Multimedia in sport – between illusion and realism

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Abstract

Multimedia has much to offer to sport and sport science. However, research and experience clearly show that multimedia is not a panacea for all the unsolved problems of information, communication, research and education. In this contribution we discuss the advantages and disadvantages of multimedia. Existing experience and future potentials are promising, but multimedia requires deliberate use and continuous critical reflection.

Keywords: multimedia, research, education, learning, e-learning, e-research

1 Introduction

In 1995, the term ‘multimedia’ was elected ‘word of the year’ by the Society of German Language. The reason for this was that this term was the main focus of public discussion on modern information technologies. Literally, ‘multimedia’ means ‘many means’. In order to demonstrate the technological innovation this term refers to a technological or electronic system that allows users to independently produce, use, manipulate, store, communicate or combine different time-dependent and time-independent media like texts, pictures, videos and audios [1]. Multimedia systems show several features that offer unique options for many applications in science and practice of sport: interactivity, flexibility, ubiquity, authenticity, multimodality and multicodality are only a small sample of buzzwords indicating the new and fascinating potentials of multimedia, particularly for learning. Therefore, the vision of multimedia is to improve information, communication, research and education and to solve at least some of the so-far-unsolved problems in these areas.

Although there is no doubt about the potential surplus values of multimedia learning, existing experiences and research results have been inconsistent. There seem to exist critical factors having a strong influence on the effects and efficiency of multimedia. Therefore, the question arises whether the potentials of
multimedia are illusions or realism. In this contribution we adopt an intermediate position: We are going to show that in order to exploit the potentials of multimedia for information, communication, research and education, the complex interaction of users (students, teachers, researchers), media, task and context (social, technical) need to be considered. An interdisciplinary understanding of multimedia is required to deal with these complex interdependencies appropriately. Multimedia cannot serve as a substitute but rather as a complement of traditional forms of information and communication. Here we put strong emphasis on multimedia as an educational tool, but we also deal with research (see also Ref. [2]).

As a first step, we introduce different types of multimedia systems regarding learning. Based on these distinctions we discuss the pros and cons of multimedia learning in a dialectic way leading to a synthesis. Then we deal with scientific basics of multimedia learning and take a look into the future of multimedia learning. Finally, we discuss the potentials of multimedia as a research tool.

2 Types of multimedia learning systems

There are several types of multimedia learning systems (MLS). One possible way to classify MLS is illustrated in Figure 1.

In learning programs interaction is controlled by the software system, whereas in learning environments learners exercise control. Learning programs can have a fixed or adaptive structure. The different subtypes can be characterized as follows:

- KIOSK systems allow for animated change of pages or browsing. Users are allowed to follow only pre-structured (especially linear) paths.
- Drill-and-practice systems are based on learning models of behaviourism. The systems continuously present tasks to be solved. These systems are particularly appropriate for exercising and establishing routine skills.

![Figure 1: Types of MLS [3].](image)

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Testing software also presents tasks in order to assess selected characteristics of a person, e.g. attention or intelligence. Various types of tasks and questions can be applied, e.g. multiple-choice tasks, drag-and-drop tasks, correction tasks and cloze.

Tutorials or tutorial systems perform all teaching functions. They deliver information, give tasks and provide feedback.

Teleteaching or distance teaching means that a lecture is broadcasted in an unidirectional synchronous or asynchronous communication style from a studio or a lecture hall to different locations. Feedback to the learners is provided in an indirect and asynchronous way. Especially asynchronous distance teaching is effective [4].

Multimedia systems with *adaptive structure* can be subdivided into intelligent tutorial systems and adaptive hypermedia systems [1]. Both systems are able to adapt to the learners’ characteristics.

*Multimedia learning environments* can also be subdivided into different categories:

- Animations are dynamic visualizations of objects and procedures that are too complex to (re)present them verbally. Animations are especially effective with sport movement. However, several aspects of perception and memory have to be considered in order to appropriately apply this type of MLS, e.g. gestalt phenomena and depth perception [5].
- Simulations are programs operating on the basis of (numerical) models. Certain parameters can be changed (e.g. angle and altitude of release and initial velocity in throwing) in order to find out how these changes affect performance (throwing width). Combining animations and simulations can be a very effective learning tool [6].
- Problem-solving environments and micro-worlds are more or less complex contexts where the learners have to solve specific tasks, e.g. operating a spaceship. This category of MLS is based on constructivist learning theory demanding maximum authenticity (‘situated learning’).
- Edutainment systems and learning games try to combine two aims: learning and entertainment. The idea is to enhance learning motivation by presenting stimulating environments like virtual competitions. One term that has come up recently is ‘serious games’. This term means that games can be used for learning and education, i.e. for serious purposes (see Section 6.2.3).

