	1	18.630	0.000	0.312
PC competence x PC version	1	0.003	0.955	0.000	1	0.190	0.665	0.005
Error	42				41			

Result 3: The use of PC-based learning media has no detrimental effects on learning for novices that have no PC competence.

Since the test results of the subjects working with the PC versions of RACE do not differ, they are grouped together for this analysis. In the pretest no differences between the PC (N = 46) and paper group (N = 8) could be found. Figure 9 illustrates the trend for a media-type effect in acquisition and retention results (table 4). The interaction *time of measurement x media type* is significant for MC% caused by the differences in the results of the acquisition and retention test. The differences achieve significance (p = 0.045) if only the acquisition and retention tests are taken into account for the analysis. Figure 10 shows in detail that the novices with PC competence are responsible for the better results of the PC group.
The learning results of the subjects that worked with the paper version do not depend on their PC competence (figure 10). Subjects that worked with the PC versions who had no PC competence had no disadvantages with regard to the paper group. A greater increase in knowledge (MC%I; figure 11) could be achieved with the PC-versions, but only under the precondition of having PC competence.

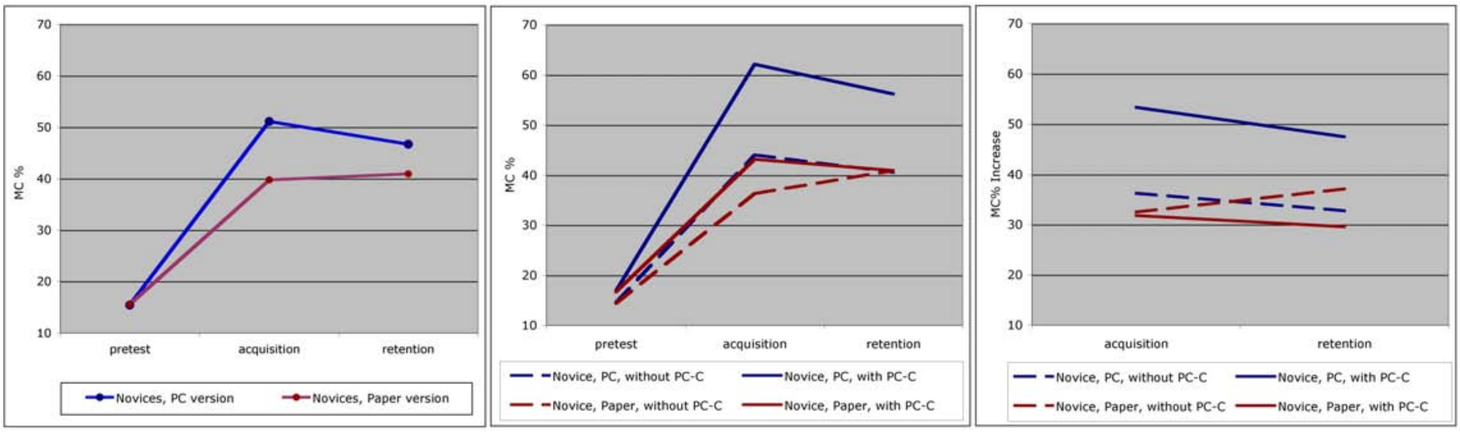


Figure 9./10./11. MC% and MC%I grouped by learning media (pc/paper) and PC competence

Table 4: MANOVA results: Novices, RACE-PC versions vs. paper version

	MC% - Novices				*MC%I - Novices*			
	df	F	p	η^2	df	F	p	η^2
Time of measurement	2	92.913	0.000	0.650	1	0.849	0.361	0.017
Time x Media type	2	3.378	0.038	0.063	1	2.288	0.137	0.044
Time x PC competence	2	1.999	0.141	0.038	1	1.447	0.235	0.028
Time x PC competence x Media type	2	1.251	0.291	0.024	1	0.326	0.571	0.006
Error (Time)	100							
Media type	1	3.211	0.079	0.060	1	4.908	0.031	0.089
PC competence	1	3.728	0.059	0.069	1	1.792	0.187	0.035
PC competence x Media type	1	1.330	0.254	0.026	1	5.241	0.026	0.095
Error	50							

Result 4: The subjects were able to apply the learned knowledge to decision situations that have to be solved under time pressure.

Statistics revealed a significant *time of measurement* effect. For all subjects that worked with a PC version of RACE (novices: N = 46; experts: N = 23), a reminiscence effect occurred (figure 12; table 5). Again the results in the retention test are a combination of forgetting and reminiscence for both groups. The experts forgot 11% and the novices 12% of the correct answers they were able to give in the acquisition test. In the retention test the experts were able to answer 18% more questions than they could in the acquisition test, the novices 19%,

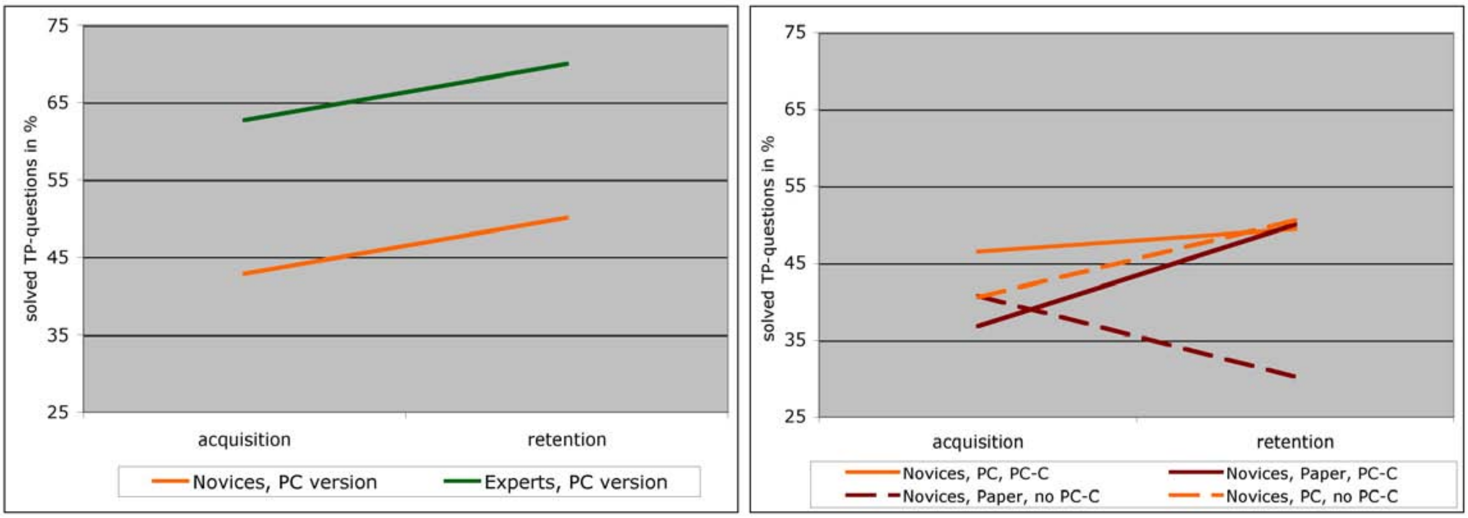


Figure 12./13. TP% = TP-questions that were answered correctly two times in each test

therefore overall better retention test results can be found.
The experts achieved better results than the novices in both tests. The results in the time pressure tests were not influenced by the factor *PC competence* (table 5). The number of MC questions the subjects worked on in the learning phase is not relevant for the TP-results. No correlation between the MC results and the TP-results can be found for either the experts or the novices.
Figure 13 illustrates the results of all novices with regard to the factor *media-type*. The subjects with no PC competence working with the paper version (No-PC-Paper) performed worse in the retention test. Follow-up analysis shows that these subjects performed especially badly in answering the questions asking for racing knowledge rather than basic sailing knowledge. This and the comparable results in the acquisition test do not support an explanation based on pure PC-handling problems.
Further analysis showed that these subjects performed especially badly in TP-questions that were asked out of the "I-perspective"[2] ($Z = -2.097$; $p = 0.036$). No other differences between the two subgroups – like time in the pools, number of questions used in the learning phase, etc. – can be found for clarification.

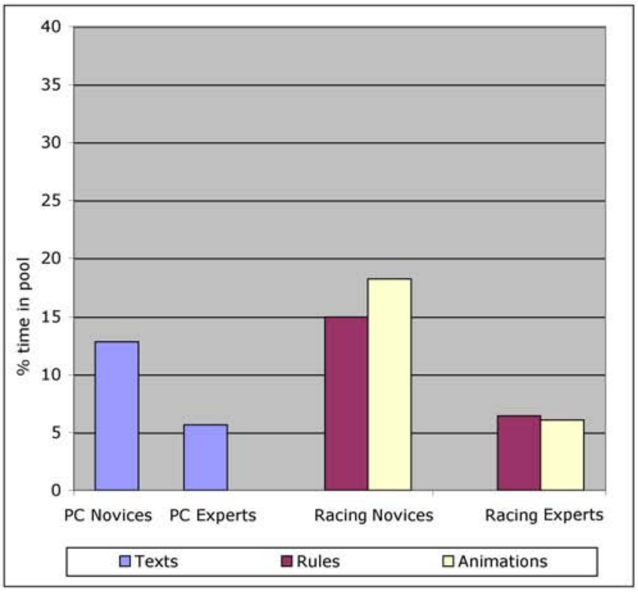
Table 5. MANOVA results: experts vs. novices; PC versions x paper

	TP% - Novices & Experts PC				*TP%I – Novices: PC/Paper*			
	df	F	p	η^2	df	F	p	η^2
Time of measurement	1	12.791	0.001	0.164	1	1.767	0.190	0.034
Time x PC competence	1	0.118	0.732	0.002	1	2.033	0.160	0.039
Time x Racing competence	1	0.115	0.736	0.002				
Time x Racing x PC competence	1	2.030	0.159	0.030				
Time x Media					1	0.771	0.384	0.015
Time x Media type x PC competence					1	0.011	0.011	0.122
Error (Time)	65				50			
PC competence	1	1.511	0.223	0.023	1	0.863	0.357	0.017
Racing competence	1	30.053	0.000	0.316				
Media type					1	1.743	0.193	0.034
PC x Racing competence	1	0.348	0.557	0.005				
PC competence x Media type					1	0.250	0.619	0.005
Error	65				50			

Result 5: The subjects used the PC versions in different ways.

The handling of the learning media could be described in several ways. Figure 14 shows the significant differences in pool use times of the novices (N = 31) and experts (N = 23) working with RACE free navigation (table 6). PC novices spent more time in the text pool than the PC experts. Racing novices spent more time working with rules and animations than the experts did.

[2] The TP-question were asked in two forms: One form was the I-perspective – „What must I do in the situation shown?“ The second was the observer-perspective – „I must judge whether or not the people in the boats act right without being directly involved“.



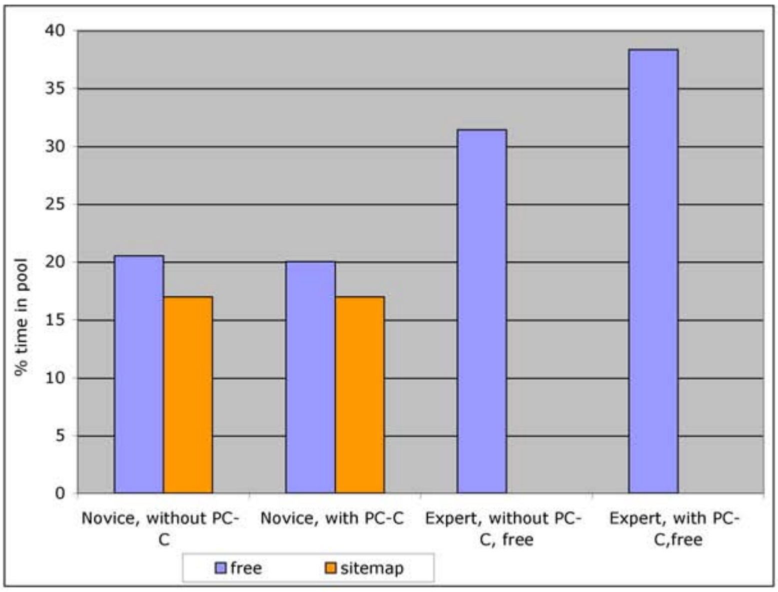


Figure 14. Time in pools; Figure 15. Organization time needed

All racing experts need significantly more time for organization than the novices (figure 15). One possible explanation is that the experts, based on their already existing racing knowledge, used more time for exploration of the software. ANOVA reveals the trend that novices using the site map version need less time for organization ($df1 = 1$; $df2 = 42$; $F = 3.923$; $p = 0.054$; $\eta^2 = 0.085$).

Table 6. Multivariate analysis

	PC competence				*Racing competence*			
	df	F	p	η^2	df	F	p	η^2
Text pool	1	7.787	0.007	0.135	1	3.734	0.059	0.069
Rule pool	1	0.195	0.661	0.004	1	14.166	0.000	0.221
Animation pool	1	1.244	0.270	0.024	1	6.200	0.016	0.110
Question pool	1	3.535	0.066	0.066	1	3.814	0.056	0.071
Time for organization	1	1.534	0.221	0.030	1	26.654	0.000	0.348
Error	50							

Concluding Remarks

In this article only some selected results could be presented. As the overview over the data collected shows (ROCKMANN ET AL. in this volume) several other aspects can be discussed. Additionally, some further analysis of the aspects discussed in this paper is needed by integrating the findings about the learning strategies as presented in THIELKE ET AL. (2003) in this volume.

Overall the statement that experiments with e-Learning products allow new insights into the learning processes seems to be adequate. But, as mentioned before, a very careful look has to been taking at the behaviour of the subjects during the learning phase to get to a reliable interpretation of the achieved learning results.

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Learning Styles and Learning Behaviour in the Hypermedia Environment RACE - Analysing Computer Log files and Questionnaire Data

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The following Paper describes an experiment which analyses in how far specific learner types, set by questionnaire, show congruent behaviour in a concrete learning situation. The a priori subdivision into surface- and deep-strategy learner types is based on established models (Schmeck, 1988; Mandl & Friedrich, 1992; Krapp, 1993). First, a group of 52 learners worked with the hypermedia programme RACE (Rockmann & Thielke, 2000b, 2000a, 2001, 2002) for one hour. Then a general questionnaire about their learning behaviour in self-regulated learning situations was given. The questionnaire data (trait measurement) and the process data from the log files (state measurement) were evaluated by cluster-analysis and compared with each other. The experiment shows that both analyses result in a two-cluster solution with clear allocation of surface- and deep-strategy variables. The congruency between these solutions amounts to approx. 70%, and a significant difference could not be determined, χ^2 (1, N = 50) = 0.581 (p = .446).The comparison of the z-transformed means for the cluster variables indicates that the analyses of the process data may be of a higher selectivity for determining these learning types. Interesting findings concerning the cluster composition can be shown when you include further descriptive variables (expert-novice status, state of training and computer experience).

Introduction: the way to the problem

This paper reports about an experiment to detect learner types on two different kinds of personal data. We also examine whether these types have an influence on learning achievement in a hypermedia environment. The experiment is part of a larger project that was finished a year ago and was supported by the German Federal Institute for Sport Science BISp VF 0407/13/01/2001 under the leadership of Prof. Dr. Ulrike Rockmann (see Rockmann, Thielke & Seyda, in this volume).

In this investigation two inquiry methods - questionnaire and process data analysis - were performed. Each supplied a different quality of raw data. A cluster analysis of that data led to a distinction of learner types. Two types were sought, a surface- and a deep-strategy learner. In this field of investigation a classical approach is the analysis of questionnaire data, interviews, or other retrospective techniques of personal self-reporting. But it's more often criticized as inadequate when considering concrete human actions, e.g. in a self-regulated learning situation. The analysis of behavioural data seems to be more suitable (Brenstein, 1996; Artelt, 2000). Using computer technology in such an investigation shows a path to an economic way of collecting and evaluating human action data. With these means we aimed to implement a classical learning experiment with the hypermedia learning environment RACE. The computer collected process data as well as a questionnaire would be used to find surface- and deep strategic learner types, and would be related to the learning outcome as well.

Theoretical background

Learner types are psychological constructions that are not directly observable. They can be defined in different theoretical dimensions. First, as a kind of disposition, style, habit or attitude, and second, on the level of implementing real learning strategies or techniques (Schmeck, 1988; Mandl & Friedrich, 1992; Krapp, 1993). The most influential concepts originate from the Metakognition research and the field of learning strategy/style research. Both lines develop different models, which try to describe and explain the relationship between strategic behaviours and the learning achievement referring to different theories like Metakognition, theory of action, cognitive psychology, information processing theory (Flavell, 1979; Brown, 1984; C. Weinstein & Mayer, 1986; C. E. Weinstein, Zimmermann & Palmer, 1988; Pressley, Borkowski & Schneider, 1989; Boekaerts, 1997). Though style and cognitive information processing concepts refer to different basic assumptions, they both contain a distinction between two contrary styles (types) or classes of behavioural techniques, which you can describe as surface- or deep-strategy. This distinction has been proved constantly empirically (K. P. Wild, Schiefele & Winteler, 1992; Artelt, 2000; Thielke, 2003).

In the classical approach strategic variables of learning were recorded using interviews and questionnaires, e.g. in Germany with translated inventories as the KSI or LIST (Heyn, Baumert & Köller, 1994; K. P. Wild & Schieferle, 1994). For the measurement of learning performance or outcome many various ways had been established (school notes, test values, expert rating etc.). It is regularly shown that learning strategy variables are not successful in predicting an influence on learning achievement. It is remarkable that factor analyses of questionnaire data often fail to reproduce the underlying theoretical structure or produce only insufficient findings (Christensen, Massey & Isaacs, 1991; Klaus Peter Wild, 2000). According to many critics, questionnaires and interviews are fit only for the measurement of dispositions or styles. The validity of the data can also be disputed (Nisbett & Wilson, 1977; Ericsson & Simon, 1980; Biggs, 1993). The outcome of a concrete learning situation depends, however, primarily on the strategic learning techniques that are really carried out while learning. To determine those requires another methodology such as a process data analysis. Such an analysis is very complex in a classical learning scenario (pencil and paper). The employment of computer-aided scenarios, like the use of a hypermedia learning environment, and the evaluation of appropriate log files can offer more possibilities.

Learning with Hypermedia

The hypermedia euphoria common at the beginning of the 90's is gone, as you can read in Negroponte's book "Being digital" (Negroponte, 1995). Whether there are other reasons for using hypermedia technology in e-learning projects or not, more and more empirical studies, as well as meta-analyses, draw a rather critical picture concerning hypertext, hypermedia or multimedia and learning achievement (Kulik & Kulik, 1987; Kulik, 1994; Hasebrook, 1995; Gerdes, 1997; Rockmann & Thielke, 2002). The belief in such forms as learning instruments is nevertheless unbroken. Constantly expanding internet technology, as well as the simplified access to this "world" help to make Hypermedia omnipresent in all areas of life, including, of course, the education sector[1]. Learning with a hypermedia environment is self-regulated learning. The use of such media requires learning strategies which have a considerabe affect on the learning outcome. Apart from some special characteristics, hypermedia learning environments show conditions which are comparable to those that are described for the

[1] This can be seen in popular slogans like "all schools must be on the internet", in calls for making the new media a required part of teaching internships, of the fact that universities are planning and developing projects like the notebook university, virtual campus, and interactive learning courses such as RACE, HYLLIS (http://134.106.184.50/RACE or http://134.106.184.50/HYLLIS) or interactive textbooks like EBUT (www.ebut.de). All of them intend a strong relationship between new media and performance.

classical self-regulated situations. Dillon and Gabbard (Dillon & Gabbard, 1998) describe these characteristics for hypermedia as follows:

- Hypermedia enables non-linear ACCESS to a vast amount of information (Nielsen, 1995),
- Users can explore information in depth on demand (Collier, 1987),
- Interaction with the instructional material can be self-paced (Barrett, 1988),
- Hypermedia is attention-capturing or engaging to use (Jonassen, 1989),
- Hypermedia is a natural form of representation with respect to the working human mind (Delany & Gilbert, 1991).

Other authors supplement this list with terms like interactivity (Issing, 1998), efficiency (Schott, 1991), adaptation (Kerres, 1998), learning control (Klauer, 1985; Chung & Reigeluth, 1992) and learning assistance (Euler, 1992; Jechle, 1998). Especially in the field of specific learning techniques (learning strategy level) important differences have to be made. A simple transfer of the well-known theoretical learning models into this new setting does not seem to be easy. Behaviour in a hypermedia learning environment is essentially navigation in the system, like browsing, searching etc.. Brenstein (1996) submitted a suggestion how this navigation can be analysed in terms of surface- and deep-strategy learner types. This concept is the basis for our investigation.

Analysing questionnaire data

To separate the subjcts into surface- and deep-strategy learners, a short scale from the FLST was used. The scale is built of items from the German learning strategy inventories KSI (Nenninger, 1992; Heyn et al., 1994) and LIST (K. P. Wild & Schieferle, 1994). The theoretical basis for these two questionnaires is the learning strategy concept of Weinstein and Mayer (C. Weinstein & Mayer, 1986) in the revision of Pintrich (Pintrich, Smith & McKearchie, 1989). The inventories sketch learning behaviors in specific learning situations. The subjects have to estimate whether the behavior is typical for them or not and mark their answer on a five-point Linkert scale.The FLST is a compounded and shortened version of the KSI and LIST. It covers 57 Items distributed on 11 subscales. The FLST test criteria were examined using an external student sample (N = 148). A factor and reliability analysis revealed the eight test items of a learner-type short scale. Five of the items relate to the deep-strategy learner type and three items relate to the surface-strategy learner type (Thielke, 2003)[2]. Within the experiment the entire questionnaire was answered, but only the eight selected items were tested by cluster analysis. We expected that persons who prefer surface-strategy techniques in self-regulated learning situations would show high values in those items of the FLST which describe surface-strategy behaviour and low values in items which describe a deep-strategy behaviour. Persons that prefer deep-strategy techniques should act the other way round. The results of the cluster analysis were expected to permit the following interpretation: The cluster analysis of the eight test items was expected to divide in two homogeneous and clearly interpretable clusters. In one of them persons rating the surface-strategy items highly and the deep-strategy items low can be summarized. The other cluster

[2] We performed a PCA with Varimax rotation because earlier findings and theoretical assumptions did not indicate a correlation between the factors to confirm the factor structure. To secure the result we also performed a PFA with oblimin rotation and a delta of zero. A replication with the experimental sample of N = 52 shows the same results. The solution yield 63.23 of total variance explained and the KMO-criteria met an accepted value with KMO=.778. The Bartlett-Test reveal a $\chi^2(28, N = 52) = 134,466$, $p < .01$. The coefficient of correlation between the factors is r = -.23. In this case the interpretation of the PCA instead of the PFA is sufferable (Kline, 1994; Kleine, 1999, p. 413). The loadings on the factors are within .499 and .738. According to Bortz (1998) the minimum loading must be higher than .4 to guarantee a meaningful interpretation. The values for reliability are satisfying or good, α (50) = .8416, for five items deep strategy and α (50) = .642, for three items surface strategy.

combine persons rating the opposite item structure. This procedure would divide the subjects into two groups of different learner types.

The theoretical task to find two clusters requires the employment of a hierarchical method. The Ward method with the square of Euclidean distance, standardisation and normalization of the values is used. Generally, there is no single solution for a cluster analysis, nor even a certainty of finding an optimal one[3] (Eckes & Roßbach, 1980; Bortz, 1988; Backhaus, Erichson, Plinke & Weiber, 2000). To transform the data they must meet the criteria of normal distribution. According to West Finch and Curran (1995) this is guaranteed if the distribution is unimodal and the inclination is smaller than two, the excess less then seven. Before using the Ward method, Backhaus et al. (2000, p. 365f) suggest a procedure to eliminate outliners with single linkage method[4]. The Dendrogramm and the elbow-criteria showing the largest increase of error square sum while changing the solution from two clusters to one cluster (*MS* = 6.265, increase = 1.44), confirm the decision for the two-cluster solution (s. Backhaus et al., 2000, p. 375). They discuss the *t*-value as a further goodness-of-fit criterium (s. Backhaus et al., 2000, p. 378). The *t*-values show whether a variable in a cluster is strongly over- or underrepresented. They can be useful finding a suitable and meaningful interpretation of the cluster solution. A positive *t*-value signals an overrepresentation. Table 1 describes the t-values of the chosen solution. A clear type-conforming separation of the variables can be shown in both clusters.

Table 1. T-Values of Clustering solution (Questionaire)

Item	t- values deep	t- values surface
Deep1 (F14)	0.752	-0.415
Deep 2 (F17)	1.563	-0.494
Deep 3 (F21)	0.723	-0.335
Deep 4 (F44)	0.748	-0.321
Deep 5 (F45)	1.332	-0.462
Surf. 1 (F15)	-0.871	0.346
Surf. 2 (F32)	-0.125	0.073
Surf. 3 (F51)	-2.121	0.308

There is no significant coefficient of correlation between the mean of both scale values, r (50) = .147 (p = .310). We performed two independent t-tests with the learner type as an independent variable of both tests and the means of scale as two different dependent variables. The result of the deep-strategy items shows a significant difference t (50) = 8.29, (d = 2.34, p<.001) in contrast to the surface-strategy items t (50) = 1.23, (d = 0.40, *power* = 0.63, p = .221). The deep-strategy items separate the persons more clearly than the surface items do. (Wiedenbeck & Züll, 2001) recommend a plot which displays the standard values of the involved item means as a line plot to assist the interpretation of the cluster solution.

[3] The exponentially increasing options of the realizable possibilities (the allocation of n objects in *k* clusters is a Stirling' number) is known as the traveller's problem or the problem of total enumeration. In addition there are two more difficulties to deal with (discrimination and dissection) (Eckes & Rossbach, 1980, p. 11).
[4] Monotonous and contracting quality of this methods will lead to a chaining cluster solution in which the outliners will finally be subsumed.

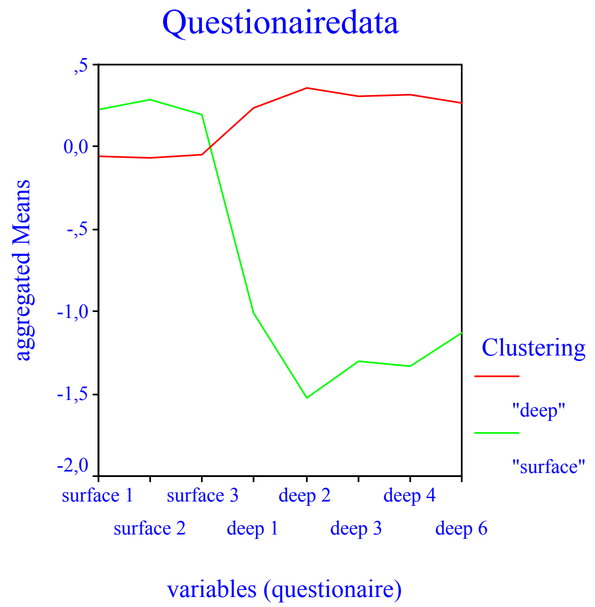


Figure 1. Standardized means (questionnaire data)

The figure 1 illustrates the clear separation of the deep-strategy variables, too. It corresponds to the results of the *t*-values. We will accept the two-cluster solution as appropriate. Assigning the 50 persons to a learner type in accordance with this solution, 35 persons are classified as deep-strategy learners and 15 persons as surface-strategy learners.

Method 2 (process data analysis)

Self-regulated learning in a hypermedia learning environment differs from the classical learning situations which are described in the reference theories (e.g. study, test preparation etc..) in the following aspects: availability of new kinds of action, and preventing other learning strategies. The transfer of the established concept of surface and deep-strategy learner types into the situation of hypermedia learning requires a new partition of strategies or learning techniques in reference to the situational circumstances(for details see Thielke, 2003). Brenstein (1996) described a way to identify learner types by their navigation behaviour.

- The navigation behaviour of a surface-strategy learner is characterised either by coincidental behaviour or by behaviour aligned to the incentive structure of the learning environment. This applies especially because an internal guidance pattern is missing, which is normally shaped by prior knowledge or interest. This kind of navigation behaviour is primarily linear in organization. Possibilities to branch out are hardly noticed, since the learner's intention is not deeper treatment of the material. Unnecessary deviations are felt as a encumbrance.
- The navigation of a deep-strategy learner is characterized by self-direction. Usually the learner gives himself an overview of the content and organisation, before he consciously, purposefully and selectively seeks information that is related to his tasks or personal interests.

The possible navigation techniques in RACE are described in detail by Rockmann , Thielke & Seyda (2002, in this booklet). The software records all user actions in RACE chronologically in an ASCII file. Since these entries are not available in clear text they have to be revealed by extensive procedures (import and export into a data base, performing several VBA macros in

Excel), finally determining four different variables: Two of them represent a navigation behaviour corresponding to a surface- learner type, the other two stand for a deep-strategy learner type. These variables are means of classes of single or complex user actions. The two variables *surface* 1 and 2 are assembled from different, serial navigation elements, which are counted and summarized. In the two surface variables you can find actions like a) using *forward*, *back*, and *next* buttons, b) viewing tables of content and c) working through items one by one form an outline or d) working in test or teaching mode. The variables *deepness* 1 and 2 include other components like a) activating a link to another pool, b) pressing buttons for additional information, feedback or steering workflow and c) changing the view by clicking in windows for a change of the type of representation. Deep strategic learners also consult the glossary for unknown terms and work with self-made lists of references. Those actions can be seized directly or indirectly by tracking user actions in both directions from the data file. Altogether 256 different entries were classified and put together into a data base. While a log file is being evaluated, a macro compares the entries with those in the data base. Each match sums the value of the appropriate variable.
Many analyses concerning the evaluation of learning processes with hypermedia commonly use such sum variables as the number of visited nodes or activated links (Glowalla, Rinck & Fezzardi, 1993; Liu & Reed, 1994; Shin, Schallert & Savenye, 1994; Hasebrook, 1995; Liu, 1995; Jih, 1996; Rockmann & Butz, 1997). The four variable were analysed with the same hierarchical cluster analysis performed on the questionnaire data before. Again a theoretically predicted two-cluster solution should be detected. The two cluster solution is supported by the dendro- and elbow diagram and could also be confirmed by suitable *t*-values. Those values show appropriate over- and under-representation of typical or nontypical items in the clusters.

Table 2. T-Values of Clustering solution (process data)

	t- values deep	*t*- values surface
Deep 1	0.763	-0.267
Deep 2	1.047	-0.367
Surface 1	-1.325	0.465
Surface 2	-1.338	0.469

The means of the scale of the respective items correlate with each other significantly, r (50) = .940 (p<.01). The results of an independent t-test with the two means as the dependent variables and the learner type as the independent variable reveal statistically significant findings for both tests; deep strategy t (50) = 8.75 (d = 2.39, p < .01) and surface strategy t (50) = -11.02 (d = 3.55, p < .01). The learner types differ significantly from each other on both scales. The line plot of the clusters in Fig. 2 below illustrates the results graphically.

It is obvious that subjects can be definitely assigned to theoretically-defined learner types using a cluster analysis of process data.

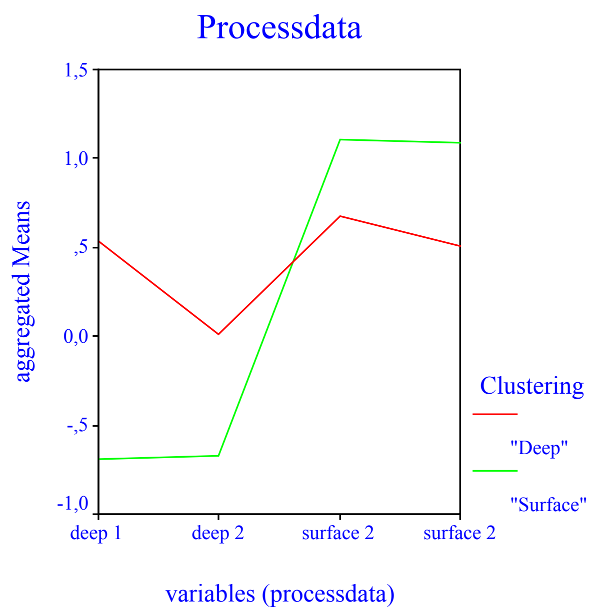


Figure 2. Standardized means (process data)

Matching

We classified the sample of 50 persons two times with the same method (cluster analysis) but using different sets of data. Do the two cluster solutions lead to the same matching of subjects and learner types? A Chi-Square-Test of independence and 2x2 contingency table test were performed to answer this question.

The classification of the subjects with the process data shows a division into 37 deep-strategy learners and 13 surface-strategy learners. The distribution is similar to the one we found analysing the questionnaire data. A Chi-Square-Test of independence which tests one distribution as an empirical one against the other as a fixed distribution does not show statistically significant differences: $\chi^2 (1, N = 50) = 0.381$ ($p = .537$) and $\chi^2(1, N = 50) = 0.416$ ($p = .519$). If you perform a 2x2 contingency table test to examine the relationship between both methods, the result shows contingency for 32 persons (64%) only for both procedures. The remaining 18 subjects(36%) differ from each other in the methods and types. But the value of Chi square is small, $\chi^2 = (1, N = 52) = 0.599$ and does not become significant ($p = .439$) nor does Fisher's exact test ($p = .493$). The Contingency coefficients (Phi coefficient and Cramer V) do not reach a significant level ($phi = 0.109$, $p = .439$ and $Cramer\text{-}V = 0.109$, $p = .439$). The effect size of the 2x2 contingency table test is $w^2 = 0.012$ and the power of the test is very small ($power = 0.116$)[5]. In respect to our findings, the sorting of persons into learner types does not depend on whether you use the process data or the questionnaire data. In Bortz's (Bortz, 1988) words, we could say that the proportion of deep-strategy learners sorted via questionnaire data analysis is not different from the proportion sorted via process data analysis[6].