3 Learning with multimedia – thesis and antithesis

In this part of the contribution arguments in favour of multimedia learning are confronted with counter-arguments. We shall start with the respective argument in favour of multimedia learning.

**Thesis 1: Multimedia learning offers appropriately structured, non-linearly linked information**

This argument is based on the fact that in general knowledge shows a non-sequential networked structure. A good example is the knowledge concerning
movement corrections in sport which comprises different types of feedback, various learning theories, psychological and pedagogical aspects. By means of hypertext or hypermedia structures, multimedia offers options for an appropriate (re)presentation of this knowledge.

**Antithesis 1: There is no evidence that learning is really supported by presenting complex multimedia structures**

Complex knowledge structures are the result of a learning process. This does not mean that this result is appropriate for beginners who are just at the starting point of this process. Looking at didactic principles like ‘from simple to complex’ or ‘from easy to difficult’ the reverse seems to be true: beginners need to experience relieved learning conditions in order to prevent overload. Finally thesis 1 does not apply from didactical and psychological points of view. The phenomenon ‘lost in hyperspace’ also indicates that one can lose orientation with too complex information environments.

**Thesis 2: Multimedia allows new freedom for learning – interactive and self-controlled learning, independent of space and time**

When multimedia systems are available online or on storage devices, learners can activate information at any time and place they like (provided that they have the technology at hand). This allows new freedom for learning. Learners can decide on their own which and how much information they get and when and where they learn. Furthermore, interactive applications, e.g. simulations and animations, offer the autonomous testing of their ideas and assumptions.

**Antithesis 2: Freedom implies responsibility – self-controlled learning requires new competences and generates new dependencies**

Thesis 2 sounds very promising. On the other hand, learners must be able to control and regulate their own learning. Self-control comprises several dimensions (cognitive and meta-cognitive strategies, use of internal and external resources; [7]). When beginners have to self-control their learning they are subject to a dual-task context: They have to exercise and learn and they have to monitor their own learning process. Possibly this causes an overload that impairs learning.

One might oppose that the learning system can be designed to take the control responsibility, but this would again constrain the freedom for the learners. In addition, there are serious doubts whether machine-control can be as good as or better than human control.

Besides, multimedia learning produces new dependencies: the appropriate technological options (internet, multimedia computer, etc.) and technology-related skills have to be available in order to exploit the new freedom. Learners need to spend money for computer equipment and internet access. This might result in a ‘digital divide’ concerning education: the gap between humans who can afford technology and those who cannot might increase. Furthermore, new and serious ‘time problems’ arise with new communication technologies like e-mail [8].
Finally, when learning with multimedia freedom may not increase or even decrease because stakeholders who produce and offer multimedia content decide which and how much information is available in which form, at which time and from which location. This also holds for animations and simulations: users can manipulate and explore only the changes that are offered by the particular program.

**Thesis 3: Multimedia offers various options for more authentic (re)presentation of information**

Contrary to a book, multimedia claims to present information in a (more) authentic way. Text and static pictures are used in a book, whereas multimedia allows dynamic representations like audio and video. Furthermore, augmented reality (AR) or virtual reality (VR) can provide three-dimensional immersive visual information and, by means of data glove, data suit and motion platform, tactile, kinaesthetic and vestibular information. The only sensory systems that have been neglected by multimedia (so far) are the olfactory and gustatory systems. Multimedia opens up an incredible number of new options to present information. This is very attractive for sport science and education: Movements can be displayed from any perspective, using any form (stick figure, wire frame, geometric model, etc.) and colour. These options can enhance authenticity of presentations. Sounds and music are presented as audios (and not as text or score) and movements are presented as videos (and not as series of static pictures). Furthermore, artificial movements can be displayed that have never been realized by a sportsman.

**Antithesis 3: Only a tiny portion of the new presentational options makes sense from a didactical point of view or is effective from a learning perspective**

Do learners really need more than 16 million colours, countless presentation forms and thousands of different fonts? The opposite is true: certain combinations of colour and luminance as well as fonts are extremely detrimental to perception and learning [5]. Furthermore, (superfluous) animations tend to distract attention from the learning subject and impair focussing attention. In this respect ‘less is sometimes more’.

The numerous options that may enhance authenticity of presentations can also cause specific problems like the well-known ‘motion sickness’ when immersing into VR due to a coupling of authentic visual and acoustic information and non-authentic proprioceptive information: the visual system perceives motion, whereas the proprioceptive system does not. Particularly, being aware of the artificial nature of information might also cause a strange feeling about VR and AR.

Rützel [9] stresses that the authenticity of multimedia learning is somewhat superficial because information processing might be affected by the fact that a double interaction is required: The learner has to deal not only with the learning subject as a phenomenon, but also with the cognitive models that stand behind the multimedia presentation. If these models are not intelligible, learning becomes casual and didactics are not possible. What looks like a support at first glance might turn out as a possible learning barrier.
Finally, the variety of multimedia options cannot solve the problem that we have to know how humans perceive and learn in order to derive guidelines for an appropriate design of form and content. The inverse direction (from technology to learning) can be chosen, but this strategy requires extensive research on the interactions with human information processing and learning.

**Thesis 4: Multimedia offers new forms of communication to enhance learning**

In the past, face-to-face conversation was the authentic form of synchronous communication. Later the phone came up. The traditional form of asynchronous communication was the letter or post-card. Multimedia offers new forms of synchronous and asynchronous communication among learners and between learners and teachers: e-mail, chat, forum, videoconference, e-lecture, etc. Compared to the phone, synchronous communication can be more authentic and gradually comes closer to face-to-face communication. New forms of asynchronous communication shorten the time interval between the message and response. Whereas the response delay for a letter usually was some days, this delay may be only a few seconds or minutes with e-mail. This augments the communicative options and allows new forms of social interactions for learning. The gap between immediate synchronous conversation and delayed asynchronous communication is filled by new options.

**Antithesis 4: Multimedia communications produce new constraints and dangers**

Although the number of options for synchronous and asynchronous communication rises, there are also new constraints and dangers. Everyone knows that when having just clicked the ‘send mail’ button, the sender expects an immediate answer. An immediate answer might be prohibited by too much Spam mail or absence of the teacher because she is ill or attending a conference. When will the answer to this e-mail arrive? This can happen at any time, maybe in a minute or after some days. So we have to learn to wait [8].

Several forms of communication, e.g. chat and forum, allow users to disguise. Without any problems users can invent new identities and prevent to be like they are not. Using the new forms of communication exclusively might cause impoverishment of communication and social experience, loss of vivid and perceptual experience, disorientation and self-relatedness [9].

**Thesis 5: Multimedia supports up-to-date information and worldwide propagation of information**

Until a textbook appears on the market usually many months or years go by. Therefore, when the book is published the content is no more up-to-date. One might accept this problem for a basic or introductory textbook that contains approved and fail-safe knowledge. But this latency cannot be tolerated if up-to-date knowledge is to be conveyed to learners. In this regard, fast publication by means of CD-ROM, DVD or internet reduces latency considerably.
Antithesis 5: Speed reduces precision and selection of good quality might become difficult facing the vast amount of information

When new evidence has to be presented as fast as possible by means of multimedia there might not be time enough for a critical inspection and integration.

When so much information is available it may be difficult to select the appropriate information that is of high quality. Anyway it may be impossible to review all the available information. By the way, this might give rise to a new professional option: to systematically select and present the appropriate information depending on the special needs of the particular customer.

4 Learning with multimedia – a synthesis

Bearing in mind the different types of multimedia systems and the result that there is no simple argument in favour of or against multimedia learning it becomes clear that there cannot be a simple ‘yes’ or ‘no’ to the question whether multimedia enhances learning or not. Rather, we have to adopt a more specific view: on the one hand and without doubt, multimedia technology offers new options for learning, but on the other hand these new options also generate new constraints and possible dangers. One way to deal with this unsatisfactory situation is to resign and to reject multimedia learning for being ‘too ambivalent’. But this would be too pessimistic. The possible surplus value of multimedia learning would be neglected. It is reasonable to ask the question: for which kind of learning and in which learning contexts are which MLS promising options? In Figure 2, a model is presented that illustrates the complex interactions of multimedia learning.