[5] The effect would be significant if we would test a sample size of 700 (power= 0.8).

[6] We are talking about proportions, not about subjects. Even if the proportions are equal , the groups may not consist of the same persons.

Table 3. Comparison of both cluster solutions

cross table			process data cluster		total
			deep	surface	
questionnaire cluster	deep	number	28	11	**39**
	surface	number	7	4	**11**
Total		number	**35**	**15**	**50**

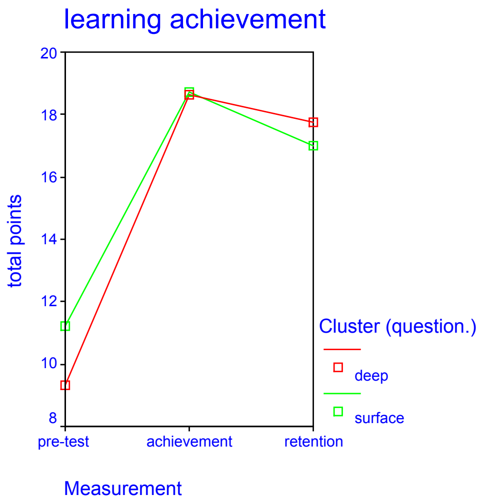
If you consider only on the proportion of the distribution, both cluster solutions look similar. The same relation between deep- and surface strategic learner occurs in both of them. But if you take a closer look at the subjects, you can find a remarkably discrepancy - 18 percent of the subjects sorted via process and questionnaire data are not sorted into the same group of learner type.

Learning achievement

A two-way measure of covariance analysis with repetition of one factor was performed to clarify whether the affiliation to a learner type has an influence on learning achievement. We expected that deep-strategy learners would achieve better learning and retention performance. Splitting the subjects ex post in two different groups, we can not secure homogeneous distribution through all relevant variables like foreknowledge or competence in media. Therefore a possible influence of foreknowledge can be controlled by a covariate. The covariate that we introduced is called "stable prior knowledge". It is defined as the number of correctly solved tasks for all three points of measurement (see Rockmann, Thielke & Seyda, 2002 in this volume). We use the learner type as an independent variable, which includes the two qualities of deep and surface-strategy learner types. The dependent variable is the yield in a test after 60 minutes of learning with the hypermedia environment RACE . The result is a simple significant effect on the measurment repetiton factor, F (N = 50, $df1_{\text{Greenhouse-Geisser}}$= 1.497, $df2$ = 90) = 53.997 (p < .01, η^2 = 0.454). The intrasubject contrasts show significant differences between every point within the group. The group effect (type) and the interactions do not become significant. Table 4 summarizes the findings.

Table 4. Tests Within subject effect of learning achievement (N = 50)

	corrections	*df*	*MS*	*F*	*p*	*Partly* η^2	*Power*
Intra-subject effect							
MZP * process data	Greenhouse-Geisser	1.467	3.059	0.207	.744	0.005	/
MZP * process data	Greenhouse-Geisser	1.467	21.731	1.472	.236	0.032	0.241
Total interaction	Greenhouse-Geisser	1.467	1.642	0.111	.833	0.002	0.06
Intra-group effect							
Process data		1	3.151	0.444	.509	0.010	0.101
Questionnaire data		1	1.374	0.193	.662	0.004	0.072
Interaction		1	5.285	0.744	.393	0.016	0.145



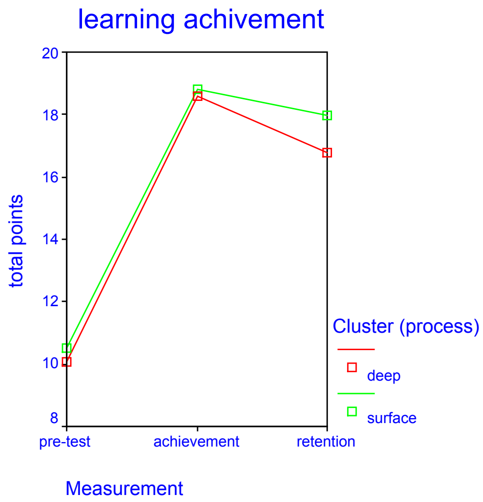


Figure 3. Means for both testing

A closer look at figure 3 does not suggest any reason to assume differences between surface- and deep-strategy learners concerning intra-group points. This can be confirmed by an appropriate examination via simple ANOVA[7], too.

Discussion

First, both methods can lead us to a reliable division of subjects into two theoretically defined learner types. Both methods come to nearly the same distribution but share only 64% congruency. A remarkable proportion of subjects (36%) are incongruent, showing different types for the questionnaire and the process data analysis. The type sorting does not have any influence on the learning or retention achievement. This effect is valid for both methods. Regarding the cluster analysis, it becomes obvious that the process data separate the subjects selectively in both dimensions. The questionnaire data permit a significant distinction of the learner type only for the five deep-strategy items. The findings of the significance test should not be overestimated, for the dependent variable consist of items which are also used to build the learner types before. On the other hand, they can be useful to decide which items are probably of more value in order to separate the subjects.

Second, there is no significant correlation between the two dimensions in the questionnaire. This is a surprising result even if the direction of the correlation (negative) runs as we thought it would. Theoretical models claim the uni-dimensionality of the subscales representing a learner type. Thus we can expect a significant negative correlation here. On the level of the action or behaviour, however, it is quite accepted that subjects perform techniques or actions which are counted in different classes. Therefore we would not expect a high correlation between those classes. This pilot investigation reports a coefficient of correlation which shows a nearly perfect negative relation between deep- and surface strategic process data. (r = -.94). There can be various reasons for this, such as inadequate items in our questionnaire asking for surface-strategic learning techniques. Subjects use strategies or techniques which do not conform to type at all, but why do they maintain them so rigidly? To answer this question, it would be necessary to examine whether this can be explained by the organization of the hypermedia environment or by other influences, like different experience in handling such programs, etc.

[7] Data available from the author

We did not really expect to find a learner-type-specific influence on learning outcome when using retrospective verbal data to divide the groups. Other experiments have shown the difficulties of dealing with such methods and predicting performance. According to the hypothesis of Brenstein or Artelt we might have expected to find such an influence by analysing the process data (1996; Brenstein & Neuser, 1998; Artelt, 2000). We found none, but in our investigation our process data are summarized values, which may not represent the "acting character" as much as needed. Perhaps is will be successful if we are able to preserve the process character of the variables while we find a appropriate operational definition for measurement (Thielke, 2003).

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Changes in motivation while working with the hypermedia learning program RACE

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Abstract

In most experiments only motives like dispositions are measured (trait measurement) although the classic psychology of motivation (Atkinson, 1957; Heckhausen, 1989) assumes that behavior is the result of interaction between situational and personal factors. Rheinberg et al. (2001) developed a four-factor questionnaire (QCM) to record the result of this interaction as a state of current learning motivation. The four factors are *fear*, *probability of success*, *interest*, and *challenge*.
We report an experiment that shows that the type of medium has an effect on specific motivational factors but not on performance. In a group comparison design, one group (N=8) worked with paper learning cards and one (N=12) worked with the hypermedia environment RACE. Before and after the acquisition phase, performance was tested. A QCM was given after subjects had been given instructions but directly before the acquisition phase and again 30 min. after the acquisition phase. The results show no specific effect on the current motivation based on the type of media ($p = .397$). Nor could any correlation between motivation and performance be detected. We found that subjects working with RACE show higher scores in factors like interest ($p < .05$) and challenge ($p < .01$) than subjects working with cards.

Introduction

This article deals with the form of motivation of learning while subjects are using the hypermedia learning program RACE and the possible effect on learning. Schulmeister describes the current state of research thus:

> „Whether hypertext has a beneficial effect on the motivation of the learner has not been thoroughly examined yet. But many authors seem to agree with such a hypothesis " (Schulmeister, 1997, 267, translated into English by the authors).

Schulmeister explicitly examines the motivating effect of hypertext. Taking into account that hypertext is always a hypermedium, one can narrow this hypothesis down using the work of Weidenmann (1993), on the relationship between hypermedia/multimedia and motivation.
In connection with the measurement of motivation, the relationship between motivation and learning performance must be considered. Here the research of Rheinberg, Vollmeyer and Burns (2001) is essential to the discussion.
For testing both of these aspects, the subscale scores on a questionnaire about motivation and the results of a performance measurement while learning with the hypermedia learning program RACE (cf. Rockmann, Thielke & Seyda, in this volume) were compared to the

scores on the same questionnaire and performance measurement while learning with a pencil-and-paper version. This study was carried out as part of the BiSP-project *Informationvermittlung durch neue Technologien II [Information Transfer via New Technologies]* (Rockmann, Thielke & Seyda, 2002,VF 0407/13/01/2001).

Theoretical Perspectives

In cognitive psychology there is no doubt that learning performance is the result of cognitive competencies, which are seen in such constructs as interest and preknowledge, but also in factors of motivation like need for achievement and interest in the thing (cf. models of determination of learning performance by Atkinson (1957), Heckhausen (1989) or Helmke and Weinert (1997)).

Yet it seems to be very difficult to empirically prove the effect of motivational factors on learning performance. Rheinberg et al. (2001) are critical of the generally poor empirical results. They see the reason for this situation in the experimental designs of classic motivational psychology. These experimental designs measure motives only as dispositions (trait-measurement), although Lewin (1946) assumes that behavioural tendencies are the result of *interaction* between situational and personal factors.

Rheinberg et al. (2001) claim that motives in current activity have more of an indirect effect on behaviour and therefore they can only predicate performance on the long term.

The motivational construct that affects the real learning situation is called *current motivation*. Rheinberg et al. (2001) developed a questionnaire (QCM = Questionnaire of Current Motivation) to measure this construct. The QCM records the interaction between situational factors and motives that affect behaviour. It represents a state-measurement of motivation.

The QCM consists of 18 items that cover the four factors *fear of failure*, *probability of success*, *interest* and *challenge*.

> "F1 (fear of failure) primarily contains items that concern the negative incentives of failure, connected with the assumption that the pressure of the situation prevents optimal learning. F2 (probability of success) contains assumptions how certain one feels of doing well here (sic). A high probability of success can come from the fact that one feels competent enough or one thinks that the exercise is generally easy (sic). F3 (interest) consists of items that concern the value of the contents of the exercise. … (sic)… F4 (challenge) covers to what extent the learning situation is interpreted as requiring achievement" (Rheinberg et al. 2001, 59, translated into english by the authors).

The construct of the current learning motivation develops as the subject confronts the learning exercise. For this reason the construct cannot be checked using classic control-group design. In this case only various scenarios of teaching and learning can be compared with each other. Thus one can make only relative conclusions. Rheinberg et al. (2001) give no concrete information about the change of the current motivation during further learning activity.

The experiment of Rheinberg et al. (cf. 2001, 61) examines the effect of the current motivation on learning success while learning with hypermedia software. In their questions they assume that there is a correlation between the sub-scales of the QCM and the learning performance in an open self-regulated scenario of learning and teaching but not in a scenario that directs the learner step-by-step through the learning content. The results show that the learning success, which is measured by a one-off learning test after the acquisition phase of 25 minutes, correlates very positively with the scores of the sub-scales *challenge* and *interest* in the learning scenario that is self-regulated. Especially in self-regulated situations of learning it seems that learning success depends on the interest of the learner in the content. In addition it depends on feeling challenged by the exercise. According to the results of

Rheinberg et al. (2001), it is thus possible to predict learning success in such learning situations with the help of the two factors interest and challenge. It is not possible to make an assumption concerning the factors *fear* and *probability of success* from the results of Rheinberg et al. (2001).
Interest and *challenge* in self-regulated learning situations is expressed in the readiness of the learners to work more deeply with the text, to organise their own learning activity and to feel a challenge in understanding the text (cf. Rheinberg et al., 61). Out of this Rheinberg concludes "that the subscales *interest* and *challenge* of the QCM (sic) allow a prediction of learning performance in cases of self-regulated and comprehension-oriented learning" (Rheinberg et al., 2001, 61). Hypermedia learning environments, as used by Rheinberg et al., can meet the criterium of self-regulated learning especially well, if they are properly programmed (cf. Dillon & Gabbard, 1998; Artelt, 2000; Thielke, 2003).
However, Weidenmann (1993), Deci and Ryan (1987), and Lepper and Malone (1987) suppose that hypermedia learning programs can increase learning motivation in any case. Weidenmann (1993) assumes that a media learning environment can have a positive effect on motivation under specific conditions. For Weidenmann (1993) media learning environments are especially "multimedia or hypermedia computer learning programs"[1]. In the argumentation of Weidenmann (1993), increased motivation has the effect of increasing readiness for effort and persistence despite difficulties that occur. For this, the following criteria have to be fulfilled by a hypermedia learning environment:

1. The possibility of self-control and autonomous action (Deci & Ryan, 1985)
2. Intentionality and experience of self-effectiveness (Bandura, 1977)
3. A supporting instead of controlling environment (Decy & Ryan, 1987)

All these requirements are fulfilled by RACE (cf. Rockmann, Thielke and Seyda, in this volume). Lepper and Malone (1987) report comparable but more general criteria that a hypermedia learning environment has to fulfill to have an motivational effect. These include variable graduations of performance demands and the possibility for the learner to regulate them. These are also implemented in RACE.

Rheinberg et al. (2001) examined answer-directed vs. self-regulated learning with a hypermedia learning software and controlled the type of media. In this examination we control the scenario of learning and teaching and vary the type of media. In this way we tried to replicate the findings of Rheinberg et al. (2001). In addition, we took a look at the retention performance too. For this the following hypothesis can be formulated:

1) *Persons, who learn in a self-regulated learning situation will show a positive correlation between the scores of the sub-scales* interest *and* challenge *of the QCM and acquisition, or to be precise, retention performance.*
2) *Further, it is expected that, in accordance with Weidenmann (1993) et.al., that persons who learn with the hypermedia learning environment RACE, will have higher scores in the scales of the QCM than persons who learn in a classic paper-and-pencil scenario.*

[1] When subsequently hypermedial learning environment is mentioned, Weidenmann`s computer program is included.

In addition to the hypotheses, two other questions should be investigated: How do the scores of the sub-scales of the QCM change during the learning period and if so, does the type of media have an effect?

Methods

Two types of media were compared in the media comparison experiment. Type one is a sitemap-version of RACE and type two is a content-equivalent paper version of RACE (cf. Rockmann, Thielke and Seyda, in this volume). The experimental design is shown in Table 1.

Table 1. Design of the experiment by Rockmann, Thielke & Seyda (2002)

process number	action
1	instruction
2	questionnaire
3	pre-knowledge test (MC and TP)
4	introduction to work with RACE/ learning cards
5	Setting the task
6	QCM (first measurement)
7	free work – acquisition phase (30 min)
8	QCM (second measurement)
9	free work – acquisition phase (30 min)
10	acquisition test (MC and TP)
11	after 4-7 days retention test (MC and TP)

First the course of the experiment was explained to the subjects. After that a questionnaire to collect demographic and learning strategy data was administered. A pre-knowledge test followed in the form of a multiple-choice test. Then the subjects got the chance to familiarize themselves with the given type of media. After this training period and the formulation of the concrete task, the QCM was administered the first time. After a thirty-minute acquisition phase, the QCM was given the second time. After another thirty-minute acquisition phase, the final test (acquisition test) was administered. After 4 days all subjects took a retention test.
To prove the hypothesis of correlation (hypothesis 1) the results of the performance tests were correlated with the scores of the sub-scales *interest* and *challenge* of the QCM. To be more precise than Rheinberg (2001) we correlated the values of the acquisition test and of the retention test as well as the stable learning performance with the scores of the two sub-scales. The following statistical hypotheses were investigated:

- *For $M_{interest}$ x values of performance is $r > 0$*
- *For $M_{challenge}$ x values of performance is $r > 0$*

The measurement of learning performance consists of the correct answers in the acquisition test minus stable pre-knowledge, the correct answers in the retention test minus stable pre-knowledge, and stable learning performance (the answers which were correct in the acquisition test and in the retention test minus stable pre-knowledge). If a hypothesis could be confirmed, we planned to analyse the correlation by type of media.

To answer the question regarding difference between the types of media and the stability of the sub-scales of the QCM, *current motivation* was defined as the dependent variable, to be measured two times. (It should be noted that the measurements of motivation and of performance did not take place at the same time. Both administrations of the QCM were in the period between the two measurements for learning, the pre-knowledge test and acquisition test). The quantification of *current motivation* consists of the sum scores of the four QCM sub-scales *interest, challenge, fear,* and *probability of success.* These are all different single dimensions of the QCM, and their interfactorial correlation was not reported on by Rheinberg et al. (2001). The values of the internal consistencies of the sub-scales, each for the first and second QCM measurement, are listed in Table 2. Under the assumption of one-dimensionality no multivariate design is offered.

Table 2. Reliabilities of the FAM sub-scales at first and second measurement

N = 20	Cronbach`s alpha (corrected)	Comments	Cronbach`s alpha (corrected)	Comments
	First	measurement	Second	measurement
Interest (5)	.8535	good	.8987	good
Probability of success (4)	.7338	satisfactory	.8314	good
Challenge (4)	.6853	satisfactory	.6713	satisfactory
Fear (5)	.8508	good	.9122	very good

The sample of our experiment contained 20 subjects, 8 working with media type 2 (learning cards) and 12 working with media type 1 (hypermedia learning program RACE). The transfer of the predictions into statistical hypothesis can be formulated for the four sub-scales as follows:

a) $\mu_{inttyp1} > \mu_{inttyp2}$
b) $\mu_{hertyp1} > \mu_{hertyp2}$
c) $\mu_{erftyp1} > \mu_{erftyp2}$
d) $\mu_{misbtyp1} > \mu_{misbtyp2}$

In addition we do not expect current motivation to change over time:

e) $\mu_{intFAM1} = \mu_{intFAM2}$
f) $\mu_{herFAM1} = \mu_{herFAM2}$
g) $\mu_{erfFAM1} = \mu_{erfFAM2}$
h) $\mu_{misbFAM1} = \mu_{misbFAM2}$

Results

The testing of the first hypothesis delivered no significant correlation of the mean of the sub-scales *interest* and *challenge* with corrected acquisition performance, corrected retention performance or stable learning performance (tab. 3).

Table 3. Results of the correlation for all subjects and group specifically

	correlation for all subjects ($N = 20$)	correlation for macromedia ($n = 12$)	correlation for learning cards ($n = 8$)
	acquisition performance	acquisition performance	acquisition performance
interest at first measurement	r =.172	r =.443	r =.043
interest at second measurement	r =.073	r =.260	r =.122
challenge at first measurement	r =-.266	r =-.121	r =-.257
challenge at second measurement	r =-.316	r =-,029	r =-.603

The testing of hypothesis $H2_{(a-h)}$ was carried out with a two-factorial analysis of variance with repetitive measurement based on factor $FAM^2_{(n)}$. Table 4 shows a summary of the results.

Table 4: Results of the two-factorial analysis of variance with repetitive *measurement*

	Repetition of measurement	*Interaction*	*Type of media*
Interest (N = 20, 1)	*F = 0,001 p = .982 η2 = .000*	*F = 0,146 p = .707 η2 = .008*	*F = 5,884 p < .05 η2 = .246*
Challenge (N = 20, 1)	*F = 0,577 p = .457 η2 = .031*	*F = 0,577 p = .457 η2 = .031*	*F = 21,678 p < .01 η2 = .031*
Probability of success (N = 20, 1)	*F = 4,536 p < .05 η2 = .201*	*F = 1,837 p = .192 η2 = .073*	*F = 1,426 p = .248 η2 = .073*
Fear (N = 20, 1)	*F = 2,886 p = .107 η2 = .138*	*F = 0,739 p = .401 η2 = .039*	*F = 0,95 p = .761 η2 = .005*

The results prove that the hypothesis is partly right. For hypothesis H2 (concerning *interest* and *challenge;* fig. 1/2), the effect of type of media is significant. The development of the means for the sub-scales *interest* and *challenge,* which conform to the hypothesis, clearly shows that the effect *type of media* stays stable in the course of the acquisition phase. It seems to be more interesting and challenging to work with the hypermedia learning program RACE than to work with learning cards.

[2] It is possible to prove the hypothesis with the t-test, which has more power. The dependent variable takes in to account that the constructs change in the course of time. Therefore one can test interaction as well. The results of the dependent variable regarding the effect of type of media are also validated by the t-test.

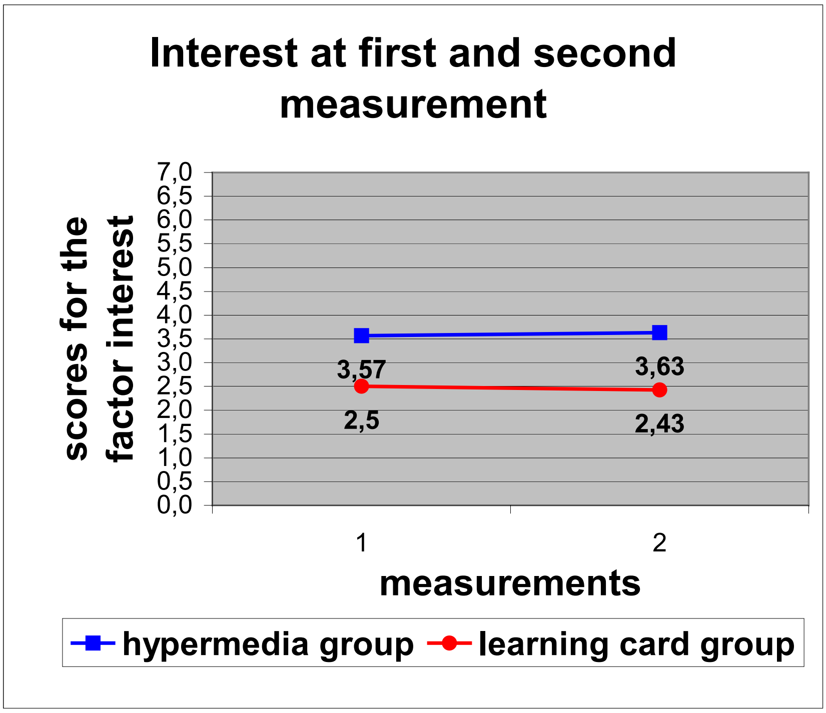

Figure 1. Course of the mean for the sub-scale interest

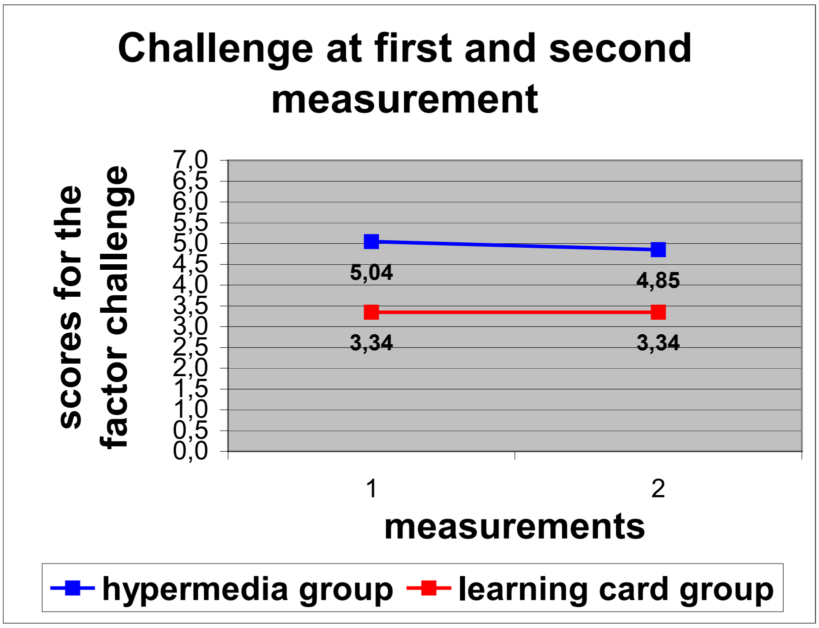

Figure 2. Course of the mean for sub-scale challenge

The results for hypothesis H2 (probability of success) show a significant effect on the factor repetition of measurement (QCM). Here the subjects' self-rating varies over the period of time. The diagrams for the development of the mean (fig. 3/4) show the same tendency for the dimensions *fear* and *probability of success*, a decrease in the values at second measurement. That means that fear decreases in both groups during the acquisition phase. The probability of success also decreases, but the distance between both groups is greater at first measurement. This distance gets smaller within the first half hour.

Testing the difference between the groups for the factor *probability of success* at first measurement leads to a non-significant result (T = -1.880, N = 20, df = 18, p =.076, D = 0,89, *power* = 0,59). This result would have become significant at a sample size N = 34. Looking at the graph intensively, it is striking that the reason for the significant main effect in the course of the acquisition phase is the learning card group. A testing of this hypothesis though gave no significant result (F = 3,29, N = 8, $df\ 1$= 1, $df\ 2$ = 5, p = .113, η^2 = .320, *power* = 0,388). This effect would have been significant at a sample size N = 16. Therefore the factor of repetitive measurement does not become significant without the variance of the hypermedia group, but recruits its main strength out of the variance of the learning-card group.

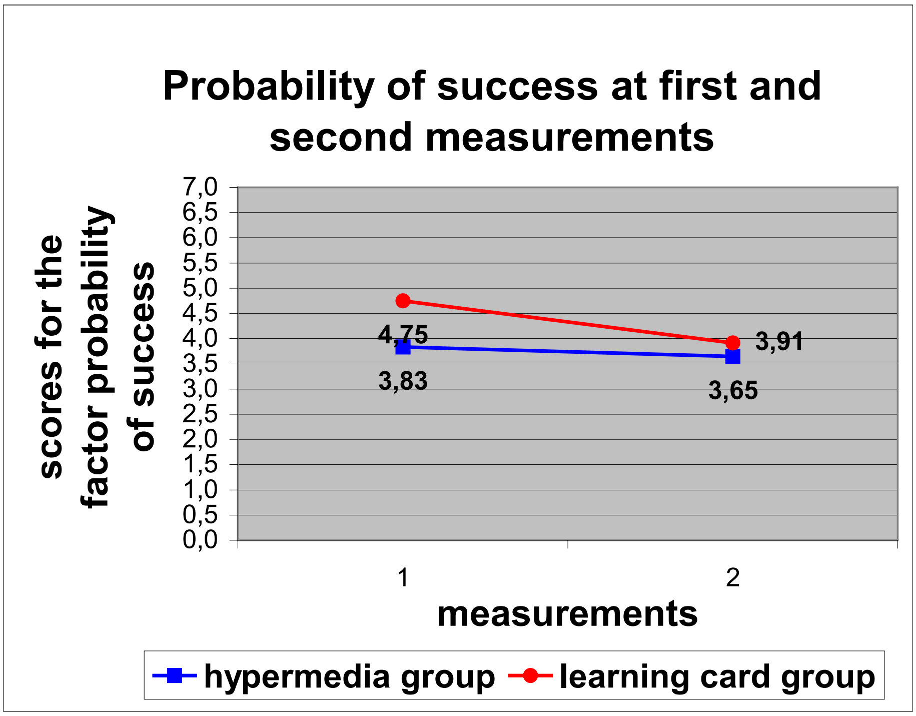

Figure 3. Course of the mean for the sub-scale probability of success

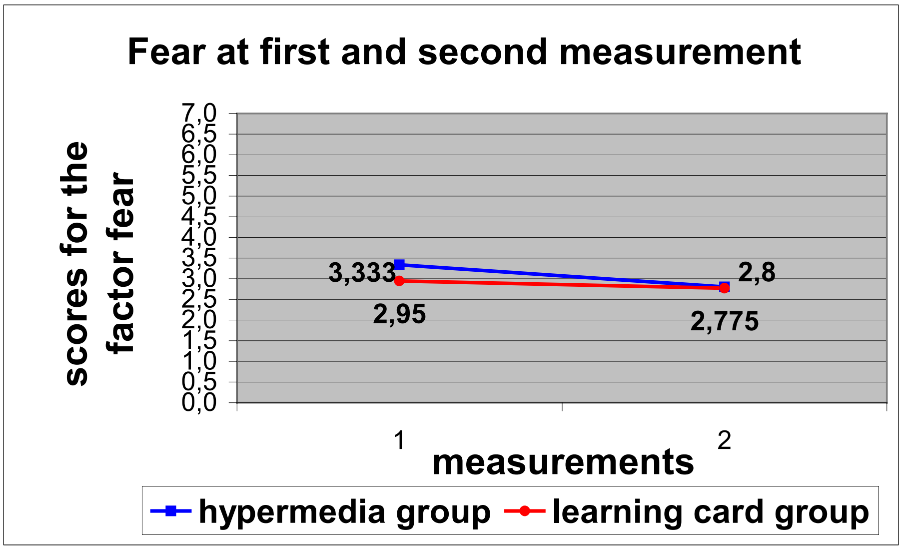

Figure 4. Course of the mean for the sub-scale fear

Discussion

We found out that there is no significant correlation between current motivation and acquisition performance, retention performance and stable learning performance. So the Zero-hypothesis is retained. Obviously there is no connection between a higher motivation in the sub-scales *interest* and *challenge* and a higher learning performance. The results of Rheinberg et al. (2001) could not be replicated. But this is not a problem for the discussion of our results because the subjects of the hypermedia group and the subjects of the learning-card group did not differ in learning performance. Apparently subjects learning with both types of media had comparably good learning performances (for details and in order to take a look to other influences cf. Rockmann, Thielke and Seyda, in this volume). The differences between the two groups we discovered in the sub-scales of the QCM appear to have nothing to do with learning performance.

A possible explanation is offered by the theoretical ideas of Weidenmann (1993) and Lepper and Malone (1987). We can posit that the subjects did not connect the items of the QCM as much with the content of learning program as they did in Rheinberg et. al. (2001). Instead, their real motivation could have been more closely related to the learning situation or work with the medium. The results of the analysis of variance speak for such an interpretation. Regarding the sub-scales *interest* and *challenge* in the QCM, we found a significant difference between the two types of media. Subjects of the hypermedia group got significantly higher scores in these two sub-scales than subjects of the learning-card group. In both groups, motivation remained stable for these two sub-scales in the period investigated. In direct comparison, the hypermedia learning environment seems to be more interesting and more challenging for working on this theme than the learning cards.

The factors of *motivation*, *probability of success,* and *fear* changed in the course of time. These results admittedly do not conform to the hypothesis, but one can also interpret them under the same aspect, as an effect of the type of media. Subjects in the learning-card group had a stronger feeling for the probability of success at the beginning of the acquisition phase than subjects in the hypermedia group. The feeling decreases in the learning card group in the course of learning significantly, while the feeling for the hypermedia group remains nearly stable. (cf fig. 3, course of mean). The sub-scale *probability of success* takes into account how safe the person feels with regard to fulfilling the task on her/his own. The expectation of the hypermedia group is rather sceptical, but in the course of working with the medium it changes. The learning-card group is more confident at the beginning of the acquisition phase and corrects this feeling downward.

Fear generally refers to situative demands. Here the learning card group estimates itself at the beginning slightly under the mean (M = 2.95 with a scale-average of 3.5). This value decreases a little bit during the experiement, which means that *fear* decreases (no significance). Subjects working with RACE generally show a higher level of *fear* in comparison to subjects of the learning card group. This value tends to decrease at the second measurement of QCM. So the hypermedia group reaches nearly the level of the learning-card group. After a less optimistic estimate at the beginning, the hypermedia group's fear of not being able to cope with the situation drops nearly to the level of the learning-card group's.

All our results seem to show that the QCM here was answered in a way that strongly focused on the medium and completing the task with its help. Under these conditions it is not suprising that the results of Rheinberg et al. (2001) could not be replicated. In our learning treatment we could not find an effect of the current motivation on the learning performance, not even in parts. The effect of the type of media on the current learning motivation we found seems to be clear, but has to be confirmed by further analysis. It is the same with a thorough examination of current motivation, the type of media and further aspects of learning performance. It is especially important that the examination use more subjects than we had in order to make our rather tentative results more reliable. In this connection, Rockmann, Thielke and Seyda (in this volume) can show that statistical evidence can be obtained about the effect of the type of media on the learning performance, but only from stringent experimentation using further variables.

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The use of GPS for continuous measurement of kinematic data and for the validation of a model in alpine skiing

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Abstract

At the Institute for Theory and Practice of Training and Movement, a model was developed to calculate the running time and the optimal trajectory in alpine skiing applying genetic algorithms. A GPS-System offers new possibilities for measuring kinematic data of alpine skiers and could be used to validate the model of alpine skiing. The advantage of this GPS-System is the direct use of the results without time-consuming calculations. Further, the data of the GPS-System could be used to produce virtual camera rides and to evaluate the results under competition conditions and with regard to safety aspects (e.g. comparison between real and optimised trajectories, analysis of the curve radius, the angle of gate entrance and the centrifugal force). The aim of the study was to validate the practical use of this GPS-System in alpine skiing. The investigation showed that it is possible to record the kinematic data of a skier using a GPS-System to an accuracy of a few centimetres. Further, it is necessary to develop a smaller antenna with differential phase correction, thus enabling this to be fixed directly onto the ski so reducing errors in measured data and real trajectory.