Figure 2: Complex interaction of learners, teachers, the learning content and the learning system.
Learners can have different knowledge level, computer experience, attitude, motivation, etc. Evidence shows that beginners need advice and guidance, whereas experts are able to navigate through a MLS on their own.

Teachers can take different roles, and have different knowledge level and computer experience. Furthermore, teachers’ didactical competence and attitude contribute to multimedia learning.

The learning contents also play an important role in multimedia learning. Depending on different types of content, complexity, quantity and structure, the MLS has to be designed in a specific way (see Section 2).

The structure and features of the MLS is the most important factor within the complex framework of interactions. Interactivity, adaptivity, adaptability, media and communication determine the options that can be used. These options have to fit perfectly into the complex interactions of learners, teachers and learning contents.

5 Learning with multimedia – what science tells us

Many scientific areas contribute to the understanding of multimedia learning, e.g. psychology, pedagogy, computer science, sociology and physiology. In this section we focus on the perspectives of learning theory and didactics and the experimental evidence.

5.1 Learning theories and didactics concerning multimedia learning

When multimedia is applied to learning, a look at learning theory and didactic concepts is mandatory. We can find an unmanageable variety of psychological and didactical approaches that are referred to in order to substantiate multimedia learning. Kearsley [10] enumerates more than 50 different theories and concepts of learning and instruction relevant to multimedia learning. A small sample of these approaches is shown in Table 1.

<table>
<thead>
<tr>
<th>Theory</th>
<th>Short description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Behaviourism (Skinner)</td>
<td>Focus: stimulus–response relations</td>
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<tr>
<td></td>
<td>Repeated rewards (consolidation)</td>
</tr>
<tr>
<td>Genetic epistemology (Piaget)</td>
<td>Focus: individual cognitive structures</td>
</tr>
<tr>
<td></td>
<td>Development through active involvement and challenges</td>
</tr>
<tr>
<td></td>
<td>Stimulation by social interaction</td>
</tr>
<tr>
<td>Constructivism (Bruner)</td>
<td>Knowledge acquisition – active-constructive process</td>
</tr>
<tr>
<td></td>
<td>Significance of learning material</td>
</tr>
<tr>
<td></td>
<td>Cooperative learning in real-world settings</td>
</tr>
</tbody>
</table>

Table 1: An overview of theories and concepts relevant to multimedia learning.
Table 1: Continued

<table>
<thead>
<tr>
<th>Theory</th>
<th>Short description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Multimodal memory</strong> (Engelkamp)</td>
<td>Modalities-specific representations&lt;br&gt;Conceptual representations&lt;br&gt;“Do-effect” – significance of action execution</td>
</tr>
<tr>
<td><strong>Cognitive-plausibility-hypothesis</strong> (Jonassen)</td>
<td>Analogy hypertext/hypermedia – organization of human knowledge&lt;br&gt;Significance of networked knowledge presentation</td>
</tr>
<tr>
<td><strong>Sociocultural theory</strong> (Vygotsky)</td>
<td>Age-dependency of cognitive development capacity&lt;br&gt;Significance of social interaction</td>
</tr>
<tr>
<td><strong>Anchored instruction</strong> (Bransford)</td>
<td>Video-based presentation of case studies&lt;br&gt;Narrative structure of information presentation&lt;br&gt;Generative learning (autonomous search for solutions)&lt;br&gt;Embedding all required data&lt;br&gt;Complex problems</td>
</tr>
<tr>
<td><strong>Cognitive apprenticeship</strong> (Brown, Collins)</td>
<td>Presentation of expert problem-solving procedures&lt;br&gt;Four dimensions: contents, methods, tasks and context</td>
</tr>
<tr>
<td><strong>Problem solving</strong> (Newell, Shaw, Simon)</td>
<td>Starting point: problem to be solved&lt;br&gt;Significance of novice–expert interaction and task context</td>
</tr>
<tr>
<td><strong>Distributed cognition</strong> (Hutchins)</td>
<td>Interactions of individual, environment and cultural artefacts&lt;br&gt;Significance of technology</td>
</tr>
<tr>
<td><strong>Cognitive flexibility</strong> (Spiro)</td>
<td>Focus: learning in complex and ill-structured contexts&lt;br&gt;Re-structuring of knowledge triggered by environmental challenges&lt;br&gt;Transfer of knowledge and skills&lt;br&gt;Basis of activities: multiple representation of context (different perspectives), many case studies</td>
</tr>
<tr>
<td><strong>Situated cognition</strong> (Lave)</td>
<td>Context-dependency of learning (problem, action, situation, culture, etc.)&lt;br&gt;Critical components: social interaction and cooperation</td>
</tr>
<tr>
<td><strong>Goal-based scenario</strong> (Schank)</td>
<td>Self-motivated, goal-oriented learning – seven principles (constructivist approach)</td>
</tr>
<tr>
<td><strong>Self-regulated learning/metacognition</strong> (Zimmermann)</td>
<td>Self-control of cognitions by the individual&lt;br&gt;Self-observation, self-evaluation, self-reaction</td>
</tr>
</tbody>
</table>
To sum it up, discussion of multimedia learning reflects three mainstreams of learning theories: behaviourism, cognitivism and constructivism. Every approach contributes considerably to the understanding of human learning. Whereas behaviourism focuses on stimulus–response relations, cognitivism (or representationalism) focuses on individuals and their mental processes. Constructivism also takes into consideration social interactions.