Introduction

GPS is the shortened form of NAVSTAR GPS. This is an acronym for NAVigation System with Time And Ranging Global Positioning System. GPS is a solution for one of man's longest and most troublesome problems. It provides the literal answer to the question 'Where on earth am I?' and was originally designed for use by the military (Leica 1999). Soon after the original proposals were made, it became clear that civilians could also use GPS and this not only for personal positioning. The first two major civilian applications to emerge were marine navigation and surveying. Applications nowadays range from in-car navigation through truck fleet management to the automation of construction machinery. A future application is in sport. GPS is a satellite-based system that uses a constellation of 24 satellites to give the user an accurate positional finding. In this context it is important to define 'accurate'. For a hiker or soldier in the desert, accuracy is required to about 15 m. For a ship in coastal waters to about 5 m. A land surveyor requires an accuracy to about 1 cm or less. GPS can be used to achieve these accuracies for all the above applications, the inherent difference being the type of GPS receiver used and the technique employed.
The object of this study is to prove that the practicability of a GPS-System in alpine skiing in surveying the slope and the trajectory of a skier. With 'traditional' instruments like a tachometer and methods like the 3D-video-kinematic it takes a lot of time to obtain information, in spite of which this is often defective or inaccurate. A further exercise is to compare the GPS data with the results of the simulation calculations and to validate and to improve the model of alpine skiing.

Methods

With a GPS-System it is possible to locate the actual position of every place on earth, at all times and independent of atmospheric conditions. The total GPS configuration consists of three distinct segments:

- The ‘Space Segment’ with the 24 satellites orbiting the earth. It is so designed that there will be a minimum of 4 satellites visible at any given point of the earth’s surface at any time. Four satellites are the minimum that must be visible for most applications.
- The ‘Control Segment’ with 5 stations positioned on the earth’s equator which controls the satellites. The master control station is located in Colorado (USA).
- The ‘User Segment’ which is anybody able to receive and use the GPS signal.

There are several different methods for obtaining a positioning using GPS. The method used depends on the accuracy required by the user and the type of GPS receiver used. With autonomous navigation devices (handheld) without corrected positioning data, it is possible to have a positional accuracy of between 20 – 100 m. A differentially corrected positioning system (DGPS) receives corrected positional data from a reference station and can position to an accuracy of 0.5 – 5 m. The PDGPS is further refined in that it exploits the Doppler Effect of the carrier phase. It has a positional accuracy of 0.5 – 5 cm (Figure 1).

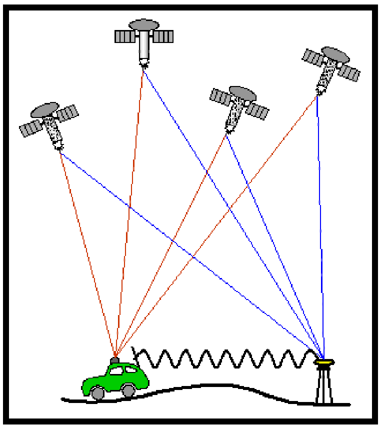

Figure 1. PDGPS with differential phase correction

Figure 2. PDGPS-System (Leica)

This study used the PDGPS-System Leica SR 530 (Figure 2). It is using a differential phase correction thus achieving an accuracy of ±1 cm. It is also possible to measure in a kinematic mode with 10 Hz. Two different antenna systems were used: the original antenna with differential phase correction (Figure 3) and a very small antenna without differential phase correction (Figure 4).

Initially the original antenna was used to survey the slope. It was therefore necessary to skid down the slope several times with the GPS fixed on the level gauge. This data was processed in the GIS-software (ArcView, ESRI) to generate a model with a triangulated mesh (TIN). The software also calculates other parameters of the slope such as slope inclination, the distance, the width and the 3D co-ordinates. The exported TIN can be directly imported to the simulation software of alpine skiing (Seifriz 2001). In a second step the start and finish gates of the course were surveyed.

To survey the trajectory of the skier, the original antenna with phase correction was fixed to the helmet and the small antenna without phase correction was fixed on one ski. The GPS-System offers a kinematic mode to survey the trajectory. The maximum sampling frequency is 10 Hz. This data was also processed by the GIS-software so that the trajectory also could be directly transferred to the simulation software of alpine skiing.

Figure 3. Original antenna; dimensions: diameter 21 cm; weight: 300 g

Figure 4. Small antenna (here fixed on the helmet); dimensions: 9 x 9 cm; weight: 90 g

Based on the number of satellites used, the GPS-System calculates an accuracy range for each data point. The results of the GPS measurement are compared with the data of a 3D-video-kinematic (DLT). For this purpose two fixed digital cameras (PAL 25 Hz) and the Simi-Motion Software were used to analyse the trajectories of the skier.

Results

The GPS-System raw data are single 3D-points (Figure 5). For each point the GPS stores a value of accuracy based on the number of reachable satellites and the information of the reference station.

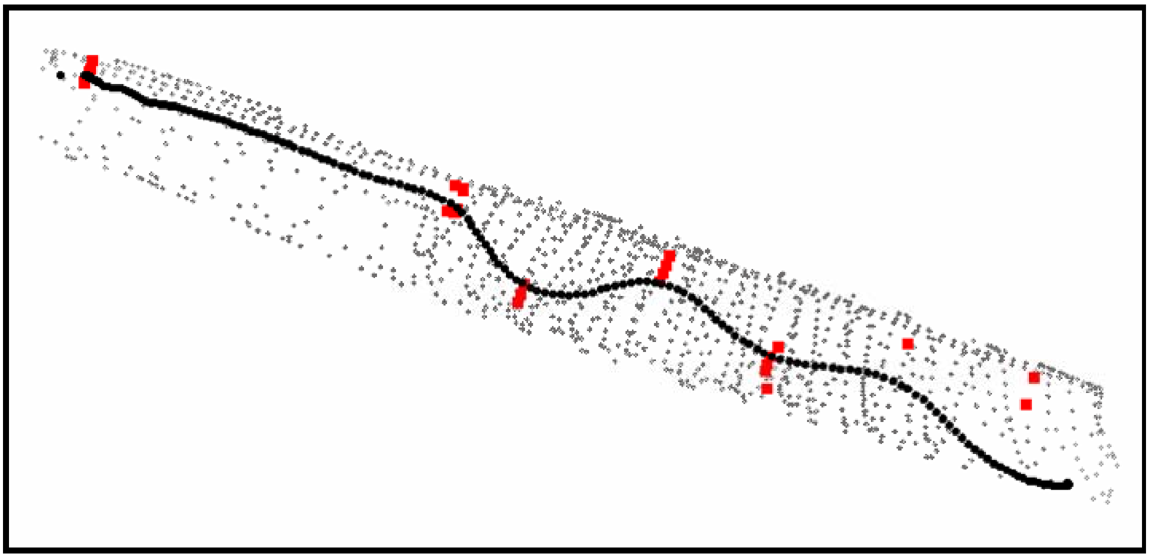

Figure 5. Raw data of the GPS-system surveyed slope (gray), the gates (red) and a trajectory (black)

For the antenna with differential phase correction and 10 Hz sampling rate in the kinematic mode data to an accuracy of 1-5 cm under normal skiing conditions was obtained. The calculated accuracy of GPS-System was 2.63 ± 0.59 cm for each point averaged over eight runs. Without the differential phase correction, the quality of the measured data deteriorates to

values of up to a few meters. Thus the data of the antenna without phase correction was not used for further analysis.
The data surveyed with the original antenna was very accurate but due to the attachment to the helmet, there is a difference between the GPS data and the real trajectory of the ski. A comparison with the 3D-video-kinematic clearly showed these differences as a function of the curve and the body posture (Figure 6). An error due to the inclination is only manifested in the x and y directions. There is no error in the z direction (elevation) because the z value can be corrected with the surveyed values of slope.

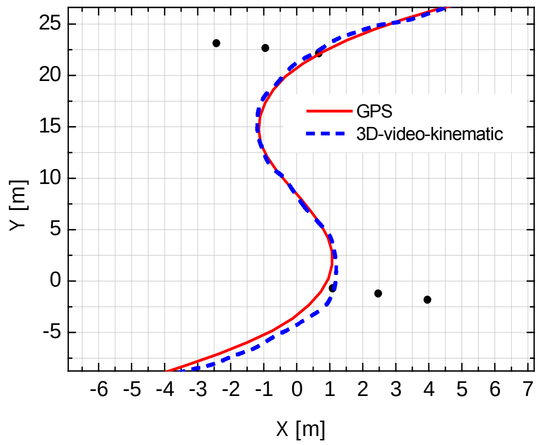

Figure 6. Comparison of the trajectory between GPS (solid) and 3D-video-kinematic (dashed).

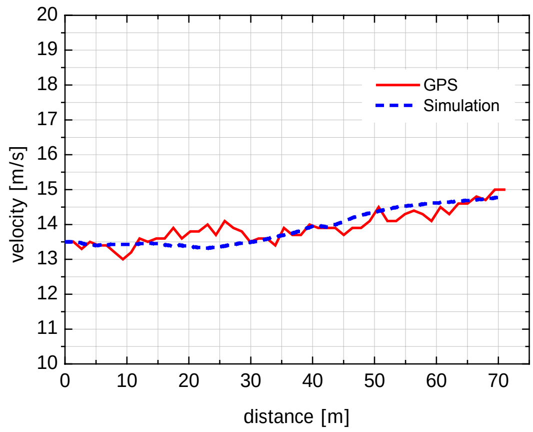

Figure 7. Velocity-distance diagram of a run: GPS (solid) and simulated (dashed).

In Figure 7 the velocity-distance diagram shows data from the GPS-System and the result of the simulation. Here the results of the simulation correspond over a wide range with the data of the GPS. The running time calculated by the simulation differs by 0.09 s to that measured by the GPS-system. Similarly small differences were determined between the simulated and surveyed end velocities and distances (Table 1).

Table 1. Comparison of the results of the simulation and the data of the GPS-System

	simulation	GPS-System
Running time	5.01 s	5.1 s
End velocity	14.78 m/s	15.0 m/s
Distance	70.0 m	70.92 m

Discussion

One of the goals in this study was to check the validity of the practical application of a GPS-System in alpine skiing in surveying the trajectory of a skier. In alpine skiing, in particular, the use of 3D-video kinematics is difficult and time consuming. For this application a GPS-System can simplify and accelerate the process. In Table 2, the main features of the two systems were compared. The application of the GPS-System and the results of the study clearly demonstrate the advantage of the GPS-System even for the case of the original antenna with differential phase correction being attached to the helmet.
It can be seen here that not only the calibration for a 3D-video kinematic is time consuming but also the evaluation of the video frames takes a long time. In comparison, a GPS-System requires no calibration and the results are immediately available. Even for movements over a long distance such as by alpine skiing, a video based system is restricted by its optical capabilities. It appears impossible to analyse a complete downhill slope with a 3D-video

kinematic. From this it can be concluded that the GPS-system is more accurate and faster than the 3D-video kinematic for fields of movement over extended distances.
In case of a small antenna without differential phase correction attached to the ski, the inherent lack of accuracy of the GPS-System was unacceptable for the following reasons:
- The lack of the differential phase correction.
- When the ski is edged the antenna is also edged, which leads to a loss of signal satellites to below those necessary to position correctly; a prerequisite for accurate measurement.

Table 2. Main features of the systems

	3D-video kinematic	GPS-System
equipment	video cameras, software	GPS-System, software
sampling rate	≥ 25/50 Hz	≤ 10 Hz
requirement	calibration	-
evaluation time	hours	few minutes
error	in all directions (x, y, z)	in two directions (x, y)

A further object of the study was to validate the simulation model of alpine skiing based on GPS-System data. After the transfer of the raw data to the GIS-Software, the trajectory can be transferred in a standard file format (.SHP) compatible with the most GIS-Software. The simulation program can read this format directly so that there is no data conversion needed. In the same way, the triangulated mesh of the slope can be directly read into the simulation program. This standard file format offers the possibility of exchanging all the information surveyed by the GPS-System or other additional details such as the results of the slope inclination calculation as done by the GIS-Software.

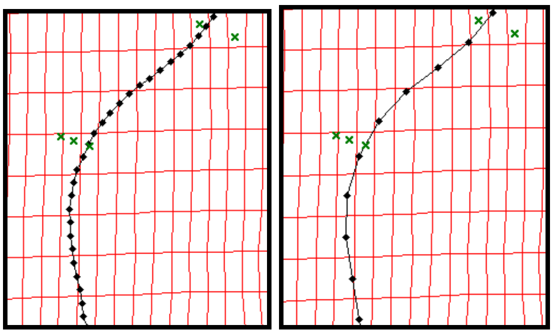

Figure 8. Raw data of a trajectory (left) and reduced trajectory (right) for the simulation

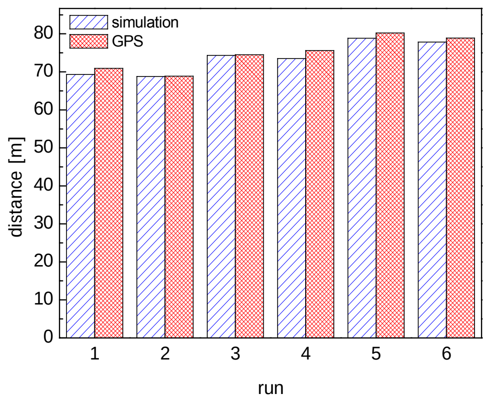

Figure 9. Comparison of the distance of the raw data and the reduced trajectories

The simulation program itself works with a trajectory approximation based on control points (B-spline). In order to minimise the calculation time for the simulation, the number of points surveyed with the GPS-System must be reduced. In Figure 8 the raw data and the trajectory approximation based on the reduced control points are shown. The differences between the distances of the trajectories are very small (Figure 9). Thus it can be concluded that the reduction of the number of control points along the trajectory only insubstantially affects the total distance.
A further application is that the GPS-System data could be used to produce virtual camera rides for evaluating results under competition conditions and aspects of safety (e.g. comparison between real and optimised trajectories, analysis of the curve radius, analysis of the angle of gate entrance, analysis of centrifugal forces). It could also be used to aid ski

resort to build new information systems or to be the base for the process animations. In these animations it possible to high-lighting key spots and offers new impression by free choice of the perspective.

Conclusions

This investigation generally showed that it is possible to record kinematic data of a skier to an accuracy of a few centimetres with a PDGPS-System. At this point in time a small antenna with a differential phase correction has not been developed. So it is necessary to develop smaller antenna with differential correction, that it would be possible to attach these directly to the ski, thus reducing the error in the measured x and y direction data compared to the actual trajectory. Because the PDGPS-System is able to survey within an accuracy of one centimetre, this could be used for the scientific analysis. With a sampling frequency of 10 Hz, the data frequency is lower than a 3D-video kinematic (PAL 25 Hz) but the results are directly available after the measurement.
The results of the GPS-system confirm the behaviour of the simulation model. In combination, the simulation models and the GPS-System offer a great potential in accessing performance as well as providing possibilities of safety enhancement in alpine skiing. These could also be used as aids in extending and perfecting modern ski resort information systems and in the area of media the results could be the basis of animations for coaches and athletes.

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An Instrument Quantifying Human Balance Skills: Attitude Reference System For An Ankle Exercise Board

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Abstract

The ankle exercise board can be used as an instrument quantifying human balance skills and learning strategies. However, this requires an appropriate recording of its movement. Using the theory of integrated navigation systems as well as simulation and experimental data, a corresponding motion measurement system was developed and qualified:

Modelling the vehicle kinematics is an essential design task of such integrated systems. It has to consider both the vehicle motion and the mechanical meaning of the used measurements. Until now, a rigid body with three translational and three rotational degrees of freedom represents the typical model applied. However, for an ankle exercise board, which is in fact a hemisphere oscillating on the floor, the design of a special attitude measurement system is possible. It is based on a model with only three rotational degrees of freedom and on considering spatially distributed accelerometers. The utilised data fusion employs nevertheless the same principle as for integrated navigation systems. It comprises additionally three micro-mechanical gyros as well as a Kalman filter estimating the three Euler angles of the board and sensor calibration values.

To illustrate the application of the system, aspects of observing the rehabilitation after ankle and knee injuries conclude the paper.

Introduction

It is a well-known fact that during the last decades the technology of inertial navigation systems has experienced extraordinary changes. The importance of the classical mechanical sensors decreased in favour of optical and micro-mechanical devices, strapdown systems replaced in many cases stabilised platforms, and satellite navigation provides meanwhile accurate complementary measurements. Thus, by also profiting from modern microprocessor technology, integrated navigation systems based on inertial sensors became significantly cheaper and are no longer left for a limited section of users.

One essential element of the system design remained unchanged during this time. It concerns the mathematical model describing the vehicle kinematics as well as the mechanical meaning of the measurements: For spatial movements, a rigid body with three translational and three rotational degrees of freedom is usual, and for the motion on a surface, particularly car navigation systems, a rigid body with two translational and one rotational degree of freedom is applied. In addition, all measurements are normally referenced to one vehicle point (Farrell & Barth, 1999).

However, neither the restriction to the two mentioned model types, nor the spatial sensor accumulation are mandatory: The ankle exercise board, being in fact a hemisphere oscillating on the floor and with a footboard attached, is a special "vehicle" with (only) three rotational degrees of freedom. It can be used as an instrument quantifying human balance skills and learning strategies. Yet, this requires an appropriate recording of its movement. Thus, using the technology of integrated navigation systems, a particular attitude measurement system was designed, which employs spatially distributed accelerometers.

The intention of the paper is to introduce the measurement system and to demonstrate its use. The next chapter explains the principle of integrated navigation systems and outlines the special system design and test. Then, by observing the rehabilitation process after ankle ligament and knee injuries, an illustration of the system application follows.

Measurement Method

Principle of Integrated Navigation Systems

The basic idea of integrated navigation systems is to fuse measurements with different mechanical meaning. Figure 1 shows the basic scheme of such systems (bold letters denote vectors). The upper left block represents the vehicle with an input $\mathbf{u}$ (like angular rates) causing the vehicle movement. This motion is described by a certain set of state variables $\mathbf{x}$. Based on $\mathbf{x}$, the upper right block provides a first set of data, the "aiding" measurements. A second set of data (representing $\mathbf{u}$) is gained through a device denoted by inertial measurement unit (IMU), which comprises especially inertial sensors. Based on $\mathbf{u}$, the component "vehicle model", containing a mathematical representation of the vehicle kinematics, determines an estimate $\hat{\mathbf{x}}$ for the unknown state $\mathbf{x}$. The block marked with "aiding model" imitates the generation of the first measurement group to derive estimates $\hat{\mathbf{y}}$ from $\hat{\mathbf{x}}$. Finally, the "control" block has the task to minimise the differences between $\mathbf{x}$ and $\hat{\mathbf{x}}$ using the aiding of the comparison result $\mathbf{y} - \hat{\mathbf{y}}$. (Wagner and Wieneke (2002) give additional background information.)

Typically, the design of the "control" device is part of an extended Kalman filter layout (Gelb, 1989). Following usual notations for the filter, the general estimation formulation of the vehicle model is a set of nonlinear differential equations

$$\dot{\hat{\mathbf{x}}} = \mathbf{f}(\hat{\mathbf{x}},\mathbf{u}) \quad , \qquad (1)$$

which have to be solved numerically. The aiding model reads accordingly:

$$\hat{\mathbf{y}} = \mathbf{h}(\hat{\mathbf{x}},\mathbf{u}) \quad . \qquad (2)$$

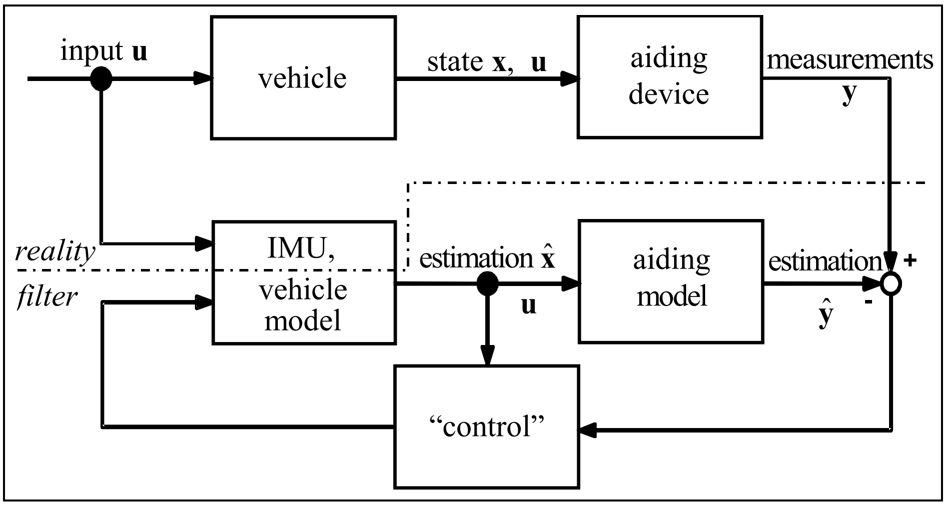

Figure 1. Basic data fusion principle of integrated navigation systems.

The main design task for the measurement system of the ankle exercise board is to choose the vectors **u** and **y** and to formulate the functions **f** and **h** as given below.

Measurement System Design

The ankle exercise board is in fact an oscillating hemisphere. Approximately, there is no sliding movement where the device contacts the floor. Thus, it is possible to model the board as a rigid body with only (three) rotational degrees of freedom. This means that the motion measurement system has solely to determine the attitude of the board. As the angular rate of the board is rather high, the use of classical inclinometers is not advisable (see below). Instead, the system design started out from the following assumptions:

- recording of the angular rate vector by three low cost micro-mechanical gyros,
- considering the direction of gravity measured by three low cost accelerometers,
- estimation of approximately constant scale factor corrections for all sensors.

These points mean that the attitude determination includes an aiding of the tilt angles by processing the accelerometer signals. In addition, an online calibration of the low cost sensors shall improve the accuracy.

To derive the functions $\mathbf{f}$ and $\mathbf{h}$, Figure 2 contains the essential geometric variables and parameters of the board: At first, two co-ordinate systems are introduced – the body fixed $\xi\eta\zeta$-frame and the floor fixed XYZ-frame. Because of moderate accuracy requirements (≈ 1°) and the use of low cost sensors, the latter shall be regarded as an inertial system. P is the point where the hemisphere touches the floor, M and ρ are the middle and the radius of the section circle, C is the board's centre of gravity, and the distance between C and M is d. $\mathbf{g}$ marks the gravity (direction of the local vertical), and A the position of an accelerometer.

Following usual definitions of mechanics, three Euler angles ϕ, θ and ψ describe the attitude of the board. (The θ-rotation axis is intermediate between the Y- and the η-axis and is not depicted in Figure 2.) These angles are the first three state variables. Wertz (1985) provides the relation between the time derivatives of the angles and the measured angular rate vector $\mathbf{u} = \boldsymbol{\omega}$ (expressed in body fixed co-ordinates $[\omega_\xi, \omega_\eta, \omega_\zeta]^T$). The additional inclusion

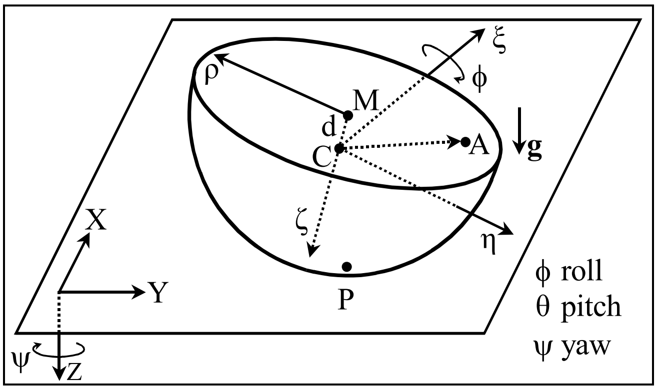

Figure 2. Geometry and co-ordinate frames of the ankle exercise board.

of scale factor corrections $x_4, \dots, x_9$, which are, as mentioned, approximately constant and equal to one, leads to $\mathbf{f}$:

$$\dot{\mathbf{x}} = \begin{bmatrix} \dot{\phi} \\ \dot{\theta} \\ \dot{\psi} \\ \dot{x}_4 \\ \vdots \\ \dot{x}_9 \end{bmatrix} = \begin{bmatrix} x_4\omega_\xi + x_5\omega_\eta \sin\phi \tan\theta + x_6\omega_\zeta \cos\phi \tan\theta \\ x_5\omega_\eta \cos\phi - x_6\omega_\zeta \sin\phi \\ x_5\omega_\eta \sin\phi / \cos\theta + x_6\omega_\zeta \cos\phi / \cos\theta \\ 0 \\ \vdots \\ 0 \end{bmatrix} . \qquad (3)$$

The accelerometers are the aiding signal sources. To obtain the corresponding function $\mathbf{h}$, the rolling motion of the hemisphere on the floor is authoritative. Denoting for instance the 'inertial' velocity vector of point A with $\mathbf{v}_A$ and for example the vector from M to A with $\mathbf{r}_{MA}$, the corresponding derivation reads:

$$\mathbf{v}_P = \mathbf{v}_M + \boldsymbol{\omega} \times \mathbf{r}_{MP} = \mathbf{0} \quad \Rightarrow \quad \dot{\mathbf{v}}_M = \dot{\boldsymbol{\omega}} \times \mathbf{r}_{PM} \qquad (\text{as } \mathbf{r}_{MP} \text{ is constant and } \mathbf{r}_{PM} = -\mathbf{r}_{MP}),$$

$$\mathbf{v}_A = \mathbf{v}_M + \boldsymbol{\omega} \times \mathbf{r}_{MA} \qquad \Rightarrow \quad \dot{\mathbf{v}}_A = \dot{\mathbf{v}}_M + \dot{\boldsymbol{\omega}} \times \mathbf{r}_{MA} + \boldsymbol{\omega} \times (\boldsymbol{\omega} \times \mathbf{r}_{MA}).$$

Eliminating $\dot{\mathbf{v}}_M$ from the second differential equation by the first one leads to the acceleration of point A. As an accelerometer senses also the negative gravity, the measurement vector is:

$$\mathbf{a}_A = \dot{\mathbf{v}}_A - \mathbf{g} = \dot{\boldsymbol{\omega}} \times \mathbf{r}_{PA} + \boldsymbol{\omega} \times (\boldsymbol{\omega} \times \mathbf{r}_{MA}) - \mathbf{g} . \qquad (4)$$

Only that component of $\mathbf{a}_A$ is of interest, which coincides with the relevant sensor input axis. This results in a scalar equation, which must also include a multiplication by x_7, x_8 or x_9 respectively. The function $\mathbf{h}$ consists of such relations (one for each accelerometer), considers herewith the sensor distribution, and is a function of $\dot{\boldsymbol{\omega}} = \dot{\mathbf{u}}$. (Within the bounds of the design, the determination of $\dot{\boldsymbol{\omega}}$ is achieved by numerical differentiation.)

Testing the Measurement System

A plain way of testing the system approach is filtering artificial measurements generated by means of simulating the board dynamics. Thus, falsified sensor signals of $\mathbf{u}$ and $\mathbf{y}$, using wrong scale factors and additional white noise according to sensor specifications, formed the basis for the adjustment and testing of the Kalman filter. The error parameters were consistent with the data sheets of the sensors chosen for the system realisation:

- Gyros: Murata ENV 05D (range: $\pm$ 1.4 rad.s^{-1}, relative accuracy $\approx$ 10%),
- Accelerometers: Seika B1 (range: $\pm$ 3 g, relative accuracy $\approx$ 1%).

Typically, such a simulation consists of numerically solving a certain system of ordinary differential equations. For the derivation of the required mathematical relations (which is a classical task of mechanics), the principle of d'Alembert for nonholonomic systems was used (Müller & Schiehlen, 1985; Schiehlen, 1986). Denoting with m the board mass, with J_1 and $J_1 + J_2$ the main moments of inertia, and with c a damping coefficient (to model a slight friction), the result for free oscillations of the board on the floor reads:

$$\begin{bmatrix} \dot{\phi} \\ \dot{\theta} \\ \dot{\psi} \end{bmatrix} = \begin{bmatrix} (\cos\psi\ \omega_x + \sin\psi\ \omega_y)/\cos\theta \\ -\sin\psi\ \omega_x + \cos\psi\ \omega_y \\ (\cos\psi\ \omega_x + \sin\psi\ \omega_y)\tan\theta + \omega_z \end{bmatrix}, \tag{5a}$$

$$\begin{bmatrix} \dot{\omega}_x \\ \dot{\omega}_y \\ \dot{\omega}_z \end{bmatrix} = (\mathbf{J} + m\mathbf{L}^T\mathbf{L})^{-1}(m\mathbf{L}^T(\mathbf{g} - \mathbf{G}\boldsymbol{\omega}) - c\boldsymbol{\omega} - (\boldsymbol{\omega} \times \mathbf{J}\boldsymbol{\omega})), \tag{5b}$$

with: $\mathbf{J} = J_1 \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} + J_2\mathbf{j}\mathbf{j}^T$, $\mathbf{j} = \begin{bmatrix} \sin\psi\sin\phi + \cos\psi\sin\theta\cos\phi \\ -\cos\psi\sin\phi + \sin\psi\sin\theta\cos\phi \\ \cos\theta\cos\phi \end{bmatrix}$,

$$\mathbf{L} = \begin{bmatrix} 0 & -\rho + d\cos\theta\cos\phi & d(\cos\psi\sin\phi - \sin\psi\sin\theta\cos\phi) \\ -L_{12} & 0 & d(\sin\psi\sin\phi + \cos\psi\sin\theta\cos\phi) \\ -L_{13} & -L_{23} & 0 \end{bmatrix},$$

$$\mathbf{G} = \begin{bmatrix} 0 & \begin{matrix} -d((\cos\psi\sin\phi - \sin\psi\sin\theta\cos\phi)\omega_x \\ +(\sin\psi\sin\phi + \cos\psi\sin\theta\cos\phi)\omega_y) \end{matrix} & \begin{matrix} d(\cos\theta\cos\phi\ \omega_x \\ -(\sin\psi\sin\phi + \cos\psi\sin\theta\cos\phi)\omega_z) \end{matrix} \\ -G_{12} & 0 & \begin{matrix} d(\cos\theta\cos\phi\ \omega_y \\ +(\cos\psi\sin\phi - \sin\psi\sin\theta\cos\phi)\omega_z) \end{matrix} \\ -G_{13} & -G_{23} & 0 \end{bmatrix}.$$

As the yaw angle can not be aided by the direction of gravity, it is the most critical estimation variable. Thus, the following test results confine themselves to ψ. Based on simulation parameters typical for a customary ankle exercise board, Figure 3 presents a filtering outcome. The lines of the chosen filter configuration (dotted) and of the simulation reference (solid) differ only little. The deviations have an order of 0.1° and illustrate the suitability of the chosen system approach. However, omitting the estimation of the scale factor corrections (which means to reduce the number of state variables of equation (3) to 3) leads to a significant deterioration. Simplifying equation (4), which corresponds to replacing the accelerometers by inclinometers, has even a more adverse effect.

Necessarily, simulation based tests require a completion by processing real measurement data. For this, six sensors of the types given above were assembled as depicted in Figure 4. The signal recording was made by a PCMCIA-card of a laptop, which included an analog-digital-converter of six channels as well as the sensor power supply. To check the quality of the real data filtering, an independent, optical test procedure was applied. It consisted mainly of a high-speed camera with a picture rate of 60 Hz and a picture-processing tool. Figure 5 illustrates the experimental arrangement to check the estimation of ψ. In parallel to the camera, the inertial sensors recorded the manually excited board motion at a sample rate of 100 Hz. (This rate was chosen for all results presented here.)

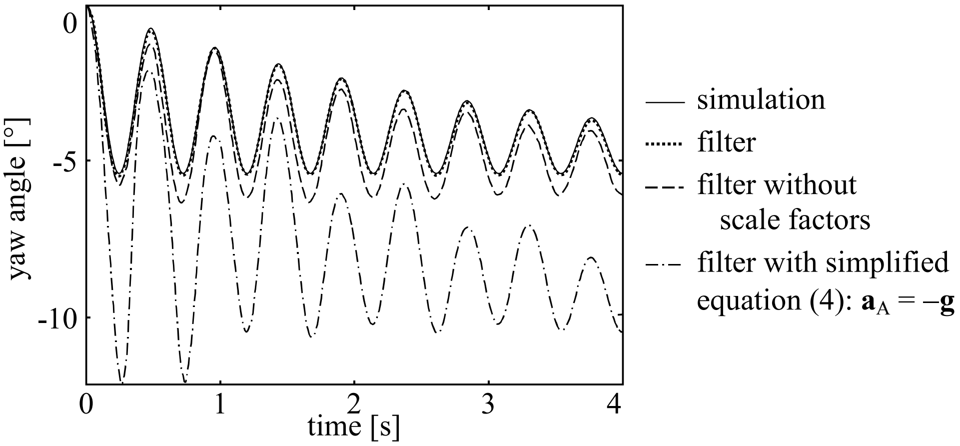

Figure 3. Yaw angle estimation with different filter variants.

Figure 6 contains the result of such a comparing measurement. The solid line represents the filter estimation of ψ, the dotted line corresponds to the picture-processing outcome. The difference between both curves is small (it is mainly caused by an incomplete sensor bias compensation due to the limited stability and the resolution of the used analog-digital-converter). Thus, the measurement system performance is sufficient for the intended use. (Wagner, Lippens, Nagel, Morlock and Vollmer (2001) present some more details about the system design, especially regarding a favourable sensor placement.)