5.2 Experimental evidence concerning multimedia learning

Dealing with empirical evidence, the first question is how to examine multimedia learning from a scientific point of view. Bearing in mind the numerous interacting factors that influence multimedia learning, it seems to be rather hopeless to examine multimedia learning in general. Only a very specific constellation of conditions can be tested. In order to ensure internal validity a max-con-min strategy is required [11]. According to this strategy, research tries to maximize the variance caused by the treatment on the one hand and to control or minimize the unwanted variance caused by intervening variables. The experiment is the appropriate research method in order to realize a max-con-min strategy. Concerning multimedia learning experiments, the appropriate experimental design is illustrated in Table 2.

In order to compare multimedia and alternative learning two experimental groups are needed. Pre- and post-tests are required to assess initial and final learning scores. Control groups help to test for longitudinal effects that may be caused by other factors that differ from treatment (e.g. maturation or seasonal effects). Examining two control groups allows to test the effects of repeated testing.

The second question concerns the choice of the independent variable(s). Concerning multimedia learning four basic types of variables are usually assessed:

- Learning scores (LS)
- Learning time (LT) or learning rate
- Learning efficiency (LE) or learning gradient (i.e. ratio of learning gain and learning time)
- Learners’ attitude

Table 2: Experimental pre-post design for analysing multimedia learning.

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-test</th>
<th>Treatment phase</th>
<th>Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multimedia learning</td>
<td>x</td>
<td>Multimedia application</td>
<td>x</td>
</tr>
<tr>
<td>Alternative learning</td>
<td>x</td>
<td>Alternative method</td>
<td>x</td>
</tr>
<tr>
<td>Control 1</td>
<td>x</td>
<td>No treatment</td>
<td>x</td>
</tr>
<tr>
<td>Control 2</td>
<td>–</td>
<td>No treatment</td>
<td>x</td>
</tr>
</tbody>
</table>
However, many studies of multimedia learning suffer from poor research design [12, 13]. Instead of appropriate experimental pre-post designs with control groups often descriptive studies, case studies or studies without control groups have been performed. This lack of quality is a particular problem for adopting quantitative methods of research synthesis (meta-analyses). Nevertheless, results of these approaches are discussed in the following text. We subdivide this section into two parts: first we discuss studies dealing with cognitive learning and second we analyse studies dealing with motor learning. Although there are some commonalities of cognitive and motor learning, the main difference is that in cognitive learning the mind is the primary means to solve the task whereas the body is used for solving motor tasks. Unfortunately, meta-analyses and reviews only exist for cognitive learning in different areas. Reviews of multimedia cognitive and motor learning in sport and sport science do not exist.

5.2.1 Cognitive learning
Firstly, reviews of cognitive learning in various areas are presented and discussed. Secondly, selected studies dealing with cognitive learning in the area of sport and sport science are analysed in more detail.

Numerous qualitative reviews and meta-analyses have been published summarizing research comparing traditional to technology-supported learning (see Table 3). Meta-analyses are specific statistical techniques that allow to summarize and integrate the results of primary studies. Furthermore, meta-analyses allow to correct the results for sampling error and poor reliability. On the other hand, meta-analyses raise some problems of validity, e.g. the file drawer problem, the ‘apples-and-oranges’ problem or the ‘garbage in – garbage out’ problem. The file drawer problem means that there might be many non-significant studies that have not been published. This may cause a strong bias towards an overestimation of effect size. The ‘apples-and-oranges’ problem denotes the fact that the studies being integrated show particular differences that affect comparability. The ‘garbage in–garbage out’ problem raises the argument that studies of poor quality might be integrated leading to invalid results. Some of these problems can be overcome by adopting specific meta-analytic procedures. Therefore, meta-analyses can serve as a first overview of a specific research area. The best way to deal with the above mentioned problems is to combine several techniques of meta-analysis with a qualitative review.

Some reviews address selected aspects of technology-supported learning, e.g. interactive video [14, 15, 16], computer-assisted instruction (CAI, [17]), computer-based instruction (CBI, [18]), web-based teaching (WBT, [19, 20]) distance education (DE, [4, 21]), educational simulations [6] or learners’ control [22]. Furthermore, papers summarize existing reviews (e.g. Ref. [18]).

Overall, current evidence shows that multimedia learning in general has positive effects on learners’ performance, learning time and attitude. The mean effect sizes (ES) are around $d = 0.5$, i.e. differences of means between experimental and control group are about half a standard deviation (medium or moderate effect). However, most of the meta-analyses reveal that $ES$ are not homogenous.
This result is a strong indicator that there are factors that moderate multimedia learning effects. In Table 3 selected moderators are listed. They range from learners’ characteristics to technical and didactic features of the learning system. Once again the complex interaction of learners, teacher, learning system, learning subject and learning environment becomes evident (see also Figure 2).

Table 3: Results of meta-analyses and reviews concerning factors influencing multimedia learning.

<table>
<thead>
<tr>
<th>Moderator</th>
<th>Reviewers and study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of learning task, e.g. fast search through complex information</td>
<td>Roblyer, Castine &amp; King [18]</td>
</tr>
<tr>
<td></td>
<td>Dillon &amp; Gabbard [23]</td>
</tr>
<tr>
<td>Learning subject: natural science and language – positive effects; history,</td>
<td>Sahin [21]</td>
</tr>
<tr>
<td>sociology, etc. – no effect</td>
<td></td>
</tr>
<tr>
<td>Knowledge and ability level of learners</td>
<td>Roblyer, Castine &amp; King [18]</td>
</tr>
<tr>
<td></td>
<td>Dillon &amp; Gabbard [23]</td>
</tr>
<tr>
<td>Interaction of knowledge level and system guidance: guidance – better for</td>
<td>Steinberg [22]</td>
</tr>
<tr>
<td>beginners</td>
<td>Dillon &amp; Gabbard [23]</td>
</tr>
<tr>
<td>Fit of learners’ characteristics and learning system</td>
<td>IHEP [12]</td>
</tr>
<tr>
<td></td>
<td>Dillon &amp; Gabbard [23]</td>
</tr>
<tr>
<td>Study duration: shorter studies – greater effects</td>
<td>Roblyer, Castine &amp; King [18]</td>
</tr>
<tr>
<td></td>
<td>Kirkpatrick &amp; Cuban [13]</td>
</tr>
<tr>
<td></td>
<td>Cavanaugh [24]</td>
</tr>
<tr>
<td>Group size: large and medium groups (≥50 students) better than small</td>
<td>Sahin [21]</td>
</tr>
<tr>
<td>groups (&lt;50)</td>
<td></td>
</tr>
<tr>
<td>Study design: control group design – lower effects than one-group plans</td>
<td>Liao [19, 20]</td>
</tr>
<tr>
<td>Substitute vs. complement: greater effects for supplement</td>
<td>Roblyer, Castine &amp; King [18]</td>
</tr>
<tr>
<td>Teacher:</td>
<td></td>
</tr>
<tr>
<td>- greater effects of different teachers</td>
<td>Roblyer, Castine &amp; King [18]</td>
</tr>
<tr>
<td>- greater effects of same teacher</td>
<td>Liao [19]</td>
</tr>
<tr>
<td>Information presentation and interaction:</td>
<td></td>
</tr>
<tr>
<td>- simulation better than interactive picture disc or interactive</td>
<td>Liao [19, 20]</td>
</tr>
<tr>
<td>multimedia</td>
<td></td>
</tr>
<tr>
<td>- simulation practice better than pure presentation</td>
<td>Lee [6]</td>
</tr>
<tr>
<td>Teacher role and didactic concept</td>
<td>Kirkpatrick &amp; Cuban [13]</td>
</tr>
<tr>
<td>better than synchronous DE</td>
<td></td>
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</table>
Another interesting publication claims that most of the studies comparing traditional to technology-based learning show ‘no significant effects’. Russell [25] collected more than 350 studies finding no significant difference. Hence he coined the term ‘the no significant difference phenomenon’. On his website (URL: http://www.nosignificantdifference.org/) Russell collects all the relevant studies and publications.