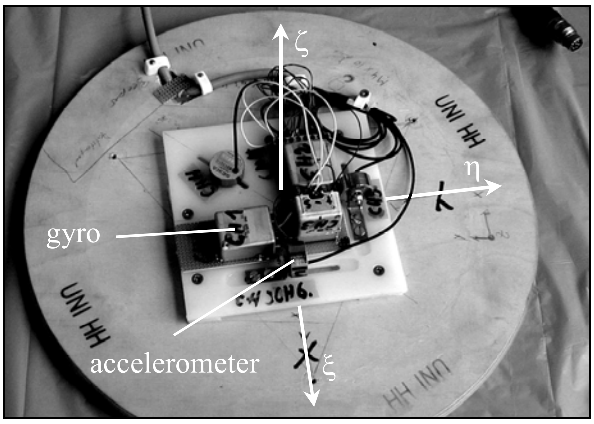

Figure 4. Realised sensor assembly.

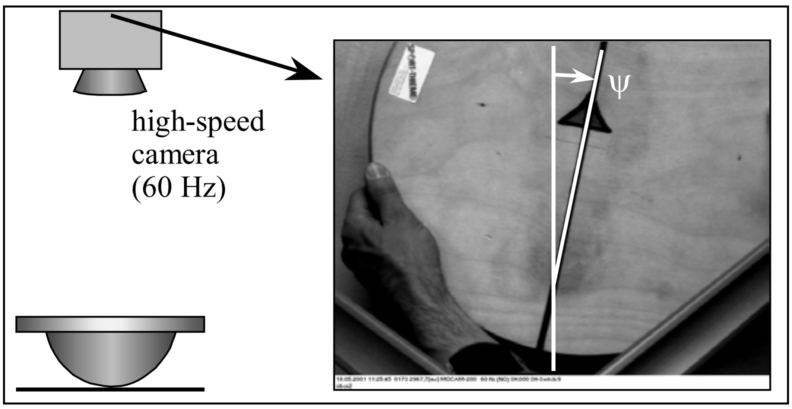

Figure 5. Independent reference measurement.

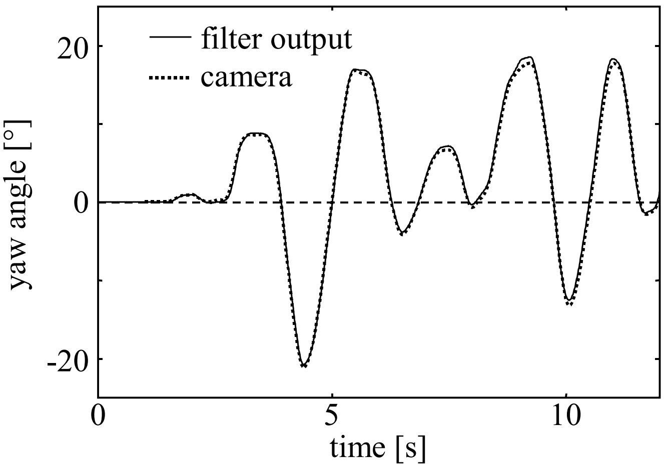

Figure 6. Comparison of the filter output and the independent reference measurement.

As an example of the normal use of the measurement system, Figure 7 shows finally a typical time series of the three Euler angles, which were generated during the test phase by an unpracticed subject.

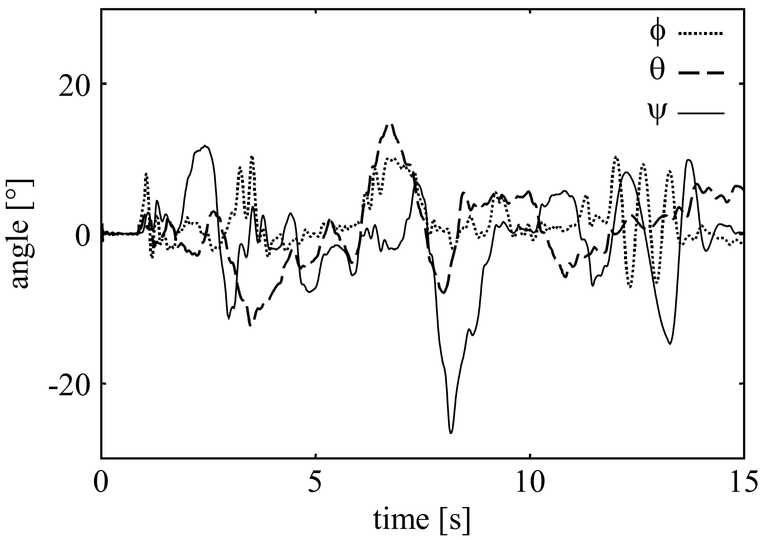

Figure 7. Typical time series of the Euler angles generated by an unpracticed subject.

Application Examples

To illustrate the application of the measurement system, two examples of investigating the effect of ankle exercise board training in rehabilitation of anterior cruciate ligaments and of ankle sprain injuries are presented. For this, a parameter of balance performance on the board was chosen, which is the ratio of the net balance time $t_{bal.}$ (of a total exercise period of 45 s) to the root mean square

$$RMS_{\phi\theta\psi} = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}((\phi_i - \overline{\phi})^2 + (\theta_i - \overline{\theta})^2 + (\psi_i - \overline{\psi})^2)} \qquad (6)$$

(Lippens, Nagel & Wagner, 2002). In this formula, the number of samples for each angle is n, the sample index is i, and $\bar{\ }$ denotes average values.

In a first study, the subject, a woman handball player of an upper performance level, suffered from an anterior cruciate ligament (ACL) in her right knee. The initial measurement of the balance performance (19.12. in Figure 8) was taken in the course of the first rehabilitation measure as soon as she was allowed to put a strain on the injured leg (the all day rehabilitation measure of 4 hours per day lasted for 2.5 months). A second measurement at the end (23.1.) completed this phase. Then, a one-month strength training followed (3 times per week). Before admission to the team training, a third measurement (21.3.) was carried out.

The development of the balance performance according to Figure 8 shows the efficiency of the rehabilitation and facilitates a quality assessment concerning the effect on the traumatized but also on the uninjured leg.

In a second study a soccer player received a special strength training because of a lateral ankle sprain in his right foot. The measure required him, morning and evening, to do his daily routine of brushing his teeth on an ankle exercise board. Three weeks after the initial measurement a control investigation was made, and again three weeks later a concluding third measurement took place. A retention study followed after three extra weeks.

Additionally, the opportunity existed to measure the subject's performance after he had been on a subsequent skiing excursion in the framework of his sport studies. Because distinctive features revealed in the improvement of his balance performance on the measurement board, a second retention test was carried out. On the one hand, the development of the scores in Figure 9 shows the effect of the strength training, on the other hand, it shows the (unexpected) influence of daily skiing on stabilizing the ankle joint. At least for the traumatized leg, however, this could not be maintained.

As shown in several pilot-studies (Lippens & Nagel, 2001), the balance performance improves if in everyday routines periods of standstill are used as exercise units. To achieve this aim, the six participants of an other study had also the task to balance on an ankle exercise board every day while brushing their teeth. Subsequent to an initial measurement (τ_1 in Figure 10) two control measurements (τ_2, τ_3) followed after intervals of three and two weeks respectively. A retention measurement (τ_4) after another five weeks, without brushing

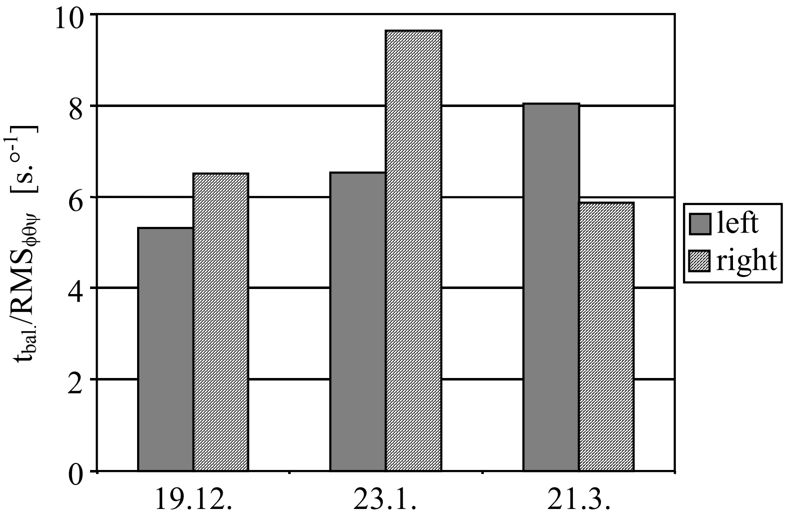

Figure 8. Effect of rehabilitation on the balance performance of a subject with ACL-injury in the right knee (19.12.: pre-test, 23.1.: post-test, 21.3.: retention).

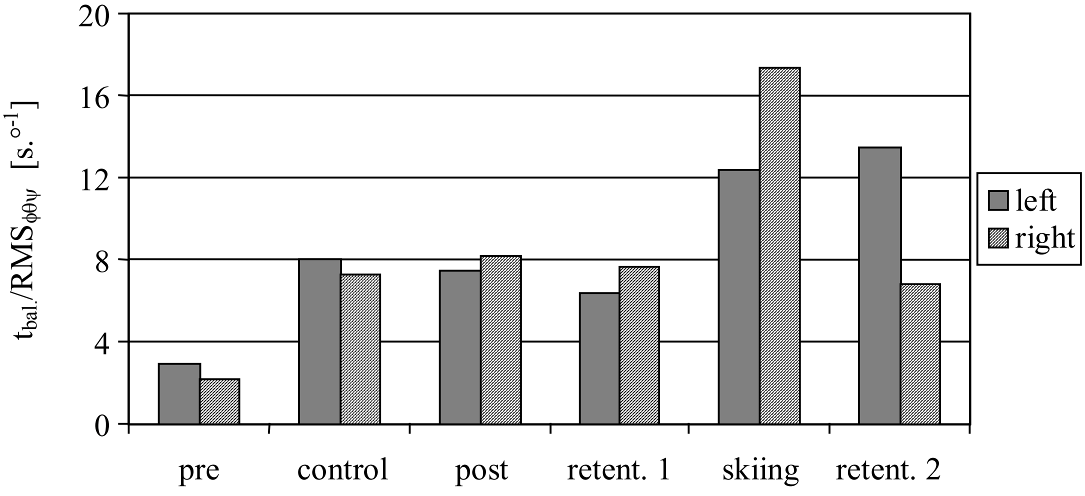

Figure 9. Effect of ankle exercise board training on the balance performance of a subject with ankle sprain (right foot).

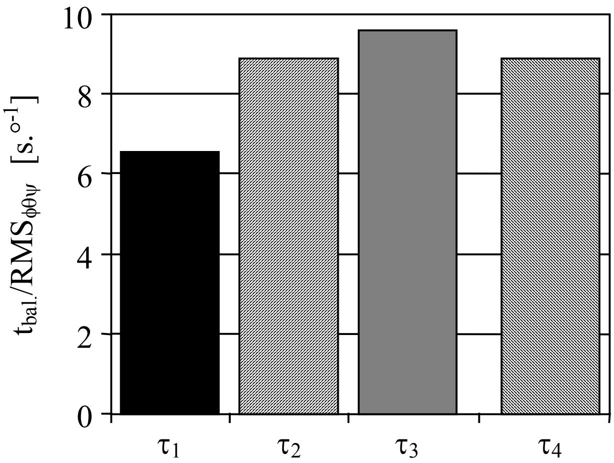

Figure 10. Increase of balance performance of six subjects with daily ankle exercise board training.

one's teeth on the board, illustrated how stable the increment had become.

Thus, if the standstill times of daily routine work are changed into well-balanced movement times (as for the given example), the balance performance can be markedly improved (Student distribution: $t_{\tau 1-\tau 3} = 2.485$ with $p < 0.05$) within a relatively short period of time (5 weeks between τ_1 and τ_3). It is, however, noteworthy that a comparable level of effects can not be maintained without further practice (another 5 weeks between τ_3 and τ_4).

Conclusions

With respect to quantifying specific human balance skills, and with respect to monitoring rehabilitation processes, it was possible to demonstrate the suitability of the developed measurement system for an ankle exercise board. Analogous investigations or assessment trials are feasible at a reasonable price as low-cost sensors were employed for the system design and test. Apart from a laptop, which is necessary for operating the apparatus, all system elements are placed inside the ankle exercise board. Correspondingly, the system usage is very simple, is not restricted to the certain environment of a laboratory, and does not require any specific installation procedure. Thus, an ankle exercise board which is equipped with the measurement system described above can serve as a flexible and cheap device for evaluating rehabilitation measures and training effects.

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The use of modern multibody-system (mbs) software in sports biomechanical education

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Abstract

The paper addresses possibilities of using modern multibody-system (mbs) software in sports biomechanical education. Several prototypical models with different complexity will be described. The first type contains mechanical models which can be used to clarify mechanical laws. This models are not of necessity biomechanical models. Another type deals with simple basic models of sporting movements and the third type handles complex mechanical models of living systems. Each of this models is suitable for different purposes in biomechanical education. The use of mbs-software simplifies the modelling but there are some risks which have to be discussed.

Introduction

The use of material models in physics education has a long tradition. A look to older physics literature shows a lot of excellent easy material models. In many cases it seems the more easy a model is the more easy is the understanding what the model describes. If we have a look to kinetic and kinematic chapters in the common physics literature we find a lot of examples referring to sports (e.g. Cutnell & Johnson, 2001). Not only in physics education but also in biomechanical education it is worthwhile to use models. The use of material models is very well – in many cases they are very impressive - but there are also some problems. One is the standardizing of the model with regard to reliability. Another is the recording of interesting values. Moreover the storage of material models is in many cases the main problem. The solution of this problems is the use of sophisticated simulation software. Many of the material models which are suitable for biomechanical education can be built by using mbs-software. Such models are named virtual models. In the following different types of (biomechanical-) virtual models will be described and rated regarding biomechanical education.

Necessary conditions

The most important condition is the existence of an appropriate mbs-software. A survey on the common tools shows many solutions which differ in costs and possibilities of modelling and simulation. It depends very much on the complexity of the modelling problem which mbs-software should be used. Even the smallest solutions are suitable for building simple models. For modelling very complex biomechanical systems higher sophisticated mbs-tools are required.

Mechanical models

The first type of models is alike the models we can find in the physics literature. This models are not of necessity biomechanical models. The advantage of such models is the reduction of complexity so that fundamental principles of physics can easily be understood. Newton's

third law of motion should be an example in the following description how to build and how to use virtual models.
The often called action-reaction law states that whenever one object exerts a force on a second object the second object exerts an oppositely directed force of equal magnitude on the first object. Based on the knowledge of Newton's second law which states that, when a net force **F** acts on an object of mass *m*, the acceleration **a** of the object is given by **F**=*m***a.** A model of two bodies which are linked with a linear spring (cp. figure 1) is a possible demonstration of Newton's third law. Further characteristics of this model are the absence of friction, the possibility to change the masses and the possibility to change the spring constant. With this model one can make virtual experiments with the behaviour of the two bodies depending on the variables.

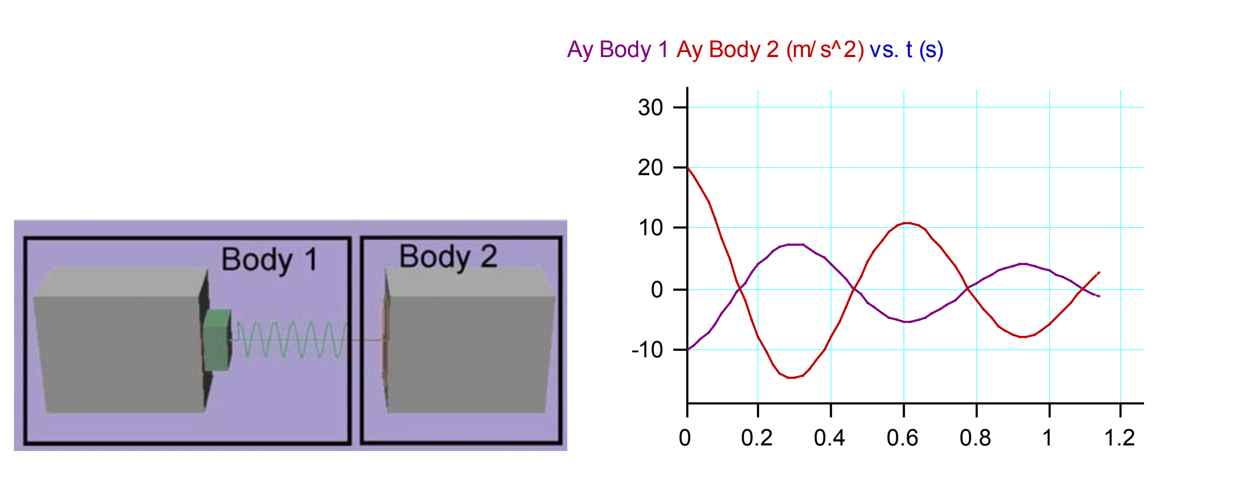

Figure 1. Two bodies (mass of body 1 = 2*mass of body 2) linked with a linear spring demonstrate the action-reaction law

One of the experiments can be the systematic change of the masses. The following examples demonstrate some reasonable situations. It is possible to simulate the situation that a body with a small mass e.g. a football pushes against a very big mass e.g. the earth. It can be seen that the acceleration of the earth is very small. Furthermore the calculation of the product of the force acting on each body shows that they are of oppositely direction and same magnitude. If we define the two masses in a way that they represent a bicycle and a trick cycling athlete it can be experienced that it is very difficult for the athlete to push off from the bicycle for example to realize a summersault.
The advantage of using such experiments is that students can make easy experiments with fundamental physical phenomenon. In doing so it seems to be important to relate the experiments to real life situations of sports.
Virtual experiments with fundamental physical phenomenon can be found meanwhile on various internet sites. So in many cases it is not necessary to design own solutions.

Basic models of sporting movements

In most of the cases sporting movements are very complex investigation objects. Because that it is necessary to have a look to basic movement principles which lead to a fundamental understanding how the movement functions. A demand which should be put into action is the transfer of biomechanical knowledge to problems in practical sports. If biomechanical education is only an academic theoretical education most of the students don't get a reference to the fascinating world of biomechanics. One of the ideas that students are able to appreciate biomechanics is to reflect on basic models of sporting movements. Two examples should explain how to profit from such models.

Jumping

In all sporting disciplines jumping is a very complex action. To understand the principles of different situations in jumping a simple model should be used. This model contains one mass which represents the body of an athlete and a spring damper unit combined with another mass which represents the legs (cp. figure 2). In the following the focus is set on long and high jumping. One of the most important characteristics in high an long jumping is the fact that the leg which is used for takeoff works like a lever. Just before the leg touches the floor the body has typical initial conditions which can be described by the touchdown angle, the horizontal and vertical speed (cp. Lees, Graham-Smith & Fowler, 1994). Depending on the force of the leg modelled via spring damper unit and the initial conditions it will result a specific take off angle and a vertical and horizontal speed. The mbs-simulation of such a model leads to the following results:

a) the touchdown angle must be adapted to the spring characteristic. If the force is small the touch down angle should be also small.
b) in high jumping it should be used a smaller touchdown angle as the touchdown angle which is appropriate for long jumping (cp. figure 3).

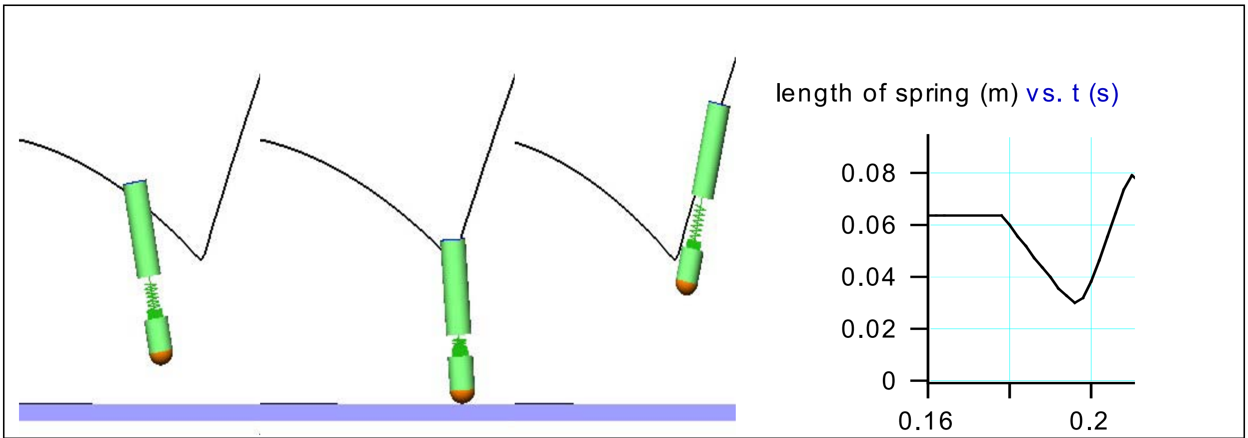

Figure 2. Jumping model (one mass and a spring damper unit)

The illustrated model is very easy to understand and it is very easy to build. Even undergrade students are able to handle such a model. But building a model and making simulations is only one part of using mbs-models. In the same way it must be reflected on the validity of mbs-models. Regarding the jumping model it must be noted that the validity of the statements e.g. is restricted because the human leg works only approximately like a spring.

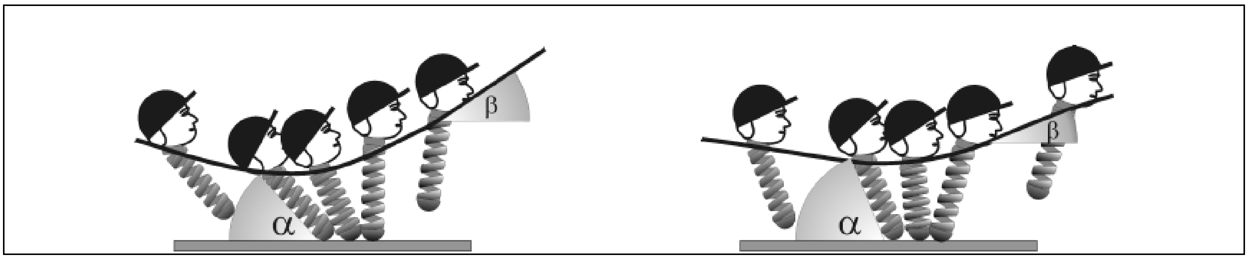

Figure 3. Different touchdown and takeoff situations in high jumping (left picture) and long jumping (cp. Göhner, 2002)

Eccentric and central collisions in volleyball services

The fundamental model for eccentric and central collisions in volleyball services describes the collisions of two bodies one with the size of a volleyball the other with a estimated size of a hand. The body which represents the hand is modelled via a cuboid. With this model one can make experience with fundamental kinds of collisions (cp. figure 4). The knowledge we get by this is very important when simulating collisions in volleyball services.

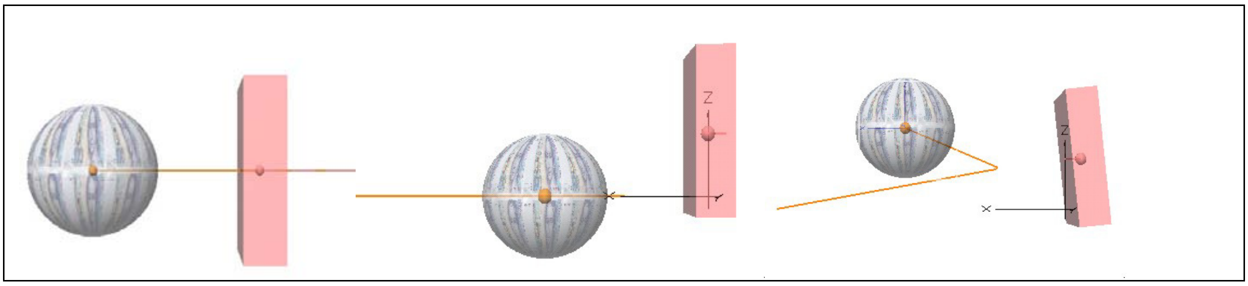

Figure 4. Fundamental kinds of collisions

For the approximation to the situation in volleyball services we have to develop the model. A first step can be the modelling of a more realistic mass distribution. When reflecting the theoretical foundations of collisions one can see that the masses of the colliding bodies are one of the main factors in calculating the results. The determination of the volleyball mass is no problem. On the other side well known human models like the Hanavan model or the model of Zaziorski can be used for a more realistic mass distribution. This models must be changed a little. The hand e.g. of the Hanavan model is a ball which should be substituted by a cuboid. The advantage of this developed model is that when a collision between the hand of the human model and the volleyball takes place we get more realistic impulses of the bodies after the collision (cp. figure 5).

With this model we can investigate all colliding situations assuming that the hand and the wrist are rigid. Another assumption must be that the collision point is in the middle of the hand and that the volleyball is not deformable.

The next step of modelling can be the implementation of a joint which include the ability of the wrist to make a dorsal (palmar-) flexion and a joint which includes the ability of supination and pronation (it must be a substitute joint in the wrist or elbow). This development allows to investigate situations if the volleyball is not hit in the middle of the hand and if the wrist is not rigid.

If we reflect more detailed the real situation of collisions between the volleyball and the hand we recognize that a more detailed model of the hand is necessary. What happens in collisions if the different parts of the hand are not fixed? What happens if only some parts are not fixed e.g. the fingers? What happens if the hand is not flat? This and many other questions can only be answered if we use a model of the hand which is made of the main flexible parts like the thumb, the fingers, the metacarpals and the carpus. This example demonstrates that the more specific the problem we want to solve is the more detailed must be the model. In the upper case if we want to simulate the work of muscles we additionally have to implement other important structures of the hand like muscles, tendons and ligaments. Such models which depicts biological structures are biomechanical models in a narrower sense.

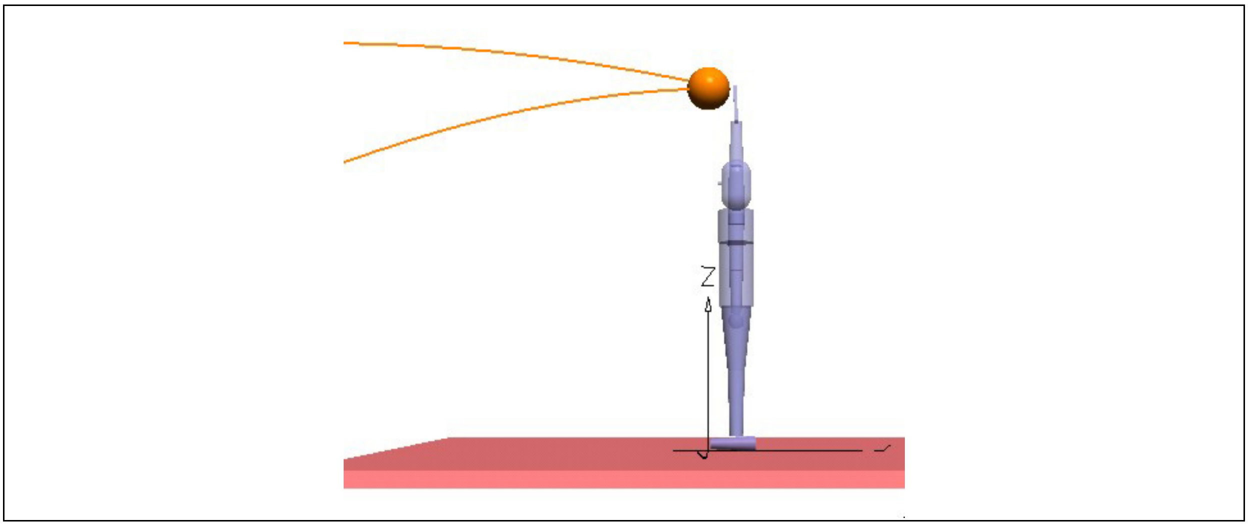

Figure 5. Collision between the hand (modified) of a Hanavan model and volleyball

Biomechanical models

An interesting biological structure of the human are the muscles which are working in combination to move the hip joint and the knee joint. As early as the 20th century Lombard (1903) demonstrates that the knee flexors can act in a paradox way as extensors (cp. figure 6 and figure 7).

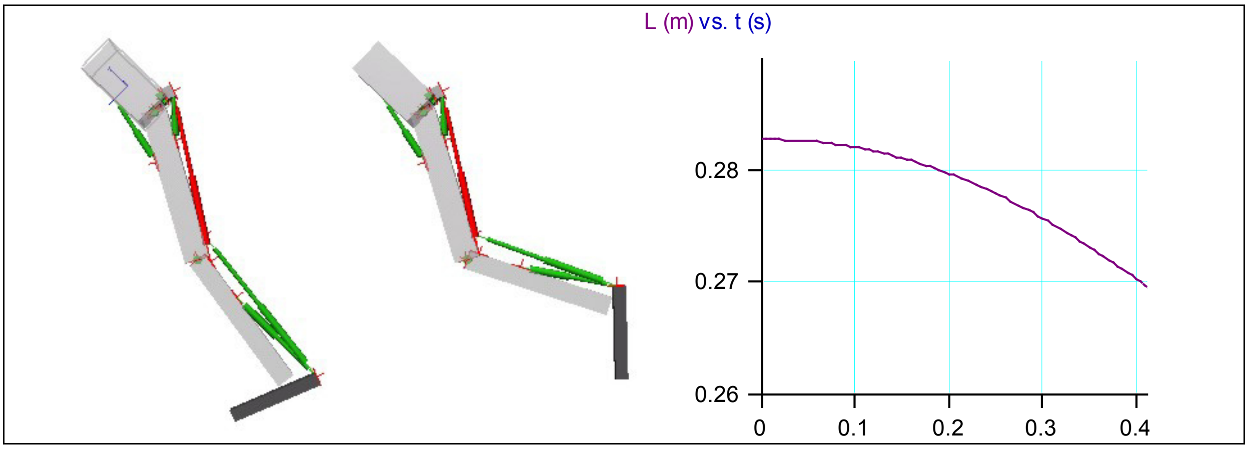

Figure 6. Model of under limbs shows a flexion of the knee when the hip is fixed – the graph shows the length of the substitute muscle (red colored) at the start position and at the end position.

This happens if the distal segments are fixed like it is e.g. in running or cycling and if the knee joint are specific (cp. Wiemann, 1991; Gregor, Cavanagh & LaFortune, 1985). To simulate the Lombard Paradoxon we have to implement biological characteristics like anthropometrics and muscles in a model of the under limbs. In reality there are seven muscles (m. semimembranosus, m. semitendinosus, m. biceps femoris, m. gracilis, m. sartorius, m. politeus, and m. gastrocnemius) which normally act as knee flexors. For the demonstration of the Lombard Paradoxon the muscles m. semimembranosus, m. semitendinosus, m. biceps femoris can be substituted by one muscle.

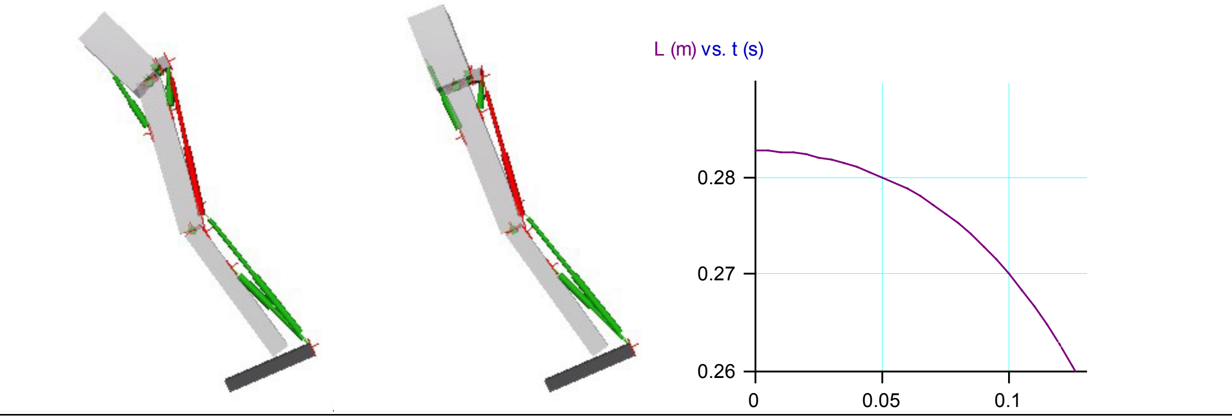

Figure 7. Model of under limbs demonstrates the Lombard Paradoxon – the extension of the knee - when the foot is fixed.

Mathematical-physical basics of multibody simulation

The use of complex powerful modelling tools will lead to several risks if various basics are unknown. The following discusses several necessary basics which should be an essential content of the biomechanical education in sports. Without these basics a meaningful simulation of sporting movements will probably not be performable.

Mathematical basics

The calculation of multibody systems based on the use of ordinary differential equations (ODE) and differential algebraic equations (DAE). The numerical implementation of these equations in mbs tools will lead to the fact that the accuracy of every simulation is limited. Students don't have to know these equations in detail but they should recognize that the following has great influence to the result of the calculation. The exact determination of initial conditions (e.g. position, impulse, momentum) is very important. Because of numerical integration principles (e.g. integration step, integration method) the result of a simulation can differ totally when the initial conditions are different. A very simple pictorial example is an inverted pendulum which is located not exactly with the centre of mass above the standing position. The example represents a canonical initial value problem, where the behaviour of the system is described by an ordinary differential equation of the form $\dot{x} = f(x,t)$. f is a known function, x is the state of the system, and $\dot{x}$ is the time derivation of x.
Another important factor is the integration method which are supported from modern mbs tools. A very simple method is the Euler integration. Let the initial value for x be denoted by $x_0 = x(t_0)$ and the estimate of x at a later time $t_0 + h$ by $x(t_0 + h)$ (h is the determined integration step) The Euler integration leads to the equation $x(t_0 + h) = x_0 + h\dot{x}(t_0)$. The advantage of the Euler algorithm is that it is very fast but the problem is that it is less accurate. Another algorithm e.g. the Kutta-Merson integration (cp. Fox, 1962 S. 24-25) is not as fast as the Euler integration but it is more precise. The integration method to choose depends highly on the required precision which is needed for the calculation of the model. The equation above shows also that the precision of the simulation depends on the integration step. If the process which should be simulated is very short (e.g. a collision) the integration step has to be small enough otherwise the simulation cannot be enforced.

Physical basics

In the same way like some mathematical basics should be known there are various physical basics. These basics can be divided into three categories: 1) rigid bodies and their

characteristics 2) kinematic and physical connections and 3) external forces and momentums which act on a system of rigid bodies.
Category one contains all the knowledge about principle characteristic of rigid bodies like mass, centre of gravity, density, moment of inertia etc. Additionally material characteristics like coefficient of static friction, coefficient of restitution, Young modulus, shear modulus etc. should be reflected.
Category two deals with different connections between rigid bodies. It can be distinguished between kinematic (e.g. a stiff rod) and physical connections (e.g. a linear spring, dampers, revolute motors, linear actuators etc.).
Category three refers to external forces and momentums which act on a system of rigid bodies. For example if a model of the human being represents a system the ground reaction force which acts on the system is an external force.
There are two generally approaches to build a dynamic model (cp. Schilling, 1990 S. 220-225) which should be known by students. The first is the inverse dynamic. Using this approach we give the kinematic data of a movement and the calculation of the model leads to the forces and momentums which are needed to produce the given kinematic. The second approach – the forward dynamic - calculates the kinematics of a movement based on the defined forces and momentums. This approach is normally used when we want to make predictions regarding the effects of actions and action modalities.

Modelling basics

Knowing the necessary mathematical and physical basics students are not yet in the position to build models of sporting movements and sporting athletes. An additionally difficulty when starting the modelling is to reflect on different characteristics of the model (cp. Stachowiak 1973, Bossel 1994). What is the purpose of the model? What is the area of validity of the model? Who is the user of the model? How should reality be reduced to a model? Only when all these question have been clarified it should be possible to build a model.

The future of mbs tools in sports biomechanics education

If we think about the possibilities to build models which represents typical human structures we recognize, that the concept of rigid bodies is not enough. The human body has a lot of flexible structures (e.g. bones) which are difficult to be modelled via rigid bodies (e.g. with super elements of rigid bodies and torsion springs). A better approach is the concept of flexible bodies (cp. Schwertassek & Wallrapp, 1999) which allows the modelling of large deformations (small deformations can be modelled via finite elements). In the near future we will find mbs tools which covers such possibilities.

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"Wassersportwissenschaft online" – Theoretical thoughts and practical experiences on the way to a virtual learning environment

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Abstract

The project "Wassersportwissenschaft online" is a virtual learning environment that has been developed as a support of direct learning within the framework of the theory- practical classes in regard to the marine sports rowing, canoeing, sailing, and surfing in the sports science faculty at the University of Hamburg.

In this article we want to reflect on our concrete experiences with the concept, realisation and also the use of the named learning environment leading from theoretical learning suppositions and general expectations to the use of virtual learning environments.

Besides the depiction of didactic-methodical decisions that are mainly orientated on the theory of constructivism which gives the elements construction, collaboration and reflection a central status with regard to the design of a learning process (cf. Hron/Hesse/Reinhard/Picard, 1997; Fischer/Bruhn/Gräsel/Mandl, 1998; Reinmann-Rothmeier/Mandl, 1999), we are especially going to have a closer look at practical experiences within the framework of the realisation. This area consists of two parts on the one hand thoughts in allusion to the programme structure, content and elements of interaction and on the other hand the suitability of certain file formats for the integration of multimedia content.

Theoretical basis

Multi media stands for a well-aimed, simultaneous or time shifted usage of different media (text, graphic, audio, animation, video) which serves to pass on a project or an idea. Multi media usages serve to pass on or depict information and are normally not connected with the theoretical concept. Whereas hypermedia -a word creation out of „hyper“ coming from hypertext and „media“ coming from multi media- adds the possibility of non linear links.

For learning and practical training virtual learning environments which in the ideal case allow active learning, experimentation and independent checking of the own accomplishments are mainly relevant. The documentation, a digital archive of data in different media, is at the same time completed by certain supportive offers. This can be hyperlink collections, simulations, search functions within the texts, video sequences of sequences of movement, etc.

Just through using multi media and hyper media the human learning will not become more efficient. Under certain preconditions they can however have a supportive function for the human learning process. For the sensible use of virtual learning environments learning psychological, pedagogical, and methodical-didactical competences are needed.

The basis of learning in learning environments consists of learning theories, three of which will be presented in the following text. We will pay special attention to constructivism because its learning theoretical background is a basis for the realisation of the „Wassersportwissenschaft online“ learning environment.

Learning by reinforcement (behaviourism)

The behaviourism theory by Pawlow (classical conditioning) assumes "that certain stimuli (Stimuli=S) are followed by certain behavioural responses (Response=R) and that such S-R connections form chains (pair associations) and can be habituated in such a way, particularly if there follows a reward to reactions that are wanted (right) whereas unwanted reactions stay without reward and are erased by this method (cf. Schulmeister 1997, 93).

The brain is seen as an organ that reacts to stimuli with given (innate or learned) behavioural patterns. The processes that take place in the brain hardly interest the behaviourists.

Learning programmes that are characterised after the behaviourist theory react immediately on the learner's behaviour and give a direct response. The learning aims are set without room for questioning them and are proofed by help of question-answer-combinations. Such learning programmes are often typewriter or vocabulary learning programmes.

Learning by insight and discovery (cognitivism)

In contrast to behaviourism cognitivism focuses on the complex processes that take place in the brain; understanding and describing the rules is very important (cf. Thissen 1999). Learning in the cognitive sense is seen as an active, dynamic process of information processing that also includes interpretation und assessment of the offer of information. It is not important to train right answers or actions but to acquire right methods for answering and problem solving skills (cf. Thissen, 1999).

Learning programmes that are based on cognitivism offer an accompanied start (e.g. through a tutor) into a topic and show the learner on the basis of real situations connections and procedures.

Examples for such learning programmes can be found in behaviour training in the job training sector or in programs with simulations for the driver's license training.

Learning by experiencing and interpreting (constructivism)

Constructivism regards the brain as an information processing system, too; - as an informational secluded and self organising system that uses most of its activities to be occupied with itself and just a small amount of activity to process information or stimuli from the outside world. This information is taken in by the sensory organs; they however do not give the brain any information about how things in the world are but just raw material that is interpreted and understood by the brain. Each single individual constructs itself its own reality which entails the creation of a variety of different realities (cf. Müller 1996). What we take in is therefore as such always our experiences with the world, not the world itself.

This means in regard to learning that learning is not a passive intake and saving of information and detections but an active process of knowledge construction. To learn something means to rework or to extent the construct within the head. In addition to that learning is an individual, self steered process which can be very different according to the previous knowledge (cf. Thissen 1999).

Knowledge is the basis for detection, thinking, and also action or rather accompanies the action. Knowledge is at the same time influenced regarding content and structure (cf. Bromme 1992, 10). Knowledge determines a) how things are perceived and b) how things are done, that means able to be done. Therefore knowledge determines c) which experiences are made, out of which new knowledge can be generated (cf. Hebbel-Seeger 1999, 23).

Learning can accordingly be the most successful in an active process in which new experiences and realisations change and personalise the individually existing knowledge and abilities as such. In this context, Keil-Slawik (1998, 84) talks about a "circle of understanding", which is formed by perception and action. Experimental orders, symbolic descriptions, pictures, modern forms of visualization, models and simulations are examples for how to create spaces of perception with technical or rather means of media.

Learning programmes that are based on the theory of constructivism differ from the programmes, that are based on the theory of behaviourism or cognitivism, especially because they lead the learner less and instruct or present him learning material less. They provide complex environments which give the possibility to try something, to occupy oneself intensively with topics and to discover contents and relations on ones own. With that a constructivism learning environment demands a lot of the learner, in particular of those who get involved in the learning environment and the learning situation (cf. Thissen 1999).
The didactic realisation of constructivism ideas is shows according to Dubs (1995) in the following characteristics:

1. Knowledge is constructed. There is no objective knowledge.
2. Regarding the content the lesson should be orientated on experience and problem sectors which are complex, true to life, close to the work world and viewed integrally. Not simplified models but reality (unstructured problems) should be looked at. Things are understood the best if they are taken in as a problem in the complex general view. Afterwards details should be viewed within a bigger connection and finally brought back into the general view.
3. Learning can only take place in an active process as the individual existing knowledge and ability is only changed and personalised as a whole from own new experiences and realisations. That means that learning has to be aimed at the individual interpretation and understanding.
4. Learning in groups is very important. The discussion of the individual interpretations and the personal understanding of possible solutions can contribute to thinking over or rather restructuring the insights.
5. Mistakes are important for learning. Only if mistakes occur in discussions and are then taken up and corrected a discussion in learning groups makes sense.
6. Complex learning fields should be orientated on the interests of the learners because it is the easiest to learn from experiences that are felt to be interesting or challenging.
7. Emotions and personal identification are very important because cooperative learning, dealing with mistakes in complex learning situations, self steering and individual experiences demand more than rationality.
8. The aim is an individual construct of knowledge and not a passive take in of knowledge and reproduction. For this reason the evaluation of the progress in the processes of learning may not be aimed at learning products; the progress in the learning processes and those in complex learning situations are to be tested.

Expectations from the use of virtual learning environments

On the one hand, "Multimedia" and "Hypermedia" are a mark of the different up to now separately used forms of media growing together. With that the possibility of a always free choice between different forms of media or simultaneous use is connected (cf. BLK 1990, 1). Hope is connected with this that the availability of the information will connect with the possibility to illustratively present courses and connections.

On the other hand, having the focus on the media side of virtual learning environments implies the danger of limiting the use of the new media to pass on animated information and therefore of throwing away the genuine potentials of the new media (cf. Kraemer/Millius/Scheer 1997, 9).

Schulmeister (1998) tries to outline these potentials by concentrating on the sector of learning. He assumes that through the support of well made learning programmes learning might take on the following characteristics: it

- is self determined in place, time and extent,
- supports the individual speed of learning,
- might be interactive
- enriches through new forms of learning and
- supports constructivism learning (cf. Schulmeister 1998, 45).

Furthermore the learner can decide himself how often he wants to repeat the subject material or parts of it. The computer is hereby the most patient and at the same time the most unforgiving teacher that exists (cf. Thissen 1997, 70).

Virtual learning environments shall not and cannot substitute the traditional teaching process but where it makes sense can be of use to use the potentials of electronic media as learning (and instruction) aid. In comparison to other media multimedia (or hypermedia) instruction and learning applications are special in two ways. First, the learners can individually according to their previous experiences and wishes determine the content and depth of information and can have an influence on the proceedings. Second, possibilities of testing different aspects of learning can be offered.

Learning environments have an encouraging function and a function of support. They encourage the learner by presenting learning requests and they support learning by presenting learning aids themselves or at request (cf. Friedrich/Eigler/Mandl et al. 1997, 9). With that the aim is the support of the learning process especially regarding the following aspects:

- Structure of content
- Influence on the way of learning
- Support of individual learning problems
- motivation
- Testing of the learning success (cf. Friedrich/Eigler/Mandl et al. 1997, 27f.)

Practical experiences with the concept and realisation of the learning environment

The production of the learning environment "Wassersportwissenschaft online" was lead by the wish to make the assignments and working results of the seminars for the students themselves as well as other interested persons available and accessible as easily as possible.

To serve this purpose we started in 1999 to collect students´ assignments from the different seminars of sports science which related to the topics of rowing, canoeing, sailing and surfing on a CD-ROM. The students were able to borrow this CD-ROM from the faculty library.

The different documents were saved on the data surface in different files according to the different classes. Those documents were handed in by the students in different text formats and therefore could not be recalled uniformly. To ensure an independent use regarding the platform and programme we integrated a HTML based surface under which the different works were integrated in the HTML format as well the next year. At the same time we wanted to ease the access to the documents so in addition to the CD-ROM the contents were provided through the internet. We completed the collection of students works` with hyperlinks to relevant water sport science websites.

Besides the difficulties of many students to draw up documents in HTML, a format which was so far only known to them from the reception side, most works were realised in "classical" formats of publication. That means that they did not use the elements of design which are given through the use of multimedia and hypermedia. In addition it was not easy to use the documents and provide them in the internet because they were not processed uniformly with regard to design (layout) and technical aspects (frameset, order, file names, etc).

Because of that we decided in a next step to use a presentation basis. With the aid of this basis, even students without knowledge in formation were able to process HTML based documents and add multi media elements such as pictures, videos or animations.

We however kept the possibility of access through the internet as well as CD-ROM because on the one hand not all students have access to an optimal computer with an internet connection that is fast enough and on the other hand the volume of data of the different applications is quite big because of the addition of audio and video sequence.

The current application

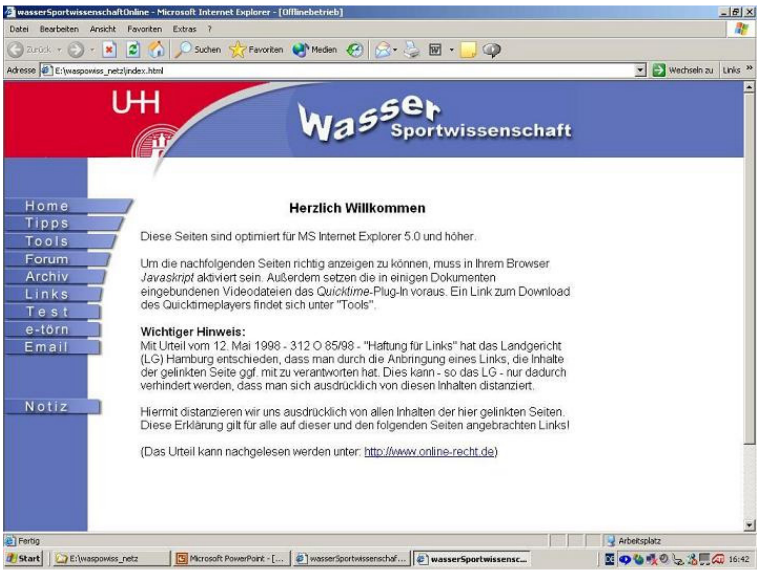

Figure 1: Front page of the learning environment "Wassersportwissenschaft online"

The experiences outlined above lead up to today to the production of an application with the following contents:

- "Home": The front page with advices about how to use the learning environment

- “Tips”: Advices about writing student assignments
- “Tools”: Presentation basis with help panel as well as freely distributable software as a file to download to write student assignments
- “Archives”: Collection of chosen student assignments of the past years
- “Links”: Collection of links that are important for sports science
- “E-Cruise”: interactive sailing simulation
- “Test”: Courseware with contents about the sports boot licence for inland waterways

The collection of links that are important for sports science in the area of water sports was given the students to use because it cannot be assumed that the current results of research are known to all students. Often they cannot be found through search engines. This additional information supports the active construction of knowledge through shifting out the important information through interpretation and comprehension.

As a learning aid especially when dealing with the filed students´ works there is a function for notes included. Here the users are able to include personal notes for the different contents in the form of a free text. The individual interpretation of the assignment helps to additionally support the learning process. If the acceptance of cookies is installed in the browser those notes will stay available for later usage. If not the inserted texts can be saved and printed out through the clipboard of every word processing programme.

The integrated function of research allows the whole text search of the filed students´ works with terms that can be randomly chosen. Therefore it is possible to select information in a way that was not intended by the student authors when preparing the information but only by the user. The whole text search was programmed with the aid of a Java – Applet. In contrast to a server based solution (with cgi/Perl) it offers the advantage of also using the search function with the CD-ROM version of the application.

This year “real” interactive elements were added to the learning environment, which are supposed to encourage students to carry out experiments and research on their own. One of those is “e-törn” (e-cruise) which is an interactive simulation of sailing. The students can try out different steering elements (sheet, tiller, weight of the crew) and their interaction regarding the control of a sailing system. Through altering different parameters of the system, the user is able to discover immanent structures and built a cognitive model or check the existing ones.

Figure 2: Interactive sailing simulation "e-törn" (e-cruise).

We also implemented a first example of courseware with multiple choice elements, drag&drop questions and cloze test. The students were able to independently work on different questions from the area of traffic regulations on waterways and therefore were able to reinforce and reflect the subject material.

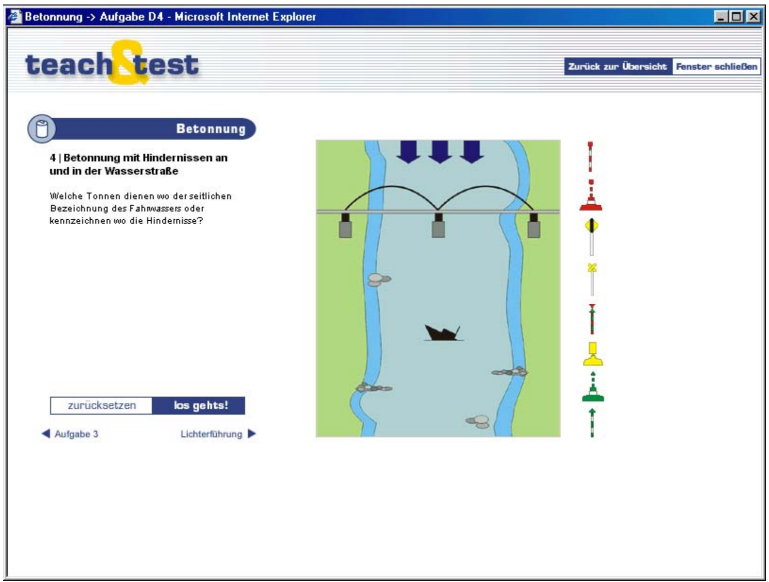

Figure 3: Example of the courseware "Teach&Test"

The presentation basis

The presentation basis is used as a foundation for the production of the students' works and the following presentation in class under the framework of the teachings of presentation. With this it is possible to arrange the students' papers in a more interesting way for the plenum with the help of different media. Traditionally transparencies are used for that because they are easy to produce. Transparencies however not only limit the use of media but in bigger numbers can become expensive fast. A second disadvantage is the impossibility to modify the content once they are produced. Formal modifications or modifications in terms of content that might only come to attention just before the lectures have to stay unchanged or can at least only be altered through another print out or photocopy. Compared with that, digital presentations offer a higher flexibility, higher possible variety of media and unlimited space. Through "Microsoft Powerpoint©" there is a widely spread, user friendly and powerful tool on the market but the programme is not freely available and therefore not for all students accessible. Furthermore it is possible to convert the file format in HTML but it does not allow the user to influence the design which makes it more difficult to publish the work later through the internet.

In our field of movement, sports and games multi media applications have a special importance because they are able to get close to a depiction of the complex object. Accordingly it makes sense to also replenish text based assignments with multi media contents for a better illustration.

The design and navigation within the basis are given. First of all this way the students can focus on the contents of the assignment without worrying about the design and/or technical aspects. Second the result is a uniform "look and feel" that especially comes into effect within the framework of collecting and publishing the assignments. In addition the content is planned to be distributed among different windows. Besides the main window there are windows for notes and comments which can be used for material like pictures, graphics, videos, etc. to illustrate the content. More than one of those windows can be opened at the same time to for example compare different sequences of movement that are described in the text.

Figure 4: Example of a students` work which was produced on the presentation basis

The navigation within the presentation works linear (backward and forward) through the arrows on the lower margin or the pull down menu besides them through which the different parts of the work can be steered for directly (see figure 4).

A further reason to use the basis of presentation is the already mentioned publication of assignments in the internet. Except the designation of individually included media the formation and names of the sides are already compatible defined and can be put into the internet without bigger efforts.

If there are video sequences included in the different assignments, they are filed in the movie format (Quicktime©). There are other file formats that sometimes have a better compression of data which would mean a smaller file size and therefore a shorter download time from the internet as well as so called "streaming" formats which can start to play the video before having finished the whole download. In our context however the movie format is the most impressive because it allows the user in addition to just playing the video sequences to determine the direction and speed of movement through a so-called “slider” (a kind of scrolling equipment on the lower margin of the video window). This way, crucial points of a movement can be studied with the movement of the mouse.

Practical experiences in using the learning environment

Working with the learning environment which has been described above the following consequences have become evident. (cf. Hebbel-Seeger i.D.):

- A higher quality of working material because the documents and materials do not need to be renewed every semester but can be extended, improved and updated. Furthermore a greater motivation of the students to hand in assignments of high quality because they are going to be published.
- A better organisation and management of the working material because the material is systemised according to the classes and types of documents. In addition the whole text search allows an individual and topic related access to the materials.
- A distributed and cooperative learning because the availability of the working material ensures a better combination of direct and correspondence learning. The wide local availability of the material makes the organisation of cooperative learning processes easier.
- An integration of additional media formats into the results of the works which are produced through the publications makes the depiction of complicated subjects like movements easier.

We tried to evaluate how the target group dealt with the described learning environment in the summer semester 2002 in a usability survey. The evaluation of the collected data is still under way but there are already first results that can be depicted:

Besides the positive consequences for instruction and learning that seem to be confirmed by the survey there were hints towards difficulties with the learning environment concerning its use which are mainly caused by the design of the user interface. In the teach ware “Teach&Test” there was for example a button with the inscription “Los geht´s” (Lets go) provided (see figure 3). With this the input of the user was tested whether it was correct. Most of the test persons however did not notice the connection between the button and the response about the correctness of their input at first.

Another difficulty was caused by a little window with information about the display and a link to the next page. The window closed itself after a few seconds because it was not needed any more after the user had clicked on the link. If the user however did not click on the link during that time and the window closed itself the user was left surprised and helpless.

The naming of the different categories of content which was kept short under design aspects to get names of about the same width also caused different associations within the test persons. Only few of them were able to imagine what was meant by the term “E-törn” (E-cruise).

The observations regarding the use of the interactive sailing simulation were very interesting: Test persons who already had practical previous experiences with sailing rated the application as very good and useful whereas those with little previous experience had great difficulties at first. The operation of the steering elements was comprehended intuitively by most of the persons. The order of buttons to get advice on the intention and use of the application however caused some difficulties. Here again the people with previous sailing experiences had less difficulties than the novices.

Future Work

Based on the results of the usability survey some modifications of the learning environment mainly regarding the design of the user interface are supposed to be made.

To strengthen the element of reflection besides the use of course ware to control the results of learning of certain contents a document related feedback system is supposed to be installed. It is intended to allow the assessment of student works regarding content, formality and design as a free text as well as on a scale basis. This way the authors are getting a feedback for their work while on the side of the users the task of assessing supports their own elaborate reflection of their knowledge and comprehension. Finally the comparison between the own assessment and the assessment of others stimulates a reflection on the meta-level of understanding.

As a completion for direct learning, a demand of the learning environment is the support of teamwork, especially in the form of so-called “communities” (cf. Bielaszyk/Collins 2000), which can be realised with communication tools that are out of synch. The supposition behind that is that the communication within a group works on the basis of reflection about the own course of action. That stimulates the process of learning. In addition discussions about individual interpretations and personal comprehension of possible results function as a stimulus to think about ones own interpretations. It also helps to structure the knowledge anew or produce new links. A main aim for the further development of the learning environment is accordingly the integration of such communities with a forum for discussion where in virtual classrooms the exchange between student (and/or lecturers) can take place. This would give room for teamwork relating to the different classes, topics and assignments.

Final remark

Based on the definition of the term of virtual learning environments we first focused on the theoretical learning suppositions that are the basis of such learning environments and then on the expectations from those. Following those we described our own concrete experience with the concept and realisation of the learning environment “WasserSportwissenschaft online” (Marine sports science online).

This year we cooperated under the framework of the “Eva:Learn”- project with the interdisciplinary centre for didactics (IZHD) of the university of Hamburg which is doing a survey of learning platforms of the universities of Hamburg. The basis for the evaluation is the plan to put up a portal for virtual learning as an addition and supplement to the direct learning. It will be possible to integrate the learning environment “WasserSportwissenschaft online” (Marine sports science online). Therefore we expect an important stimulus because of the concentration of resources. So we can continue the progress and add for example the mentioned integration of further interactive simulations and learning tests.

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About the concept and realisation of multi-media instruction and learning applications. On the example of the software "Snowboarding – Guide to Ride"

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Abstract

The production of multimedia applications is shaped by various, itself partially mutually causing aspects. These components, from the conception to the realization, should be discussed in the available contribution by the example of the multimedia application of training/learning Snowboarding – "Guide to Ride" (Hebbel Seeger, 2001).

Introduction

The production of a multi-media application is influenced by numerous components which determine each other. If the application is supposed to accomplish more than just the adaptation of conventional learning methods attention has to be paid to the interaction between user and application. Therefore the focus of interest of the didactic concept has to be the human being whose learning patterns, previous experiences and expectations need to be treated equally with the adequate illustration of the subject matter when preparing the contents of the application.

Furthermore it is quite important to already define the technical preconditions and requirements on the side of the production as well as on the side of the future users when drafting the application. This is for the reason that the technical expenditure of computer-aided learning system increases with the increasing comfort regarding the variety of didactical possibilities and can reach financially and operationally unacceptable costs fast (cf. Freidrich/Eigler/Mandl et al., 1997, 37).

In order to conceive and design a multi-media project it is therefore necessary to understand the integrative interaction between the different components and use it systematically (Wand, 1998, 187). Those components –from the concept to the realization – will be outlined in the following text on the example of the multi-media instruction and learning application "Snowboarding – Guide to Ride" (Hebbel-Seeger, 2001), which has been nominated for the edut@in - award 2001.

Principles

Where in the past multi-media instruction and learning applications were defined through the existence of at least three of the following media formats: text, sound, graphic, animation, photograph, film and data, now interactivity reaches a growing importance within the ongoing discussion.

Multimedia is more than just the combination of different media like text, sound, picture, moving picture and animation. Multimedia is a new form of presenting and representing information with the aid of a computer. Here the information is coded in different media. The new thing however is that a multimedia system presents its information in small units (modules) which are linked in diverse ways. Documents and links make up the so called hypertext (cf. Thissen, 2001, p 22).

For the description of the requirements and realization possibilities of multi-media instruction and learning applications this means that one does not anymore only have to deal with the medium "multimedia" but also with the interaction between user and application that means with the effect on learning processes in the learner.
At this point first of all the approaches based on the constructivism theory which depict learning as an active process of constructing knowledge determine the current discussion about the didactic concept of multi-media instruction and learning applications: In dealing with its environment the human being creates a construct of knowledge a subjective theory (cf. Groeben/Wahl/Schlee/Scheele, 1988) as explanation and projection of its self- and world-view. In this model learning is therefore understood as an individual comparison between the anticipated consequences of acting and the actual result. The process of learning is hereby marked by a selective choice of information which depends on the pre-existing knowledge as well as by an individual adjustment/modification of the individual knowledge structures to the new information.

As it is self-evident for other learning aids one also has to develop didactic principles for multi-media instruction and learning applications. Up to now only few computer aided learning materials represent new learning methods because often only conventional methods are adapted. Traditional methods however cannot represent the connection between text, picture and sound as a randomly explorable learning network (cf. Antritter, 2000), the hypertext. Still one has to take into account that creativity can easily turn into chaos and the consequences of the choice become difficult to grasp (cf. Thissen, 2001, p 24). In the centre of a didactic concept therefore has to be the human being whose learning patterns, previous experiences and expectations need to be treated equally with the adequate illustration of the subject matter when preparing the application. Multi-media instruction and learning applications are –as mentioned above- special because of the possibility of interaction. That means the possibility for the user to (co-) determine the order of the learning process. Therefore the functionality of interactive instruction and learning applications is based on the interaction between human being and technology. This implies that the multi-media learning environment needs to be accomplished in a way that takes the previous knowledge and attitude of the participant into consideration (cf. Friedrich/Eigler/Mandl et al. 1997, p 38).

The data of an information system itself cannot be used unless certain requirements are fulfilled:

- The user needs to recognize and assess the data as relevant for himself.
- The user has to be able to relate the data to his previous knowledge .
- The data has to be presented in a way that enables the user to perceive, absorb and process it.
- The structure of the data needs to be comprehensible that means intuitively understandable for the user.
- The system that makes the information available needs to react accordingly to the user's anticipation (cf. Thissen, 2001, p 19).

For the interaction between human being and technology the design and user interface play an important role. They need to be derived from:

- The requirements of the target group,
- the specific discipline and movement features of the sport,
- the "look & feel" as well as
- the technical possibilities.

The **requirements of the target group** contain the users expectations concerning the choice and processing of the contents as well as the familiar learning behaviour. Only a precise and detailed description of the target group allows a fitting production! The success of a multi-media production depends on a thorough and correct analysis (cf. Franz/Franz, 1998, p 1-12).

Even the "best" contents and messages, the "most innovative" games and the "most effective" learning programme will reach the target group if they appeal to the users' language. A game that fascinates a 15 year old pupil is trivial for a 50 year old engineer (cf. Thissen, 2001, p 26).

The **Specific discipline and movement features** relate to an appropriate processing for the contents. This concerns the choice and combination of different media types as well as the focus on certain sequences of movement and/or body parts. In addition one needs to find a suitable form of interactivity for the subject of representation.

The **"look & feel"** of an application constitutes the connection between the users on the one and the contents on the other hand. The interface design –design and navigation- has to meet the expectations of the target group and be adequate for the subject of representation. In the ideal case the "look & feel" of an application carries an image which encourages the user to occupy himself with the application and its contents without being overtaxed. In this case interface design is more than just having an optically well designed surface. It is the organization of the relationship between human being and machine:

- No design is impossible. There can only be a good or bad one. (aspect of competitiveness).
- The design needs to be target group oriented. (aspect of acceptance and motivation).
- A standardized design increases the recognition, simplifies the orientation and accelerates the decision making (Efficiency aspect I).
- An intuitively working user guide shortens the training period and reduces careless mistakes (Efficiency aspect II).
- Software mistakes are design mistakes! A good design minimises the possibility of human error (Efficiency aspect III).

The aspect of the **technical possibilities** relates less to the maximum possibilities on the production side and user side but more to the estimation of feasibility:
The technical expenditure of computer-aided learning systems increases with the increasing comfort regarding the variety of didactical possibilities and can reach financially and operationally unacceptable costs fast: the more media is used in a programme the more complicated, disruptable, incompatible and expensive its hardware configuration and software production gets (cf. Friedrich/Eigler/Mandl et al., 1997, 37).

Concept

Based on the principles of multi-media instruction and learning applications one can start to put up a concept. This is mainly divided into six steps:

- Recording the requirements
- Development of (realization-) ideas
- Defining the basic conditions
- Drawing up a rough draft
- Working out a precise draft
- Carrying out a feasibility analysis together with planning the costs and time.

Recording the **requirements** corresponds with describing the target as to what the application is supposed to be able to accomplish. In this example –the development of an instruction and learning application for the discipline snowboarding- first of all the target group was chosen: Those are new and advanced learners between the age of about 20 to 35 years. Combined with suggestions for practical training they are supposed to be given a methodical access to the discipline and the different complex movement techniques are supposed to be illustrated.

Based on the description of the target **realization ideas** can be developed. In the area of movement, games, and sports the specific discipline and movement features play an important role besides the target group. Therefore it is necessary to determine as accurately as possible which aspects of a movement are supposed to be focused on: Is for example the whole movement of interest or just the influence of a particular part on the sequence of movements? Are discipline and/or movement comprehensive aspects supposed to be shown or special movement techniques? When showing cyclical movements shall the focus be on one isolated cycle or on the flow of movements? Which means of representation are appropriate, pictures, sequences of pictures, videos, sounds, texts etc. and/or the combination of those? What way of interaction is the best? How can the application offer a different access for the users with different previous experiences and requests? etc.

The next step is to check those visionary realization ideas in the context of the **basic conditions.** Those are on the production side:

- the available budget,
- the personnel, what persons with what kind of qualification are or can be involved in the production at the different positions,
- the presentation platform for which the application is supposed to be designed (oriented on the web and/or client, to be used on one or more operating systems) as well as
- the technical possibilities that means the available hard- and software to produce and work on the desired contents as well as integrate them into an application,
- the time frame within which the application has to be put into realization.

On the side of future users first of all the expected hardware and if necessary the software equipment have to be taken into account.

The basic conditions give the background to the **rough draft** which represents the adaptation and reduction of the realization ideas to what is feasible. That is without letting the wanted function of the application out of sight. When drawing up the rough draft the aim is to determine the frame of the application. It is necessary to determine which contents/information are supposed to be taken in, how the contents shall be coordinated regarding the tasks and logic in terms of content as well as what functional extent the application is supposed to have. Before the navigation can be designed, the contents need to be clearly defined. After that the relation between the different aspects of contents regarding the ways of information and depths of depiction within the application can be determined.

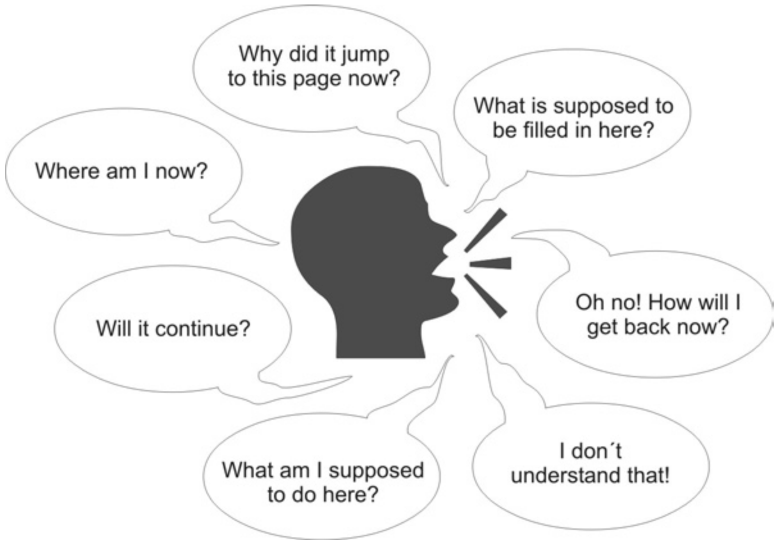

Figure 1: The art of navigation is to find simple solutions for complex structures.

Altogether the phase of drawing up the rough draft contains four different steps:

- Reviewing of contents and extents
- Structuring the information
- Drawing up the navigation with the goal of minimizing ways, hierarchies and redundancy
- Saving the results of the first three steps on a flowchart with descriptions of the contents and practicalities of each screen.

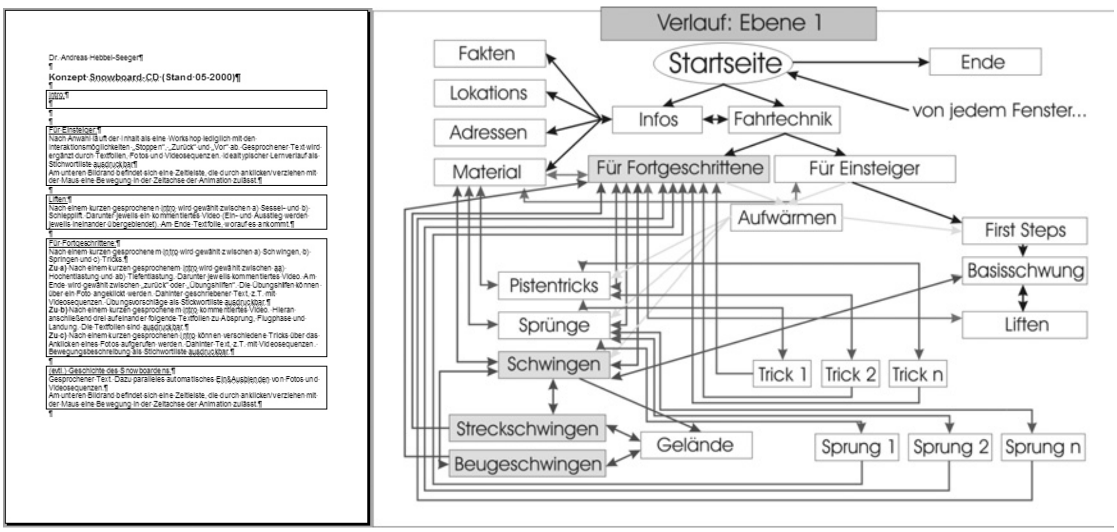

Figure 2: Example of a flowchart with textual descriptions for the depiction of contents and functionalities.

As Franz/Franz (1998) state the planning uncertainty is the highest in this phase of production. A great amount of information needs to be processed. The interaction within the multi-media product needs to get going properly. The same holds for the organisation. Therefore it is very important to take enough time for the concept organisation in this phase and to assure the quality (cf. Franz/Franz, 1998, p 1-18).

After having drawn up the rough draft, the **precise draft** can be worked out. The architecture of production that has been defined in the rough draft needs to be improved. The concept needs to be developed to the last detail, more information needs to be collected, processed and assessed (cf. Franz/Franz, 1998, p 1-27). In the phase of the precise draft the definite contents concerning functionality, controlling and use of media (texts, pictures, sound, animation etc.) are established. The final stage of this phase is marked by the completion of the storyboard of the application. Within the process of production the storyboard is used as a basis for coordinating everyone involved in the process. As the storyboard includes all the necessary control elements and media formats that need to be integrated it forms the work foundation for the screen design as well as IT and developers.

The close of the concept stage is made up of the **feasibility analysis** as well as a **plan of costs and time** needed for the following phase of realization. It might be practical to produce prototypes for critical parts of performance and/or production of the application in the frame of the feasibility analysis. The planning of costs and time can follow as soon as it is sure that the application can be produced as described in the storyboard which might have been altered after the prototyping. The planning of costs and time can be seen as an aspect of the feasibility analysis because it is checked whether the given budget is kept. For planning the costs and time the different steps of the working process are given a certain budget, time frame and a concrete position within the time frame of the whole production process, which does not necessarily have to correspond to the chronological order of the production. Furthermore it makes sense when choosing the time position to include constrains from the outside if necessary. If you are dealing with a nature sport it might not be possible to get suitable shots in every season. Actors have to be available and a recording studio might have to be rented.

Realization

The media contents are produced and revised (picture, video and audio production) in the realization period as well as integrated into the user interface. Based on the storyboard, which holds the information for the functionalities and navigation elements, the design is drafted. Usually more than one draft for the screen design is produced. Those drafts normally comprise the start screen and -depending on the production- one or more screens of the sub levels. As soon as one design is chosen it is used to formulate a style guide which contains the optical guidelines for the technical production. At this point the “real” production of the application can start.

In a first step all the surfaces of the planned screens are made. While doing so the corporate design (CD) plays an important role. The corporate design…

- lets the whole application appear as a unit,
- is modelled according to the target group,
- gives an adequate design for the content.

The functional aspect of the screen design is orientated on the ideal type of a screen as developed initially for programmed learning. It is supposed to

- present and visualize an instruction information
- encourage the learner to develop his own activity
- integrate responses by the instruction system regarding the learners activity as corrections or advices
- contain recommendations for operating the application as well as have a motivating effect to continue using the application. (cf. Issing/Klisma, 1998).

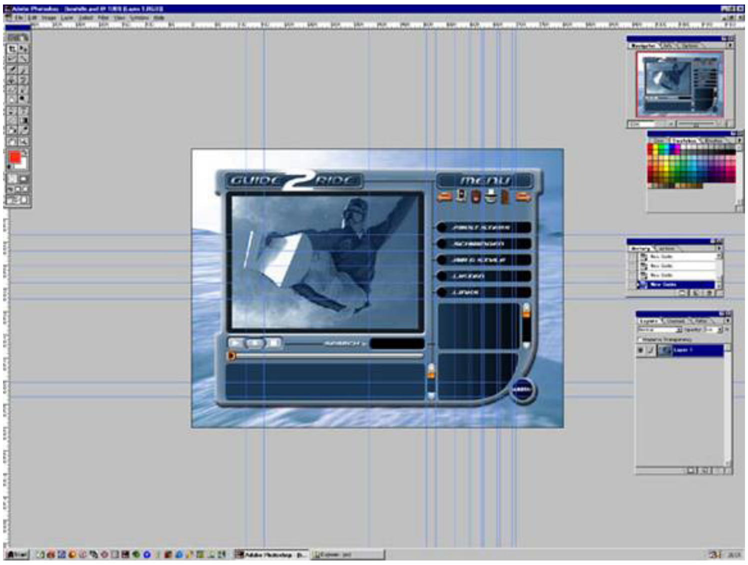

Figure 3: Screen design for the software “Guide2Ride”. Produced with graphic programme and image processing, Adobe Photoshop© and others. Because of the target group the interface was designed stylishly.

The screen design constitutes the frame within which the different media types and elements can be put together to a complex application. The contents are already fixed in the storyboard and now need to be processed during the phase of production.

As the main element of depiction for the software “Guide2Ride” we decided on video sequences with commentary for the different techniques and exercises. After shooting the needed material we went through it and cut the different sequences. The next step was to fit the size of projection and resolution to the projection surface that had been determined in the screen design, correct the colours and adjust the contrast.

At this point in time the decision about what video format and video codec to use already needs to be made because it is critical for performance and production (cf. part 3). The decision is critical for the performance because the choice of the size of projection and the resolution in correspondence with the video format has a crucial influence on the file size and performance. The decision is critical for the production because it entails consequences regarding requirements for hard- and software on the side of the users. If for example the application is supposed to be used comprehensively on different platforms it does not make sense to use a specific Windows© format. For the depiction of the different video formats there are usually also special software players or plug-ins that are used which might not be spread far enough and/or be under rights of licence.

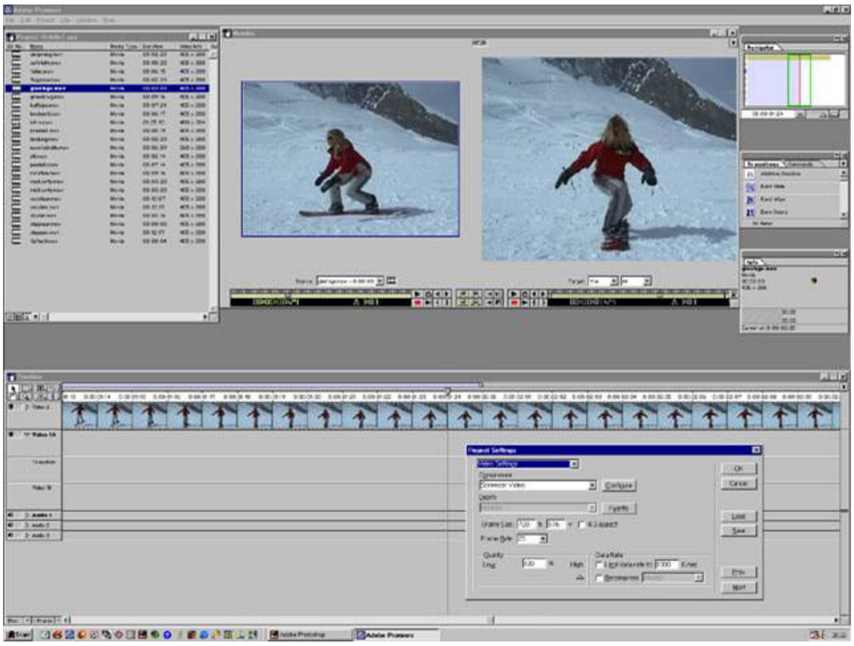

Figure 4: Working on the videos for the software “Guide2Ride” with Adobe Premiere© and others.

Within the production of the “Guide2Ride” software the audio editing marked the second focus. Texts needed to be recorded to accompany the video sequences and background music and jingles needed to be composed and put together. Besides recording those the frequency needed to be optimised, interference needed to be removed and compression needed to be adjusted.

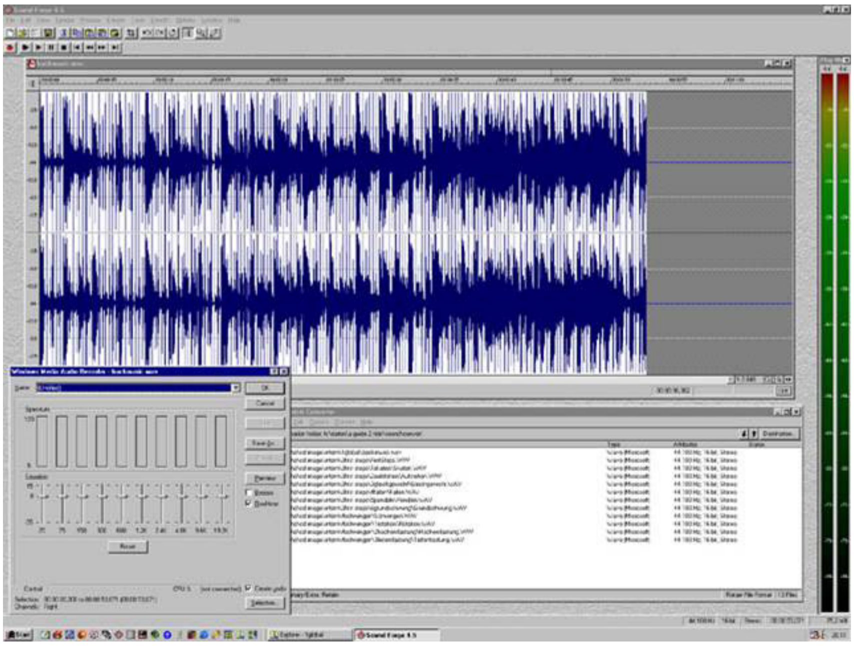

Figure 5: Working on the sound of the software “Guide2Ride”. With the aid of different sound tools the recording of the spoken texts was carried out. In one of the next steps the sound designer composed and mixed the background music.

As soon as all the surfaces of the screens are put together and the media elements are produced the different parts can be put together to form a whole. To accomplish this so-called authoring-tools are used.

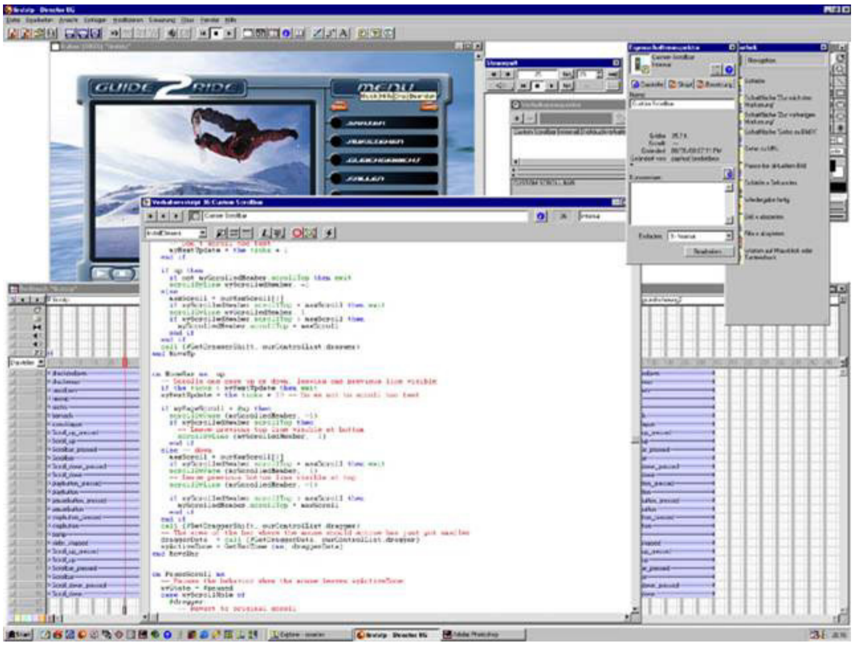

Figure 6: Programming of the software "Guide2Ride". Realisation with authoring tool Macromedia Director©, which works on the object oriented programming language "Lingo": Putting together the different elements to form an interactive application.

After finishing the first version it needs to be checked for comfort of operation, the hard- and software requirements and system compatibility. If necessary it needs to be optimised. Finally the finished application can be used.

5 Conclusion

Putting a multi-media production into practice is more than just putting together the different contents and types of media. As outlined in this article about the software "Snowboarding-Guide to Ride" the finished application is the result of an interdisciplinary group of experts in this subject, designers and multi media programmers.

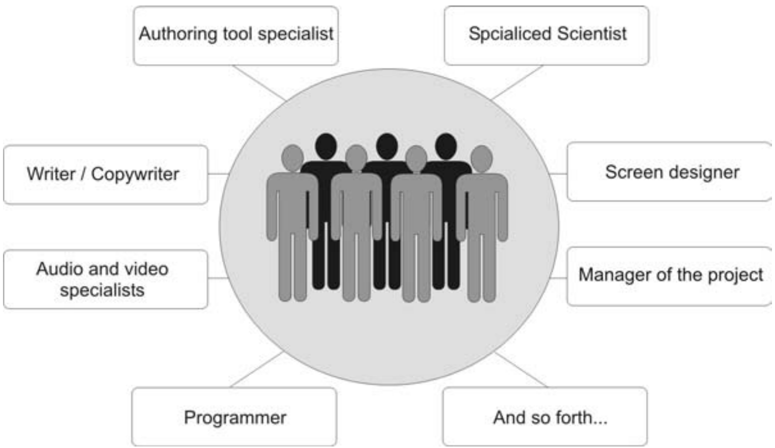

Figure 7: Qualifications involved when processing a multi media production.

Depending on the size of the project the members of the group need to have more than one qualification. In the area of games and sports this probably is most often the case. This, however, should not have an influence on the ideal typical course of concept and production.

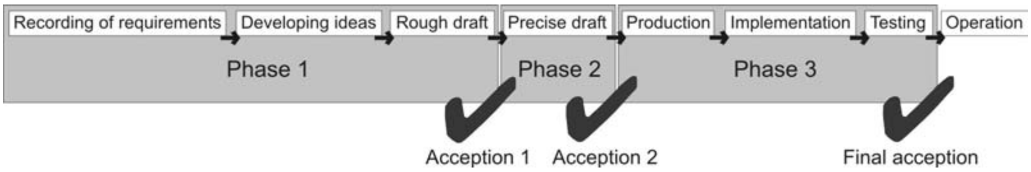

Figure 8: Ideal typical course of concept and realisation

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An internet-based information system for the sport scientific theory of selected sport disciplines[1]

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Abstract

An information system is developed to transmit scientific basics of four selected sport disciplines using internet and multimedia technology. The aim of the project is to arouse the interest in studying theoretical sport scientific concepts more intensively and to obtain a more rapid understanding for complex connections. We expect to improve the interdisciplinary understanding in sport science both in research and education and to achieve a more economic and effective education.
Four modules are developed. The online availability of the modules shall enable users to earn, refresh or deepen their knowledge, independent of time and place. Computer animations, video sequences (e.g. to control the ability to diagnose anomalies in motion performance or to specify the cognitive representation of movements) and simulations (e.g. to illustrate the influence of different parameters such as that of the effect of the ball rotation to the trajectory in tennis) are included into the modules in order to achieve a high degree of interactivity.
The first module (Alpine skiing) is available since September 2002. Evaluation results comply with the expectations.

Introduction

Multimedia is becoming a key technology for learning and teaching sport scientific knowledge (cf. Mehler, 1997). The interest of teachers, students and coaches in multimedia and web based education and training tools is increasing (Baca & Nuc, 2001; Haggerty, 2000; Katz, Liebermann & Sorrentino, 2001).

Theoretically based teaching and learning materials are rare. Often they are textually only and technically overaged. Throughout the last years increasing efforts in developing and using multimedia based courses and materials can be observed (Rockmann, 1998; Weigelt & Starischka, 2000; Weigelt, Velmeden & Starischka, 2001; Sorrentino 2001 a,b; Kilb, Raz-Liebermann & Katz, 2001; Bales & Schäfer, 2001).

Sport scientific information systems have been developed for several sport disciplines or for sub fields of sport science. Interdisciplinary approaches have been an exception, the development of multidisciplinary, comprehensive information systems shows a deficit.

Sub fields of sport science are thematically overlapping. Up till now this may result in a certain uneffectiveness and redundancy in education.

[1] The project is funded within the framework of the Research Program "New Media in Education" by the Austrian Federal Ministry for Education, Science and Culture.

This deficit shall be reduced by the cooperative project "SpInSy" between the Departments of Sport Science of the Universities of Vienna and Salzburg.

SpInSy

SpInSy – Sport Scientific Information System – is funded from the initiative "New Media in Teaching at Universities and Colleges of Higher Education" of the Austrian Federal Ministry for Education, Science and Culture. Project partners are the Faculty of Human and Social Sciences (University of Vienna) and the Faculty of Fine Arts (University of Salzburg) as parent organizational units of the departments of Sport Science involved. The total project period is two years (October 2001 – September 2003).

The aim of the project is the development of four internet based multimedia modules. Students shall work with these modules in parallel and complementary to courses.

Sport science is divided into different sub fields. Based on four selected sport disciplines abstract theoretical concepts of different sub fields of sport science (mainly from natural science) will be presented interdisciplinary.

Table 1. Modules and sub fields

Sport disciplines	Sub fields
• Alpine Skiing • Tennis • Track and Field Athletics (in particular running and jumping disciplines) • Soccer	• Sport Biomechanics • Sport Medicine and Exercise Physiology • Sport Psychology • Kinesiology • Applied Computer Science • Exercise Science

Starting with a practical application – the sport discipline or the specific movements – we expect that

- the interest is aroused in studying theoretical concepts more intensively and a more rapid understanding for complex connections is obtained
- the interdisciplinary understanding in sport science improves both in research and education
- a more economic and effective education is achieved

Figure 1 shows the basic structure of the modules. It is equal for all the modules and supplemented by specifics of the sport discipline considered.

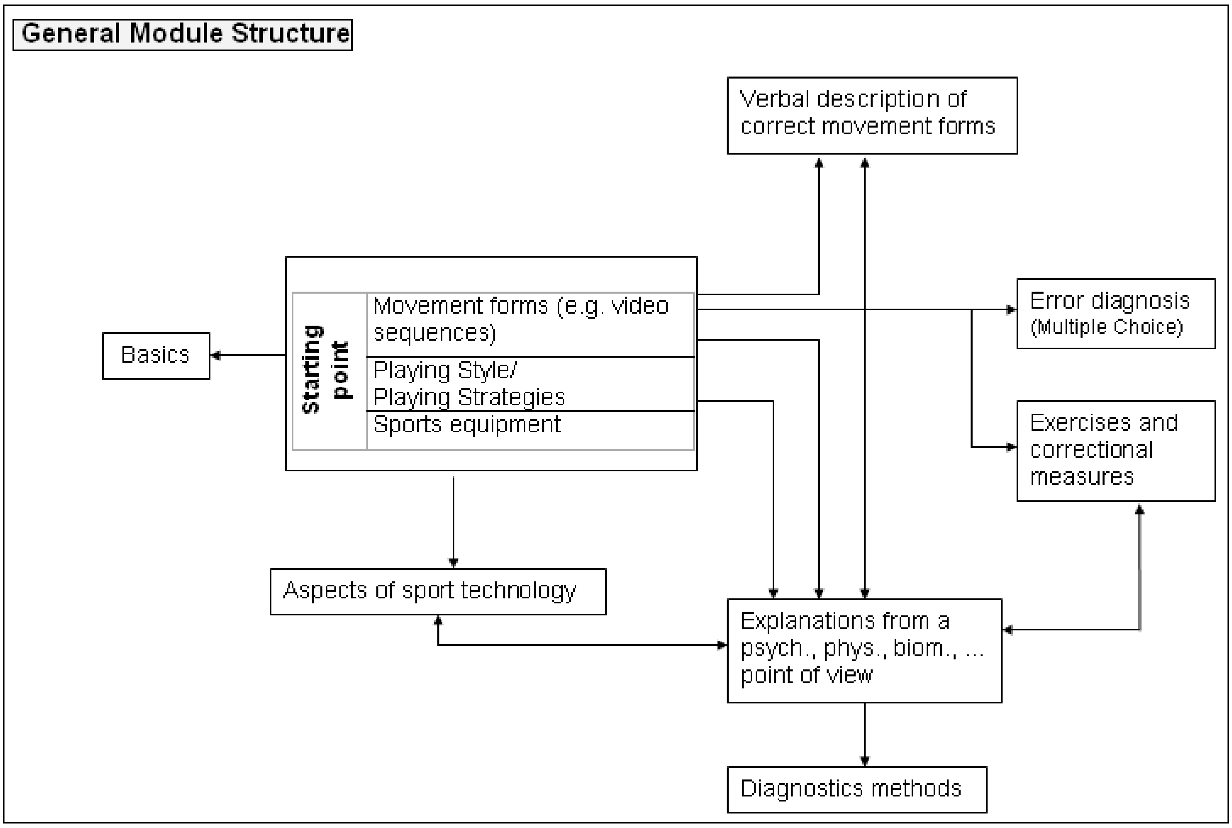

Figure 1. General module structure of SpInSy

Each module contains a sub module on basic knowledge (e.g. history, rules) of the sport discipline.

Since theoretical concepts presented in one module may be of relevance for other modules as well, cross-linking between modules has been provided.

Expected effects

The system should stimulate the critical, networked and holistic thinking. Because of the practical examples given, the theoretical connections and overlappings of the sport scientific sub fields should become transparent. Although numerous studies do not prove significant better learning with multimedia (Haggerty, 2000) two main positive effects are expected:

- The practical relevance of the theoretical concepts presented will become clear. Users of the system will gain a better understanding of the necessity of studying these concepts.
- The motivation to learn will increase. In particular this is caused by the use of multimedia elements such as computer simulations, video sequences and animations.

In addition, the project will stimulate the intra- and interdisciplinar discussion.

Target groups and curriculum integration

Potential users of the system (target groups) are:

- Students of Sport Science and Physical Education
- Graduates of these studies
- People interested in further education or interested in the theory of sport
- Coaches and Sport Associations

At present students of sport science often acquire knowledge from different disciplines without much linkage. An interdisciplinary learning system developed with the cooperation of contributing specialists from these disciplines should improve this situation.

The modules shall be used as accompanying and complementary materials within the studying process. A formal integration of the materials developed into the curricula is intended. ECTS credits shall be assigned.

It is expected that sport associations and coaches will also be very interested in such materials. An integration of the materials in coach education programs is aimed at.

Didactic approach

Through the use of an explorative learning concept the learners shall take an active role in discovering and absorbing knowledge on their own. The material is structured into small and logically interrelated pieces. The learners may choose their own passage, they are able to interact within the environment and to explore certain problems. It will be possible to navigate selectively through a closely knit network of knowledge modules. This concept supports the free investigation of complex contents. The users themselves are responsible for the success of the learning process. This teaching method is new for most students. Teachers and tutors will have to give detailed information on the concept before use of the system.

Multimedia elements support the theoretical information as modern teaching aid with interactive experiments and with exercises. Simulation components allow users to take an active part in working with the product. Questions of different kind and degree of difficulty are integrated in order to enable learners and teachers to control the knowledge acquired. Cognitive and motor tasks are included to gain a better understanding of the principles of motion. Observation tasks, for example, are provided for judging motions.

Great emphasis has been put on aspects of software ergonomics and the design of the human computer interface. A standardized navigation system and a consistent toolbar have been developed for all modules. Help, history and search menus have been included and can be accessed whenever desired.

A glossary of technical terms is integrated. Highlighted words within the text serve as links to explanations.

Development environment

A cross-platform approach was a major criterion for selecting the development environment. The system developed should run on both Windows PCs and Macintosh computers. Beside the possibility of accessing the system via internet the production of a CD-ROM version was aimed at.

In order to a satisfy these requirements the authoring system (Macromedia) Authorware 5.0 resp.6.0 has been selected. Authorware is a system, which makes it easy to realize multimedia applications via graphic programming.

Some animations have been / will be generated using the features of Authorware, more complex animations have been / will be produced in Macromedia Flash MX resp. Curious Labs Poser 4.0 (character animations) and than imported into Authorware.

To achieve high video quality and small data files DivX (5.0.2) compression technology is used.

Module 1: Alpine skiing

The first module implemented is "Alpine Skiing". Aspects of Sport Biomechanics, Kinesiology, Sport Psychology and Sport Technology in their application to Alpine skiing are dealt with.

The module includes informations on different skiing techniques, on biomechanical modelling (in general and in skiing) and on unweighting mechanisms. Kinematic, dynamic and electromyographic analyses of Alpine skiing techniques are presented. Psychological aspects covered include implicit and explicit learning and self instruction training.

Figure 2 shows the structure of the module.

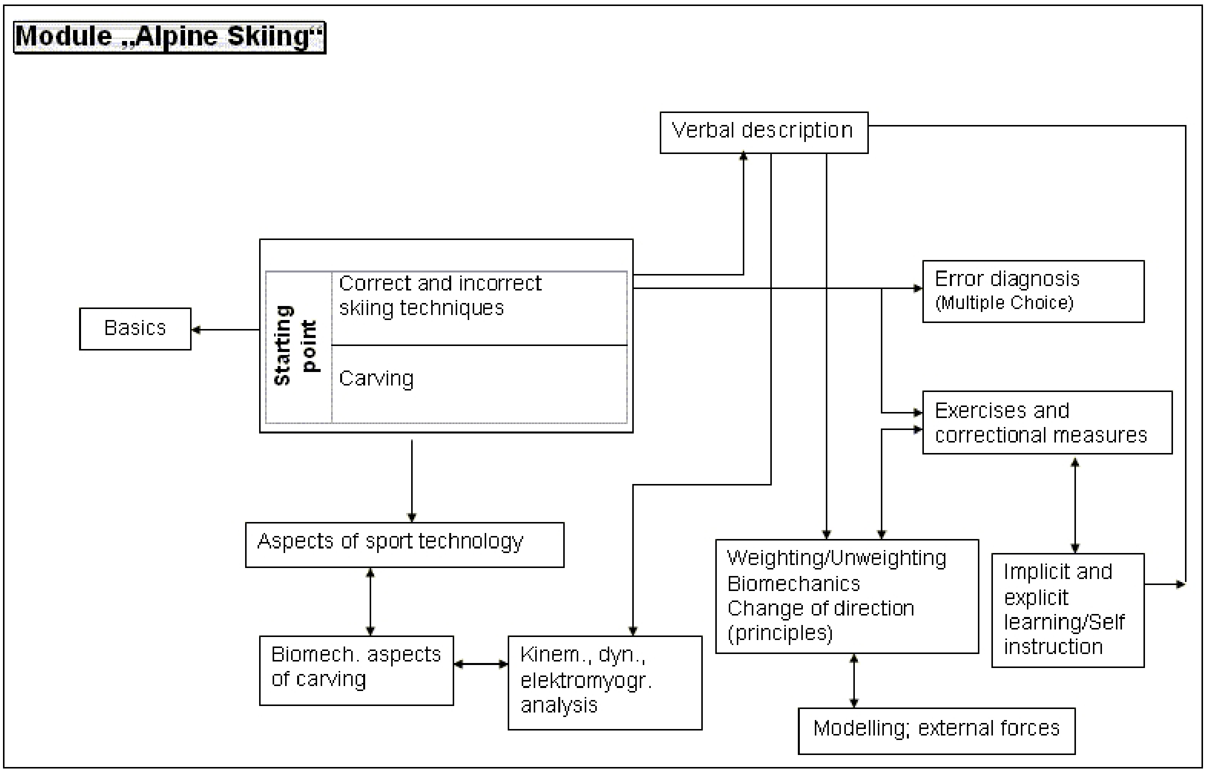

Figure 2: Module structure "Alpine Skiing"

Starting with the presentation of correctly executed movements and the option to diagnose incorrect techniques (a screen shot is shown in Figure 3) the user may navigate to scientific explanations and related topics from the different sport scientific sub fields (an example – biomechanics – is shown in Figure 4) via hyperlinks.

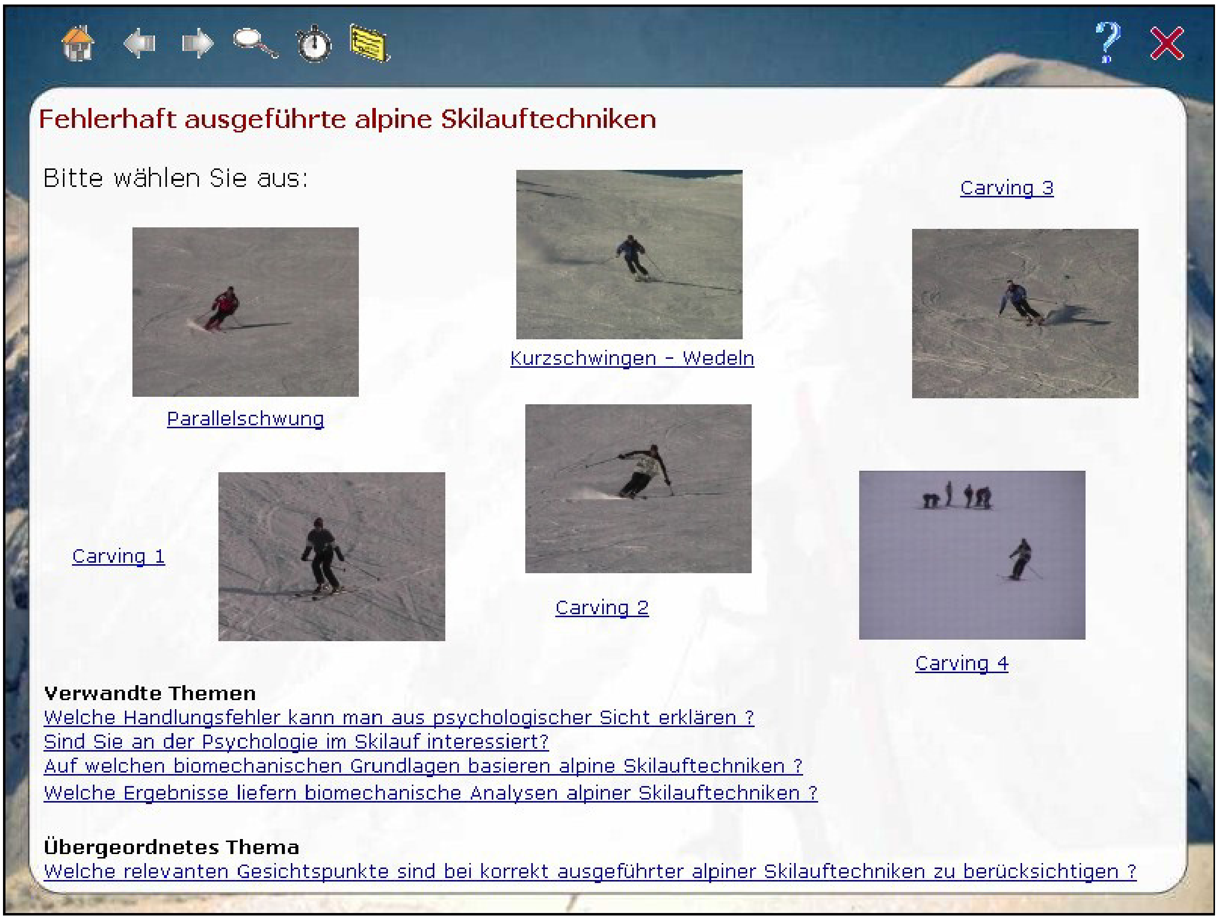

Figure 3: Screenshot of the menu “incorrect skiing techniques” (in German)

An example for an animation is shown in Figure 5. The user may interactively select the coefficient of friction and the angle of inclination of the slope. The resulting motion is presented.

Evaluation results

A prototype of module 1 has been evaluated by 51 students of sport science (mainly first and second year) using an online questionnaire. The questionnaire comprised questions relating to *technical criteria* (usability, design, downloadtimes, etc), *quality of media components* (videos, animations, graphics), *quality of learning* (learning atmosphere, difficulty, support of creativity, feedback, etc.), *target group, competence provided* (knowledge transfer, problem solving competence) and an open question for improvements. Each criterion could be rated 1-5, 1 being excellent, 5 being poor.

The system has not yet been compared to traditional teaching methods at the present stage of the project. With respect to the main positive effects expected (see above) only some indicators can therefore be provided: *Learning atmosphere* was rated 2,1 (mean value), *learning intensity* (“Does the system stimulate to study the contents presented?”) 2,33, *comprehensibility* (“Are the processes for solving problems understandable?”) 2,22 and *interest to explore the system* 2,25.

Concerning the technical criteria the results were satisfying and complied with the expectations. Improvements were claimed to result in higher interactivity, creativity (additional online trials and experiments), immediate feedback, more exercises and problem solving tasks.

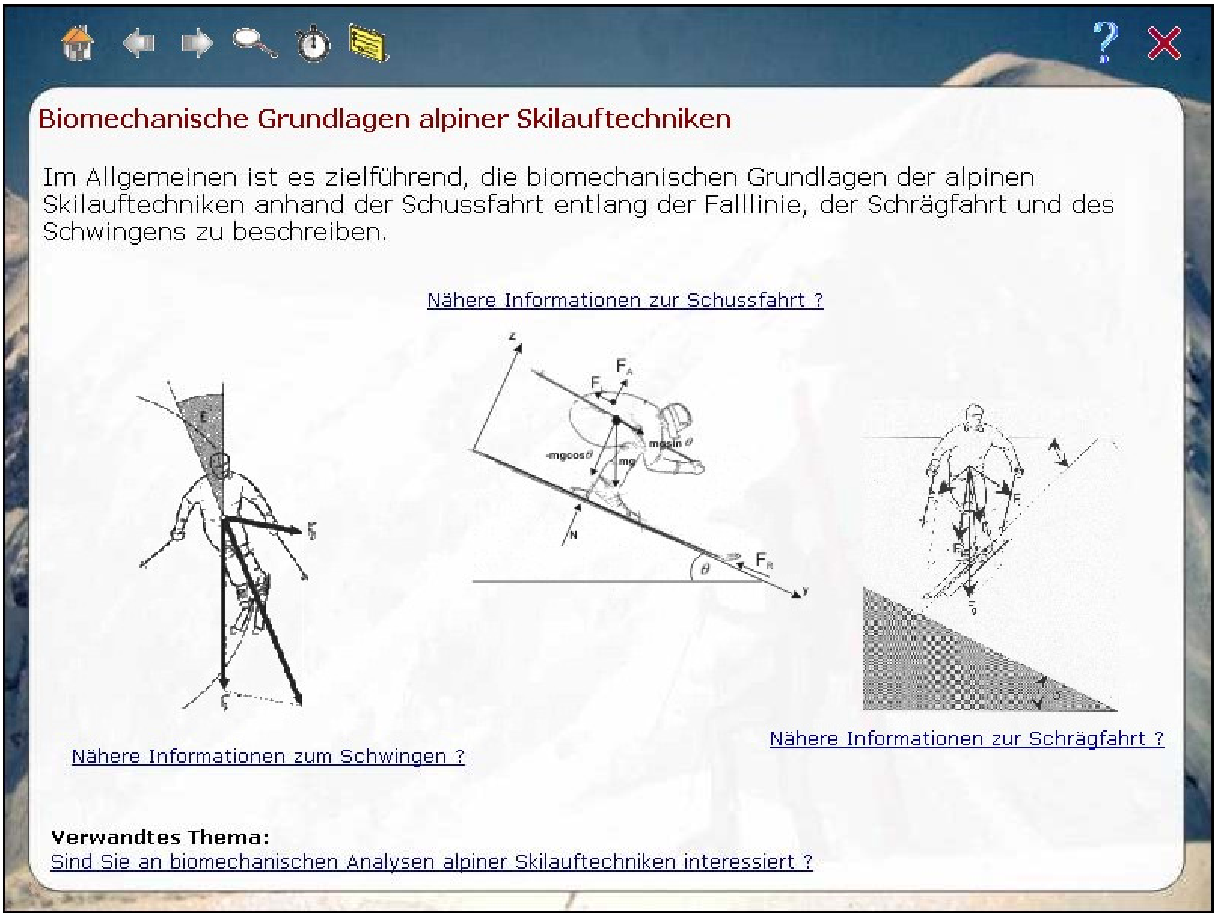

Figure 4: Screenshot of the menu “biomechanics of skiing techniques” (in German)

After completion of the module “Alpine skiing” a second evaluation using the same questionnaire was performed by 19 students of sport science. Moreover, the system was discussed with these students very detailed.

More differentiated results were obtained. The reason might be that evaluation group was made up of more experienced students (third year and above).

Main results were:

- Students were unfamiliar with the explorative learning concept. More navigational help in order not to get lost in the complexity of the structure was required.
- Maps for tables of contents that represent the logical structure as a means of navigation support were asked for.

- Better marks were obtained for the comprehensibility (2,05). It is assumed that this is due to the increased use of animations and simulations.
- More video sequences and more interactive capabilities to work with these sequences were demanded.

In addition, the second evaluation showed improved results in the fields of quality of animations (from 1,86 to 1,52), feedback (from 2,69 to 2,33), matching of learning objectives (from 2,44 to 1,48) and knowledge transfer (from 2,16 to 1,76).

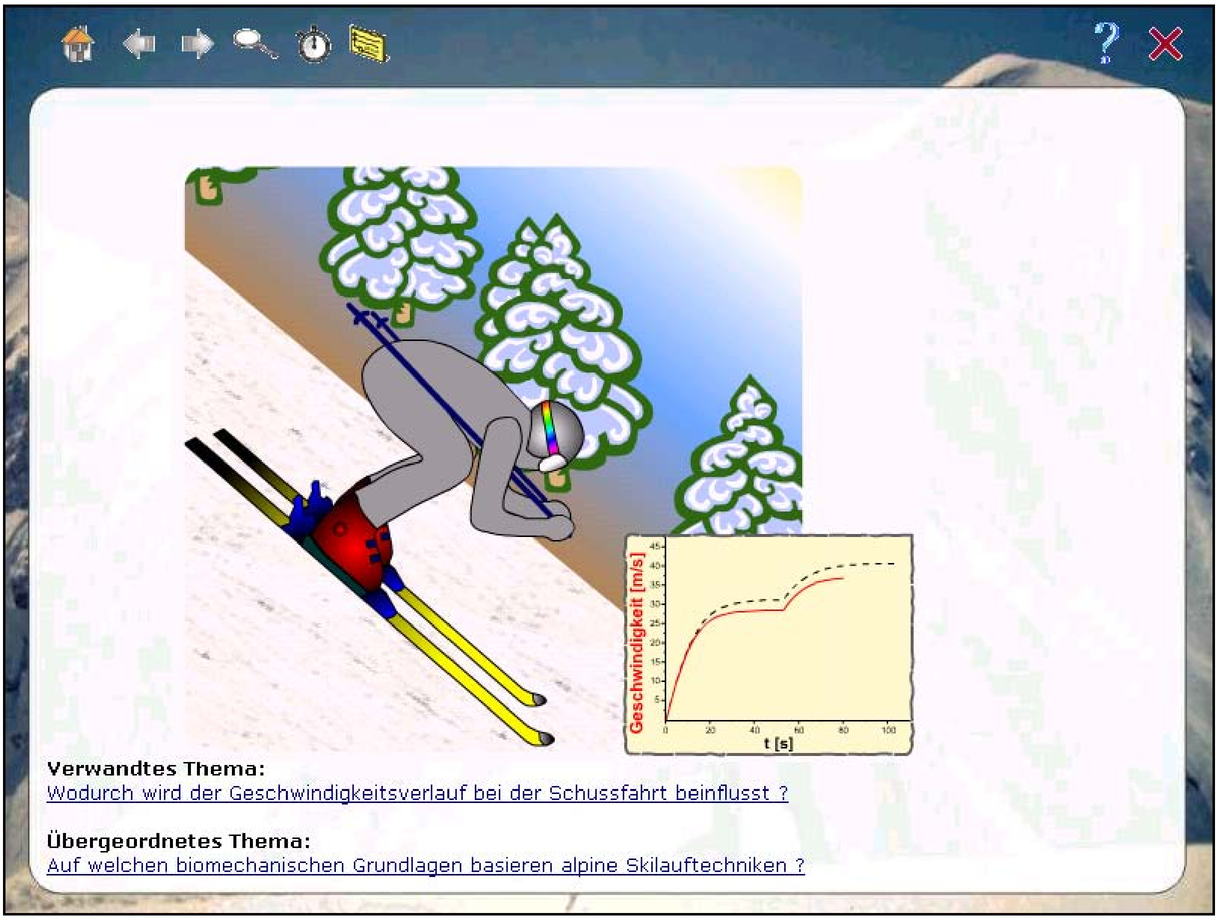

Figure 5: Screenshot of a downhill racing animation (in German)

Perspectives and Conclusions

Based on the experiences of the first module, the modules “tennis”, “track and field athletics” and “soccer” will be produced and integrated into the information system. The explorative learning concept will still be followed. We believe that there is no harm in getting a little lost – it fosters explorative behaviour. SpInSy shall be completed and made accessible to educational institutions in Austria in autumn 2003. Extensions to additional sport disciplines and the development of an English version (the present is in German) are intended.

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Integration of internet-based teaching- and learning-systems into teachership studies in sport

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Abstract

Virtual university is not expected to become reality very soon. Hypermedial teaching offers likely will complete and accompany traditional teaching step by step. At present, internet-based learning- and teaching-modules are produced in the project "eBuT" (e-learning in Movement- and Training-Science) by cooperation of several universities. During the development of these multimedia-concept, among other things, the assumptions, and expectations of the target group, students in sport science, in and the using of the world-wide-web are continously evaluated. Therefore one hundret students were interrogated by questionnaire. Aside the general data exploitation, gender differences were brougth into focus and analysiszed regarding separately for the grouping of basic-study students and main-study ones. Data show several differences between students in basic- and such in main-studies. In contrast to that no gender-specific estimations, expectations and using of the world-wide-web for participants of sport studies were found. The findings of this study point to an increasing relevance of internet-based teaching and learning in sport science. However traditional teaching should be extended and completed and not replaced by multimedia-offers forthcoming.

Introduction

The rapid growth and vast supply of production of information demand more effective forms of access to it. One possibility is seen in the using of the world-wide-web (www). Even in academic teaching at traditional universities, time- and place-independent learning as well as access to information in the www possibly seems to improve learning and teaching process and make them more effective. Knowledge of the expectations of users in and their using of multimedia services is one requirement to optimize such offers (Igel etal. 2000). However at present little is known about multmedia offers and the way students in sport science use those services during their studies. Former investigations show a higher figureshape of personal, in comparison with specific use of the information highway for sport science purposes (Baca & Nuc 2001, 6-7, Igel etal. 2000, 282). This could may be a consequence of a lack of sport science specific internet offers for the target group. In order to extend and complete traditional teaching, internet-based learning-lessons for Movement- and Training-Science were developed in cooperation with several universities.Therefore the objective of the following study is to evaluate the acces of students in sport science to the www, the using and individual importance of multimedial offers for students and their expectations for future studies.

Methods

A questionare, based on pilot studies, was presented to students of sport science at the university of Dortmund. The students took part in seminars and lectures in basic and main studies during the summer semester 2002. Beside questions about demographic data, access to multimedia services at home as well as the requirement for and expectation of online multimedia offers for present and future studies were ascertained. Frequencies of the categories are provided and differences between male and female as well as between students in basic- and main studies are tested by Chi-Sqare-Test at 5 percent level of significance.

Results

Data from 100 students, age 23,45 years (SD 3,66) are available, 47 were female and 53 male. These persons take part in basic- (N = 53) and main studies (N = 46, one data missing). There is no significant difference (student-t-test for independent samples: $T_{(98;\ 0,05)} = -1,384$, n.s.) between age of women (22,91 y., SD 3,59) and men (23,92 y., SD 3,69), whereas students in basic-studies (21,77 y., SD 2,83) are significant younger ($T_{(97;\ 0,05)} = -5,585$, $p< .001$) then those in main studies (25,39 y., SD 3,61). The number of semesters of 98% of the participants varied between 1 and 13. Two students are at their seventeenth respectively thirty-first university semester. A high share of 40% were students in the first semester of their sport studies. The availability of the world-wide-web at home of sports students is shown in figure one. 85 % of the students can use the internet at home (figure 1). The share of those with access to the www in male persons and those in basic studies is somewhat greater, but the differences are not statistically significant ($\chi 2 = 2,74$ male-female, n.s.; $\chi 2 = 0,335$, n.s. for basic and main studies). Even if a great majority of students have the oportunity to use the www at home, not all students of sport science have an access to the internet at home.

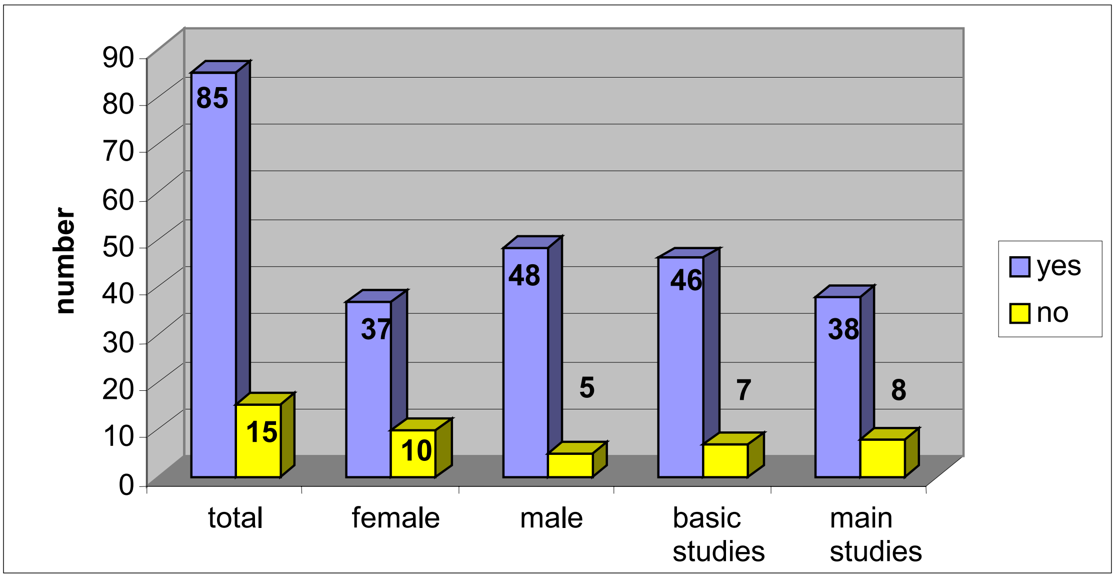

Figure 1. Availability of the world-wide-web at home

The students were asked, to value the relevance of the www for their present studies in sport science on a five step scale, between “indispensable” and “unimportant” (see figure 2). Most of them estimate the the internet as “important” or “very important”, but the most frequent single answer given, was the estimation that the world-wide-web is “less important” for sport studies. The portion of those persons who take the internet to be “indespensable” or “very important” for studies in sport science in male students and students in basic studies is somewhat greater, but not significant.

None of the sport science disciplines (e.g. sport-psychology, sports-medicine, sport-history, movement-science, training-science) is rated with poor suitability for internet-based learning and teaching offers in sport studies. Men and women just as students in basic- and main-studies value all disciplines as "well" or "very good" suitable for internet-supported teaching.

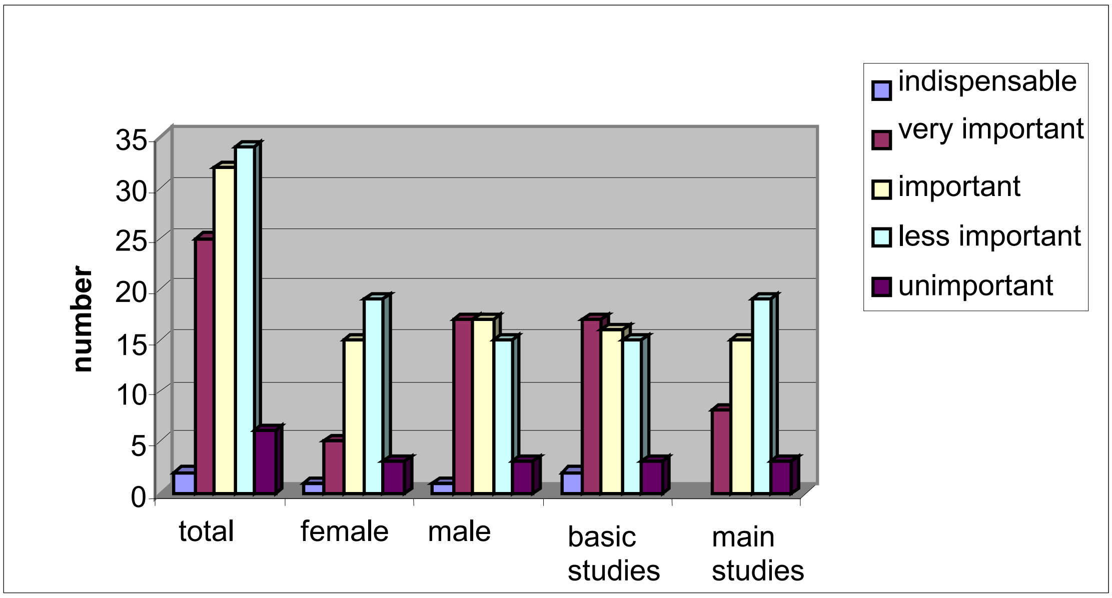

Figure 2. Importance of the world-wide-web for studies in sport-science

The opportunity to prepare and adapt from lectures (see figure 3) or seminars (see figure 4) is "important" or "very important" for most of the students who where interrogated. For 30% it is important and for 40% it is very important or indispensable to have the opportunity to use the world-wide-web beside personal tied learning offers, for their studies in sport science. This request for internet-based multimedia learning offers is found likewise for women, men and students in basic- or main studies. Merely male students express a more clearly wish for preparing seminars by internet than women did it. While 2,1% of the female students find it "indispensable" and 19,1% "very important" to have the opportunity to prepare seminars by utilizing the www, the corresponding values for the male students are 5,7% and 50,9% ($\chi 2$ = 15,042, $p< .05$).

One of the expected benefits of internet-based teaching- and learning-offers is its place- and time-independent usability. Over 80% of the students answered, that this aspect is "important", "very important" or "indispensable" (see figure 5). Whereas male and female students do not differ significantly, students in basic- and main-studies gave different statements ($\chi 2$ = 10,139, $p< .05$). The shape of those who consider that place- and time-indipendent learning-offers are "unimportant" or "less important" is higher in the group of main study students. In this group 23,9% take it for less important and 4,3% for unimportant to make place- and time-indipendent teaching- and learning-offers for sport studies, whereas only 9,4% of students in basic studies considered this aspect would be less important and for no one it is unimportant.

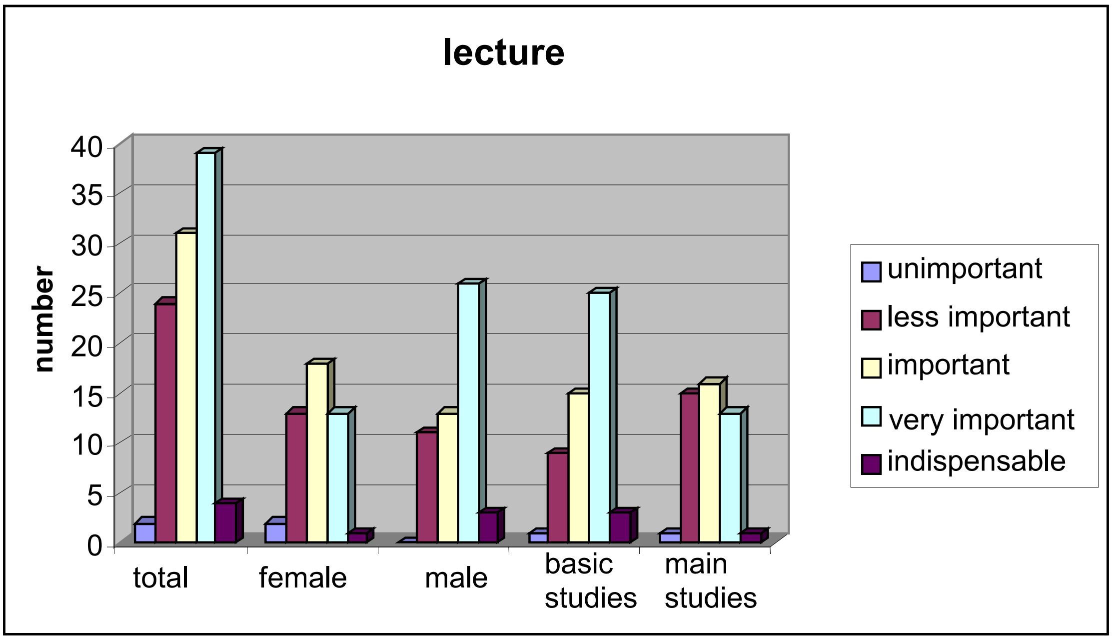

Figure 3. Individual relevance of the possibility to prepare lectures by the aid of multi-media internet offers

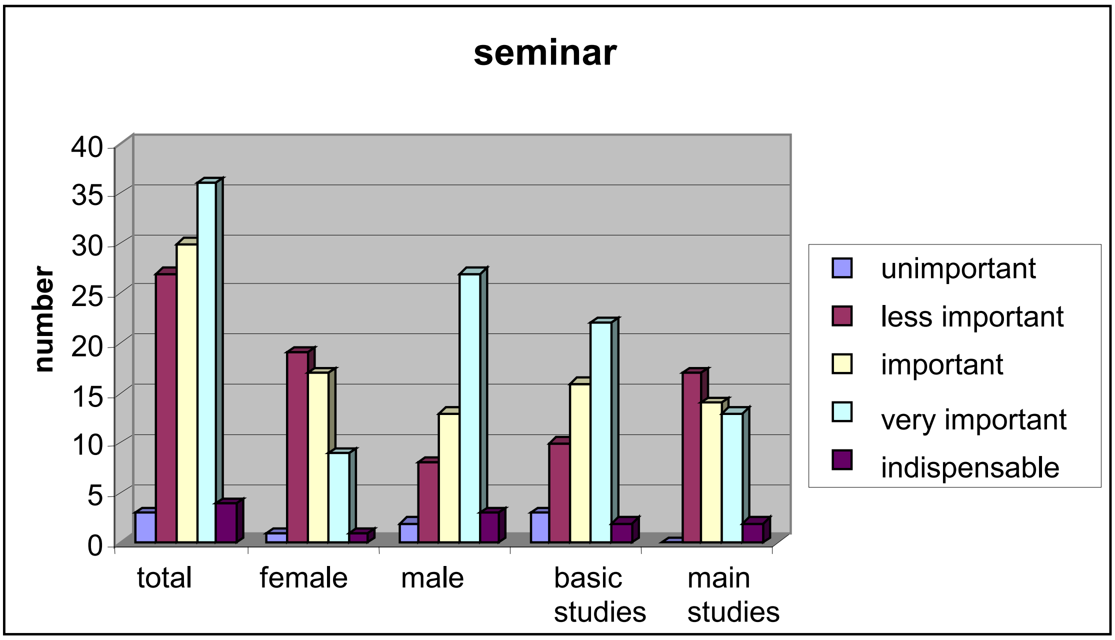

Figure 4. Individual relevance of the possibility to prepare seminars by the aid of multi-media internet offers

The expectations of the students relative to the future importance of technical books and literature in sport science is represented in figure 6. No one of the one hundret students expects technical literature in sport science to become unnecessary current by now. A constant relevance of literature is expected by 61,6% whereas 37,4% are of the opinion that former importance of literature will decrease because of an increasing use of the world-wide-web. The data for women and men do not differ systematically. A tendency can be found after which a greater score of students in basic-studies expect an decreasing relevance of technical literature in sport science (47,2%) than in main-studies (26,1%). The Chi-Square-Test barely failed the 5%-level of significance ($\chi 2$ = 5,905, p= .052, n.s.).

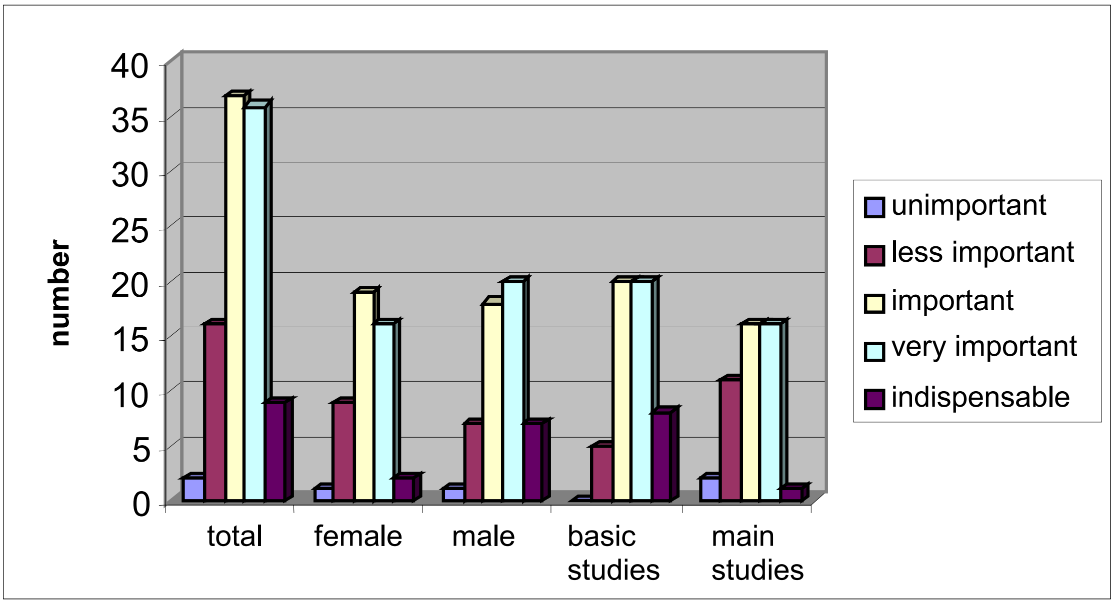

Figure 5. Individual relevance of place- and time-indipendent teaching offers

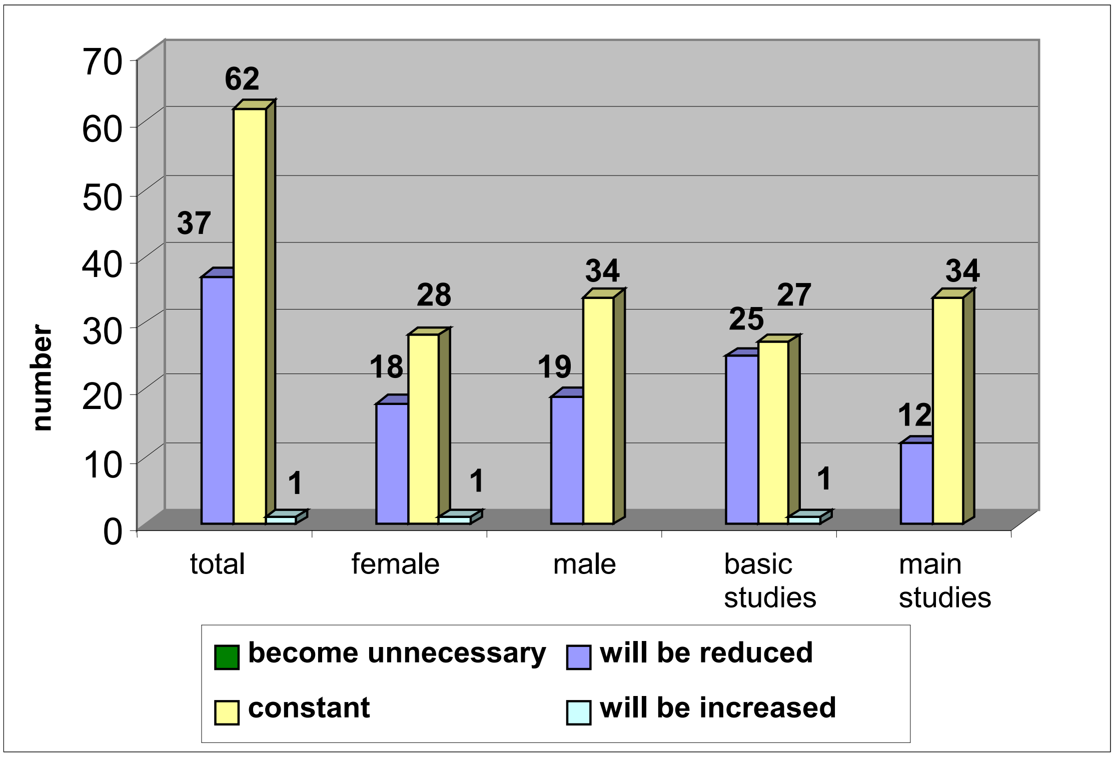

Figure 6. Changeable importance of technical literature in sport science

A majority of 55% of the students has not used the www to prepare lecture-lessons or seminars till now. The portion is somewhat higher in females and students in basic-studies. Because of the high score of participation of students in the first semester of their studies, this difference can not be interpreted, beyond it those differences are statistically not significant. Very unexpected were the answers to the question, if one would prever – if having the choice – to take part in the lecture for training- and movement science in the common semester either in a lecture-hall or at home via internet. Over 70% of the students thereafter would prever a “traditional” lecture. Even those students who have an access to the www at home would choose the “face-to-face” teaching in majority. In order to specify these statements, the students were asked, how they imagine an optimal relation of internet-based and “traditional” personal teaching on a 5-step-rating scale (see table 1). In the view of most of the students in sport studies the desirable relation between traditional and internet-based teaching offers would be charakterized by accompaniment and completion of “face-to-face” teaching offers and multimedia offers via internet. Only one students votes for an entirely replacement of traditional lectures and seminars by time- and place-indipendent internet-based offers. Six students expressed the opinion, that an optimal relation of traditional and internet-based teaching and learning would be characterized by offers only for those students who declare a special interest in internet-based learning. The frequencies of answers for the different categories do not differ significantly between women and men ($\chi2$ = 4,295, n.s.) or students in basic- and main studies ($\chi2$ = 1,167, n.s.).

Table 1. Optimal relation between traditional and internet-based teaching (N = 97)

	replace entirely	**replace as far as possible**	**always accompany**	**partly complete**	**offer only for interested students**
women	0	0	21	20	4
men	0	1	33	16	2
all	0	1	54	36	6

If the statements and opinions of the students mostly base upon individual experience or wishes without accompanied experience, was approximative prooved among the present practice of the use of the www for preparing lectures or seminars in sport science studies (see figure 7). Most of the students (55%) hitherto haven’t use the www in order to prepare for, or touching up lectures or seminars in their sport studies. The score of students so far without experience with the use of the www for their studies is somewhat greater in women and students in basic-studies, but this differences fail to be statistically systematic.

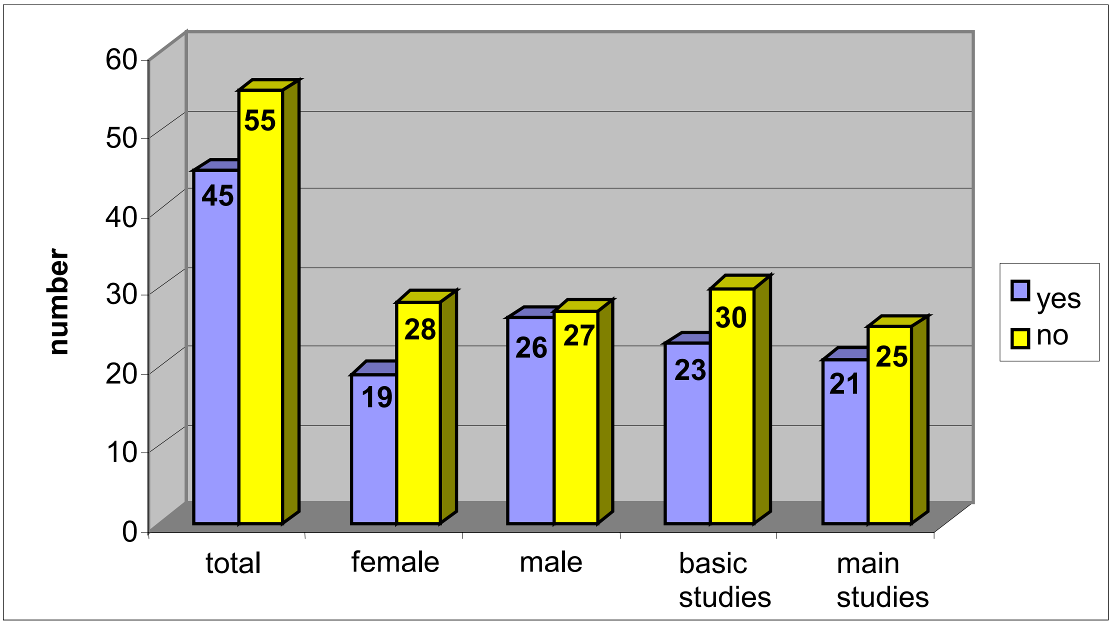

Figure 7. Experiance with the use of the www for preparating lectures or seminars (N = 100)

Discussion

The increase of using of internet offers in sport science studies is confirmed by the few data available. Whereas Baca & Nuc (2002, 3) state a portion of students with access to the internet of about 45% in 2000, two years later we find a quota of 85%. Despite of this high quantity, over 40% voted the internet to be less important or unimportant for sport studies and only 45% so far had used the www for their studies in sport science. One possible explanation for this could be a lack of adequate internet-based learning offers for sport science. The result, that the students don't see a personal advantage in internet-based offers likely is established by the missing experience with the use of multimedia learning systems in sport. This again maybe is a consequence of the relative high quota of participants in this study who stated in the first semester. In contrast to the practice of internet using of students in sport science, the expectations and estimations are somewhat different. The opportunity to use time- and place-independent learning offers in former studies in sport science is of high relevance for students. Herein younger students – in our study this were those who took part in basic studies – differ from elder students. Women and men who are now at the beginning of their studies, estimate time-and place-independend learning as more important and at the same time show a tendency to rate a decreasing future significance of technical literature in sport science. Because there was found no significant difference in the experience of using the internet for sport studies between students in basic- and main-studies, the significant difference in the age of both groups could be one aspect of explenation. A central outcome of our study is the request of the students of time- and place-independent learning- and teaching offers for their future studies. A great majority of over 70% prefers “traditional” teaching in sport studies. At the same time over 90% rate accompaniment and completion as the optimal relation of internet-based and traditional teaching offers. Therefore, the wishes for a more extensive integration of internet-based teaching and learning process in sport studies, is at the same time not accompanied by a wide use of the internet for sport studies or the hope of a swift replacement of traditional lectures and seminars by multi-media offers.

Conclusions

The realization, that learning only by means of computer and learning-software is less effective than the combination of several well harmonized offers (Rockmann & Butz 1997, 141, Wiemeyer 2001, 224) is confirmed by the represented study, based on the the view of the interrogated target group. Therefore, internet-based learning offers should be planned and developed in order to complete other forms of learning- and teaching-systems efficient. Beside technical aspects and didactically and psychologically well proofed features, the evaluation of the respectively special target group may be of great importance. Whereas gender related using or expectations do not seem to be of prior relevance, age, period of the actual studies and previous experience and practice with multimedia-learning could mark important factors. In any case, the production of internet-based multimedia teaching offers should be evaluated already during the process of development.

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„New media serving the teaching and learning process in the sports scientific education" - An empirical study about the Internet utilisation for the university sports scientific education

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ABSTRACT

An 'optimal' preparation of the students for the teaching practice with the new media necessarily demands corresponding 'self-awareness ' in the own university education.

The present empirical study tried to receive a present picture of the actual offers of Internet based lectures as well as of the personal suppositions and attitudes of the students (and teachers) concerning the Internet and computer utilisation for the university sports scientific education.

Under this point of view at the winter term 2001/02 an analysis of the present Internet based teaching offers of the German institutes of sports science took place. The existing information concerning the sports scientific education had been classified in the following way:

1. The kind of implementation into the learning and teaching process, especially regarding the coupling degree of the Internet based information to the real lectures.
2. The ascription of the internet based lectures to the different sports scientific fields.
3. The localisation of the Internet based lectures in the structure of the websites.

INTRODUCTION

The questions of contents and methods, of (objective) benefits and disadvantages – that's the central points in the today's discussion about the utilisation of the „new media" in the university education. But very often the important (subjective) part of Internet and computer utilisation for the university education is only insufficiently taken into account: who needs and who wants Internet based education at all? With other words: Is the majority of students and lecturers at present time able and willing (!) to use the Internet in a broad range as transfer medium of learning and teaching contents? Is supply and demand for an Internet based education in a well balanced proportion? The present empirical study is a first attempt to approach to this question especially from a sports scientific point of view.

‚The future teachers are well prepared for the common handling of computers, but they feel insufficiently prepared by the universities for the teaching practice with the new media. (study of the university of Bielefeld by order of the Bertelsmann-Foundation and the Heinz-Nixdorf-Foundation): *98,2% of the consulted students used a computer, 70% had an own PC - but ¾ of them criticized the insufficient offered lectures.* Only each eighth student felt himself best prepared for the teaching-practice with the new media.'
from: Berliner Zeitung (2000, 01. Januar)

This short information shows a typical problem: An ‘optimal ' preparation of the students for the teaching practice with the new media necessarily demands a corresponding ‘self-awareness' in the own university education - own practical experience with learning and teaching with and by the „New Media“.
The present empirical study tried to receive an present description of the actual offers of Internet based lectures. In a second step these offers should be compared with the personal suppositions and attitudes of the students (as the decisive target group) concerning the Internet and computer utilisation for the university sports scientific education.
Under this point of view at the end of the summer term 2001 a consulting of the students and lecturers at the institute of sports science of Humboldt-University of Berlin was carried out, concerning the application of „New Media“ (multimedia, computer, Internet) for the university sports scientific education.
An additional analysis of the present Internet based teaching offers of the German institutes of sports science took place at the winter term 2001/02.

METHODS

(1) Analysis of the present Internet based teaching offers at the German institutes of sports science
The analysis went out from the 67 institutes for sports science at the universities in Germany. The present state of internet utilisation for the sports scientific education in Germany was analysed during the winter term 2001/02 on the basis of the address-index of the German Society for Sports Science (dvs, 2002), as well as on the basis of the homepage-summary of German university institutes for sports science at the website of the institute for sports science of the University of Hamburg (IfS Hamburg, 2001) and the University of Hannover (IfS Hannover, 2001).
The analysis of the web pages took place between October 2001 and February 2002. The central homepages and department pages of the websites, which had been analysed before December 2002, were controlled in January/February 2002 once again. It was restricted to the existence or not existence of the appropriate contents – a valuation of the contents wasn’t carried out.
Going out from the analysis of the websites of German institutes for sports science by Theis, Mäncher (2001) – the websites of the sports-institutes had been rated under a qualitative point of view. That means, that all websites of the sports-scientific institutions, including the personal sites of the staff, had been examined for the existence of information about / for the educational process. For this analysis – similar to Theis, Mäncher (2001) – a simplified scale was used, to obtain information about the existence of teaching related contents on the websites of the institutes for sports science: element present or element not present.
This simplified scale allowed in a first step a direct comparison with the results of Theis, Mäncher (2001) and by this an rating of the development of the Internet representation of the German institutes for sports science in the area of the sports scientific education.
In a second step the attempt was undertaken to classify the real existing information concerning the sports scientific education regarding the kind of implementation into the learning and teaching process. The decisive criterion was the coupling degree of the Internet based information to the real lectures.
In a third step the existing teaching and learning contents was furthermore classified relative to a) the assignment to the different sports scientific fields and b) the localisation of the Internet based lectures in the structure of the websites.

(2) Consulting of students and lecturers
The aim of this consulting was to achieve a present figure of the students and teachers mind concerning their fundamentals and previous knowledge for the learning with „New Media“ – as well as to ask for their interests and attitudes concerning the application of „New Media“ for the university sports scientific education.
231 questionnaires had been distributed among the students at the institute of sports-science of Humboldt-University of Berlin, 24 questionnaires among the teachers of the same institute. The questionnaire was arranged into 3 parts:
(1) Personal information
(2) Questions about the computer- and Internet utilisation
(3) Questions about the usage of multimedia-elements via Internet for the sports-scientific education.
For further information to this part of the empirical study see Knoch (2003).

RESULTS

Changes on the websites of the German institutes for sports science 2000 – 2001/02

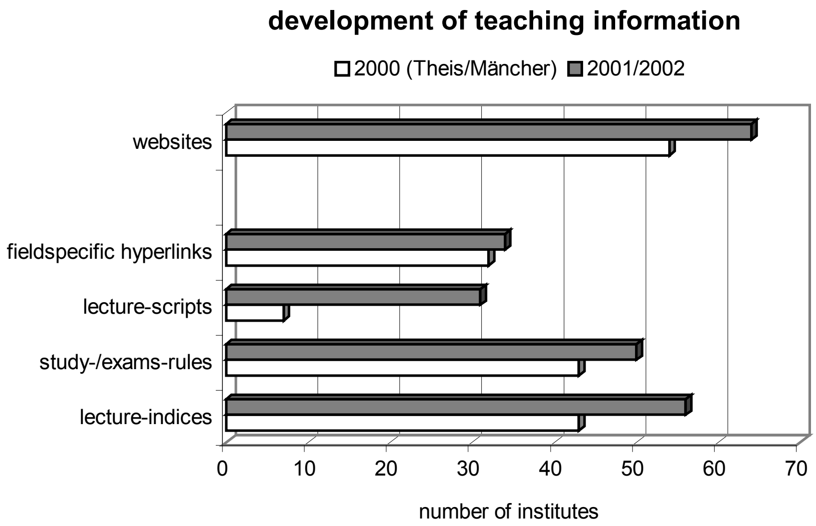

Figure 1. Development of teaching information on the websites 2000-2001/02

The comparison of the teaching and learning related information on the websites of the institutes for sports science (Figure 1) shows, that on one side the number of institutes, which are present with an own website has been grown up as well as the number of teaching related information on these websites. But the focus of this information lies unchanged in the field of organisation and administration (e.g. study- and examination-rules or lecture-indices)

Integration of Internet based teaching and learning information into the teaching and learning process

The systematisation of the Internet based teaching and learning information concerning their integration into the teaching and learning process of the sports scientific education is classified in the following way (Knoch, 2003):

1. **Study information:** common information about the study of sports science (e.g. study- and examination-rules)

2. **Study organisation:** common information about the organisation of the study (e.g. lecture-indices)
3. **Lecture accompanying information:** specific information about the organisation of specific lectures/seminars (e.g. dates, literature, themes)

4. **Lecture contents:** specific contents of lectures/seminars (e.g. scripts, exercises, specific collections of hyperlinks)

5. **Lectures online:** complex online-lectures/seminars with special learning-space

6. **Virtual lectures:** lectures/seminars exclusiv usable via Internet

The idealized existence of all subcategories at all sports institutes corresponds total realisation extent of 100% (Knoch, 2003).

Study information:

1) Study-rules are present at 47 institutes
2) Examination-rules are present at 28 institutes
3) Information about suitability-examination are present at 30 institutes
4) Enlarged information about the degrees are online at 16 institutes
5) Information about a potential foreign study exist only at 2 (!) institutes

The 5 criteria above have a total realisation extent of less than 40%. Figure 2 shows the corresponding percentage of the sports-scientific institutions, with information to the above criteria.

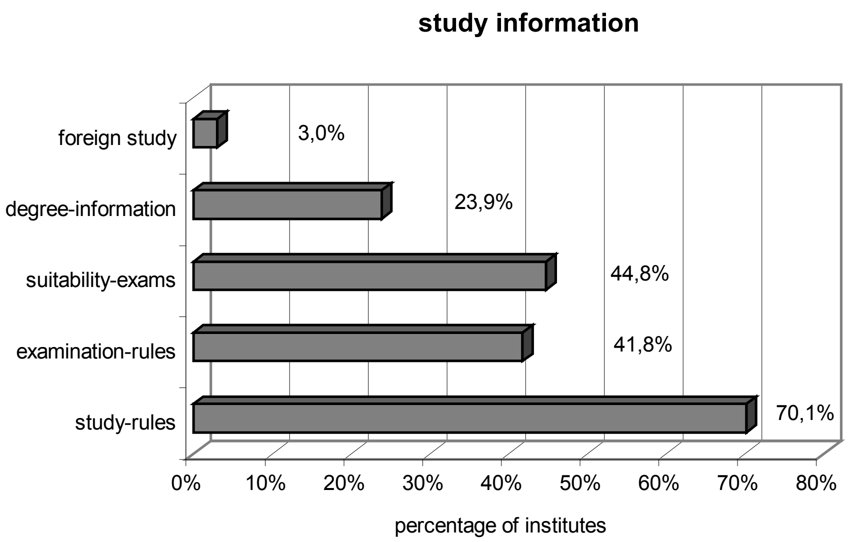

Figure 2. Study information online

Study organisation

1) Common plans and hints about the organisation of the study can be found at 16 websites
2) Simple lecture-indices or lecture-overviews have been found at 45 websites
3) Annotated lecture-indices exist at the websites of 30 institutes
4) Information about exams, (e.g. standards, topics and/or dates) exist at the websites of 19 institutes
5) Forms and/or patterns can be found online at 21 institutes

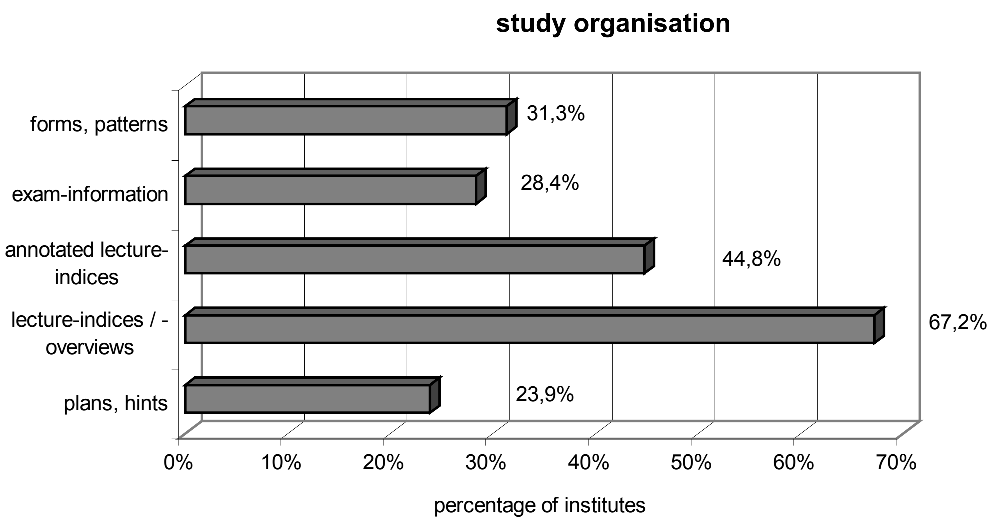

Figure 3. Study organisation online

The 5 criteria of study organisation have also a total realisation extent of less than 40%.
Figure 3 shows the corresponding percentage of the sports-scientific institutions, with information to the above criteria.

Lecture accompanying information

1) Information, concerning seminars and lectures (e.g. standards and/or contents and/or dates of the respective seminar/lecture) exceeding the information of the lecture-indices have been offered online at 11 institutes
2) Possibilities to inform online about single tests and the respective results exist at 5 institutes
3) Online-registration for lectures/seminars or online-placing of student reports for the appropriate seminars is possible at 9 institutes
4) Common guides/ instructions (practical training, scientific work) have been made available at the websites of 16 institutes

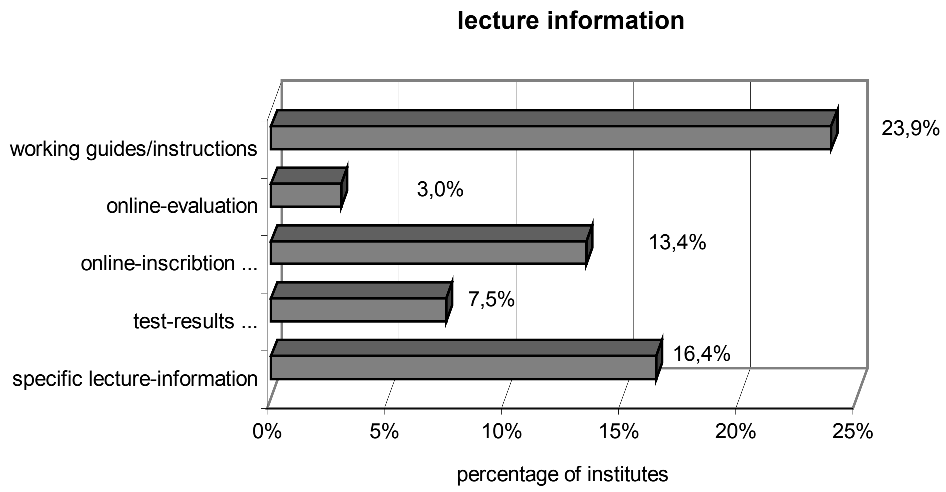

Figure 4. Lecture accompanying information online

The above criteria of lecture-accompanying information have a total realisation extent of less than 15%. No one criterion shows a spreading from more than 25% of the websites. Figure 4 shows the corresponding percentage of the sports-scientific institutions, with information to the above criteria.

Lecture contents

1. Specific information, additional to the standard contents of the lectures/seminar e.g. by means of hyperlink-indices, collections of papers, talks and homework or written material have been offered online at 14 institutes
2. Lecture-scripts and accompanying foils exist online at 32 institutes
3. Exercises and trial-tests can be found at 6 institutes online

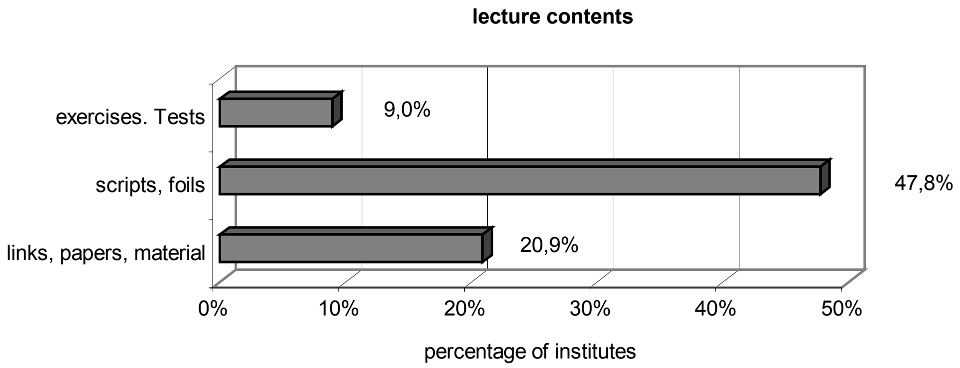

Figure 5. Lecture contents online

In summary it can be said, that also in the field of lecture-contents only a very small spreading exist. The above criteria of lecture-contents had a total realisation extent of less than 25%. Figure 5 shows the corresponding percentage of the sports scientific institutions, with information to the above criteria.

Summary

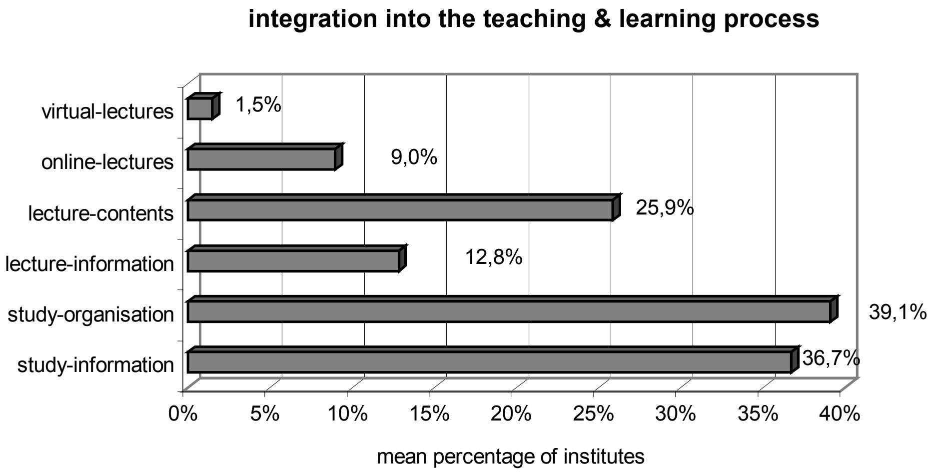

Figure 6. Integration of Internet based teaching and learning information into the teaching and learning process

Figure 6 shows an overview of the proportional spread of different levels of internet-based teaching and learning information concerning their integration into the teaching and learning process of the sports scientific education at the websites of the sports institutes in Germany (march 2002).

Common information about the study of sports science at all and about common organisation of the study have a much stronger presence on the websites of the sports scientific institutions in Germany, than contents related and lecture/seminar specific information. Especially information with a higher need for maintenance is strongly underrepresented. Online-lectures are like „singular points“ in the web appearance of the sports institutes, virtual-lectures are actually not existent.

Lecture contents online

Assignment to the different sports-scientific fields
Classifying the online-lecture contents corresponding to the different sports-scientific fields the following categories had been summarized:

(1) Natural-scientific orientated sports science: lectures of biomechanics and motor activity, training-science, sports medicine
(2) Social-scientific orientated sports science: sports psychology, sports pedagogic, sports didactics, sports philosophy, sports sociology und sports history
(3) Methods und sports management: lectures completing the traditional sports scientific fields, e.g. sports informatics, statistics, scientific methodology, sports law etc.
(4) Theory & practice of sports

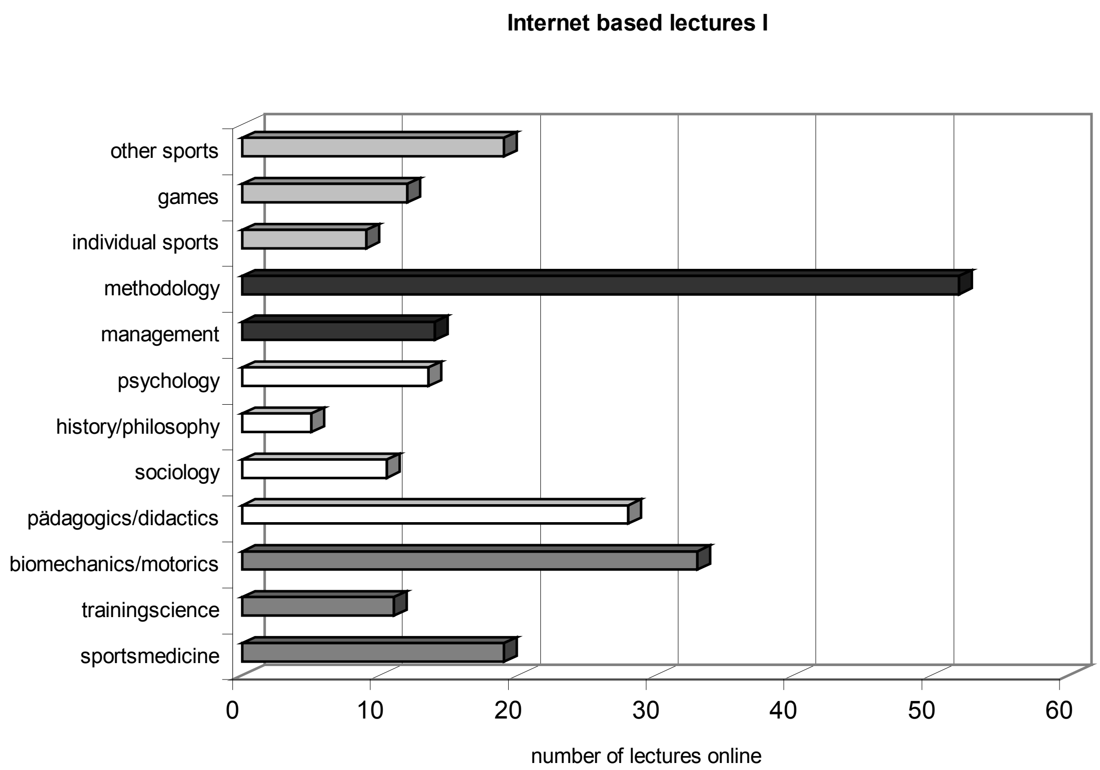

Figure 7. Distribution of the Internet based lectures in different fields of sports

Figure 7 shows the absolute distribution of the appropriate Internet based information
It is to be seen, that the majority of lectures online (186) are from the fields of the sports scientific theory (1-3) – only 18% are accompanying the field of theory & practice of sports.

Comparing the lectures relating to social- or natural-scientific orientation there is no great difference to be seen (Figure 8), contrary to the expectation of the students, who see a greater potential for the natural science orientated fields (Knoch, 2003).

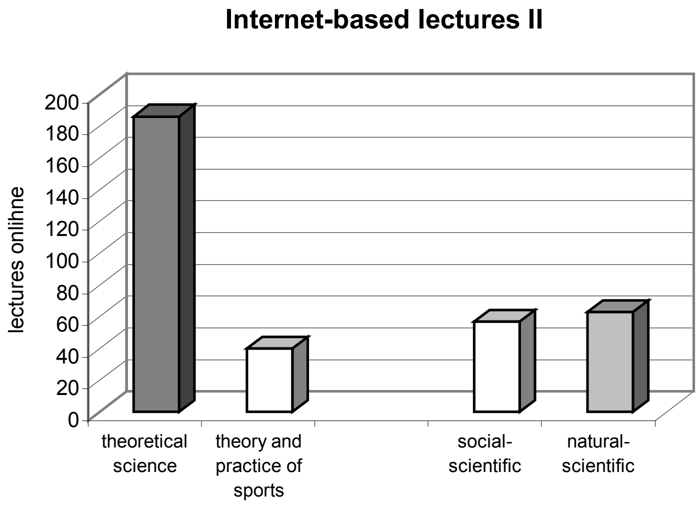

Figure 8. distribution of the internet-based lectures

A possible explanation for this result could lie in the small amount of lectures which present parts of their contents via Internet, so that at present time the personal engagement of the lecturer (and her/his attitude to the „New Media“) is the decisive part for Internet representation – not the affiliation to a specific field of sports science.

The localisation of the Internet based lectures in the structure of the websites

Under the point of view that, besides contents and relevance to the present, a simple and reliable localisation is of great importance for the users, accordingly to the contents based classification of the Internet based lectures, in a second step an assignment of the Internet based teaching offers to the localisation in the structure of the websites took place. 2 fundamental criteria for an easy and fast access to the Internet based lecture contents are: 1. The Internet identification of the sports institutes within the structure of the respective university/college and 2. The localisation within the web presence of the respective sports institute

Internet addresses of the sports institutes

Examination the description of the various sports institutes within their Internet addresses, it has to be seen, that very often a tedious navigating is necessary within the quite different structures of the respective university/college to find the websites of the respective sports institute. Essential problems in finding the correct websites result from the following points: First of all there is no standardized term for the sports institutes within their Internet addresses – secondly no standardized place of these terms within the Internet addresses. 67 sports institute have 35 (!) different terms! But even with identical terms the structure of the Internet address is not predictable: For example the most spreaded term „sport“ exists on 15 different places within the Internet address, e.g.: http://www.sport.uni-augsburg.de/; http://www.uni-bielefeld.de/sport/; http://www.phil-fak.uni-duesseldorf.de/sport/; http://www.uni-bayreuth.de/departments/sport; http://www.sport.uni-bremen.de/spowi/spowiger/spowiger.htm. The memorable and logical Internet addresses „www.sport.uni.de“ and „www.uni.de/sport“ have the most vasted spread in fact (see Figure 9), but in the end only less than 27 % of all sports institutes use these addresses.

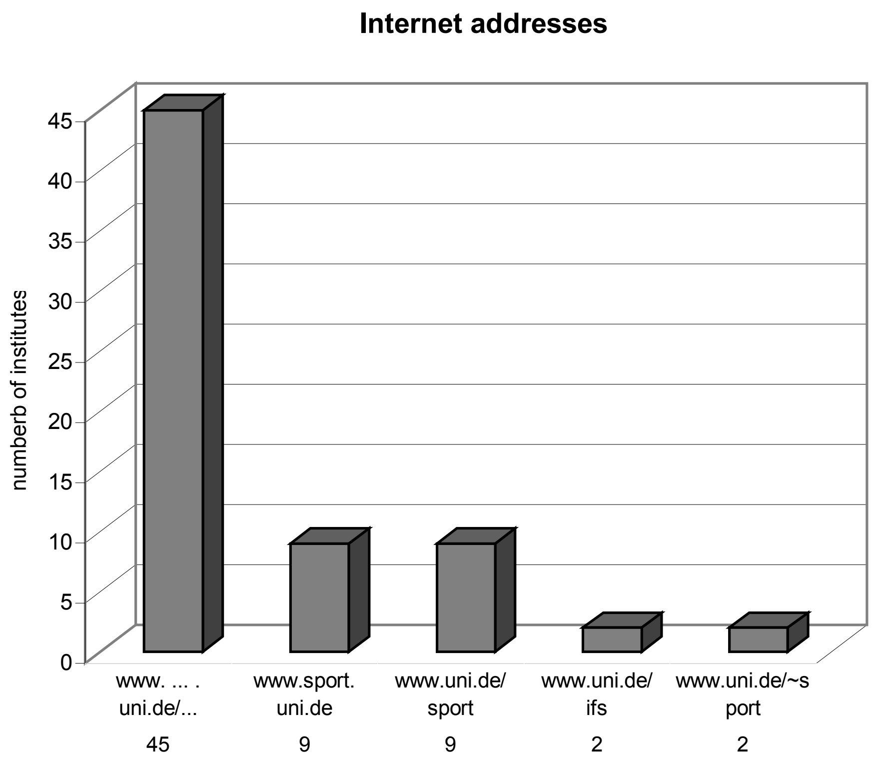

Figure 9. spread of Internet addresses of the sports institutes

The localisation of the Internet based lectures within the web presence of the respective sports institute

For the localisation of the Internet based lectures within the structure of the web presence of the respective sports institute 4 levels have been classified:
Level 1: access to the Internet based lectures via the starting page of the web presence
Level 2: access to the Internet based lectures via a central page of the institute, e.g. study („Studium") or lesson („Lehre").
Level 3: access to the Internet based lectures via the pages of the various departments
Level 4: access to the Internet based lectures via the personal or private homepages of the lecturers.

The result of this classification is shown in Figure 10. At the end of the winter term 2001/02 only 4% of the Internet based lectures have been located on the starting pages, but 24% on the personal or even private homepages of the lecturers.
But also within the respective web presences of the sports institutes is no uniform structure to be found: the Internet based lectures have to be searched on different levels. At present time there is no homogeneous system within the localisation of Internet based lectures.

contents within the website-structure

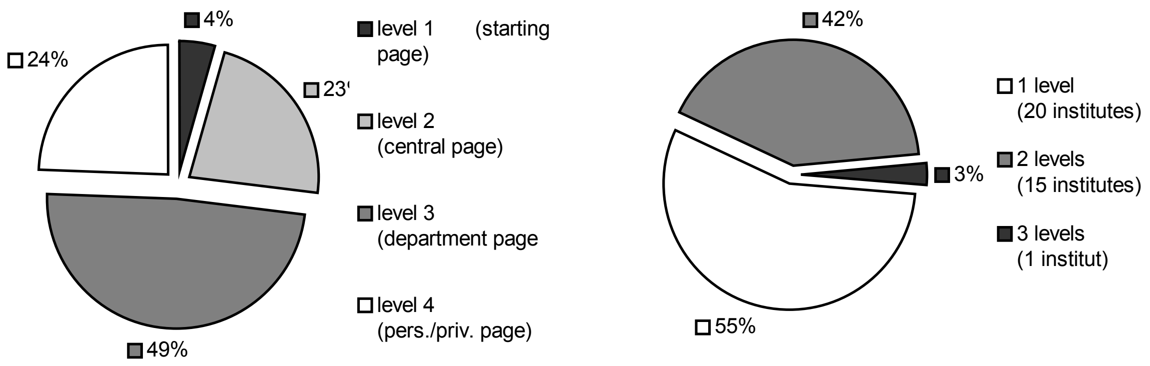

Figure 10. Distribution of teaching contents within the website-structure of the sports institutes.

The left figure shows the distribution of access points to the Internet based lectures of all sports institutes. The right figure shows the diversity of access within the website structure of single institutes.

SUMMARY/CONCLUSION

The actual description of the present offers of Internet based lectures at the German sports institutes shows a great need of catching up on everyday dealing with Internet utilisation for the sports scientific education. An analysis of the Internet based educational information makes clear:

1. Since the analysis of Theis/Mäncher 2000 the number of institutes with web presentations online as well as the correlating teaching information on these sites has been increased.
2. Administrational and organisational contents dominate the Internet based teaching offers of the sports institutes – directly lecture contents related information of the single sports scientific fields are found only sporadically.
3. Durable text-based information dominates clearly over perishable, multimedia-based information with corresponding high effort of production and maintenance.
4. The theory orientated lectures of the traditional sports scientific fields are predominant over Internet based lectures of the theory and practice of sports.
5. Comparing the lectures relating to social- or natural-scientific orientation there is no great difference to be seen.
6. Last but not least, there is no uniform navigational structure to be found for the Internet based lectures in sports science. The Internet identification of the sports institutes within the structure of the respective university/college as well as the localisation within the web presence of the respective sports institute show no standardized systematic.

In the future additional to the improvement of quality and quantity of the Internet based lectures a permanent collateral evaluation and comparison with the personal suppositions and attitudes of the students will be necessary to avoid defective development. A gradual, continuous approach of the students and teachers to the use of Internet in the teaching and learning process is necessary to achieve an effective everyday dealing with Internet utilisation for the sports scientific education. In this sense the primacy of the Internet based lectures should be found also in the next future in the fields of temporal and local flexibility for an easy and fast access to the related contents. Simple, preformatted learning space should attract all teachers to use Internet based materials.

For the navigational structure of the Internet based lectures in sports science this means to find a standardized Internet identification of the sports institutes like „www.sport.uni.de“ or „www.uni.de/sport“. On the other hand a standardized structure of the presentation of the Internet based lectures within the website of the respective institute is necessary. The basic principles of the Internet makes it possible to use multiple access points from the starting page, the department pages and the lecture indices to one common ‘lecture place’. Further investigations on this field are necessary.

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