Concerning cognitive learning in sport and sport science the following studies have been published comparing traditional and multimedia learning.

Kerns [26] compared traditional (TI) to CAI in teaching tennis rules and strategies. The subjects (43 undergraduate students) were instructed for eight weeks by means of either TI (8 times 50 minutes) or CAI (first tutorial: $M = 44.6$ minutes; second tutorial: $M = 53.1$ minutes). Before and after the treatment and five weeks later a written test was administered. The results show no significant difference between TI and CAI.

Everhart et al [27] compared traditional (TI) to CBI in learning about nutrition and physical activity. The subjects (78 high school students) were divided into two groups: one group used a multimedia program (four times within one year) whereas the other group did not. Concurrently all subjects participated in physical education (PE) class activities for one year. Before and after the treatment subjects passed a physical fitness test and completed a questionnaire on physical activity engagement. There was no significant difference between the two groups and no interaction but a tendency for better results of the TI group.

Antoniou et al [28] compared TI to multimedia computer-assisted instructions (MCAI) and a combination of TI and MCAI (CI) when learning basketball rules. The subjects (73 PE students; age: $18 \pm 1$ years) had to learn rule violations in basketball for 5 hours. The MCAI group used a multimedia program whereas the TI group was educated by an international referee. The CI group received 2.5 hours MCAI and 2.5 hours TI, respectively. Before and after the treatment students passed a written and a video test, respectively. One week later a retention test was performed. Concerning the written test, the authors found a significant interaction of measure $\times$ instruction, i.e. only the TI and CI groups showed significant learning effects. There was no superiority of the multimedia groups. Concerning the video test neither the main effect of instruction nor the interaction of measure $\times$ instruction was significant.

In general most of the studies analysing multimedia learning in sport and sport science do not find a significant difference between traditional and multimedia learning.

Overall, current evidence shows that multimedia learning has the power to enhance learners’ effectiveness, efficiency and attitude compared to traditional learning if the various constraints are taken into account, specific constellations of conditions are present and a fit of learning system, learners’ characteristics, teachers’ characteristics and learning content is ensured. However, there is a great number of studies finding no or only little advantage of multimedia learning (e.g. Refs. [4], [25]). There is no general superiority of multimedia learning over traditional learning.
Furthermore, multimedia learning shows an interesting side effect: due to high motivation and interest, learners engage more in multimedia learning [29, 30]. In Table 4 general benchmarks for learning score, learning time and LE of different media and combinations of media are presented. Except for computer training programs, all other media increase the learning time. Depending on the outcome (learning score) the LE increases or decreases compared to ‘normal’ text-only applications. From this perspective computer training programs seem to be the most efficient learning systems but they do not fit every learning goal and learning context. Combinations of media are also very promising whereas animated pictures may decrease learning efficiency.

5.2.2 Motor learning

Only recently a few studies on motor skill learning have been published by the research group of Vernadakis et al [31–33].

Vernadakis et al [32] compared TI to CAI when learning the setting skill in volleyball. The subjects (32 pupils; age: 12–14 years) had to learn the skill within 9 weeks. TI comprised nine 40-minute periods of direct teaching style (verbal instruction: 15 minutes; supervised physical practice: 15 minutes). The CAI received the same formal schedule (computer time: 15 minutes; unsupervised physical practice: 15 minutes). Before and after the treatments, a knowledge test and a skill test were performed. Both groups improved but there were no significant differences between TI and CAI.

Using a similar design, Vernadakis et al [31] compared TI, CAI and mixed instruction (MI). The subjects (48 pupils; age: 12–14 years) had to learn the shooting in basketball within ten sessions. This time the teaching periods lasted 45 minutes (verbal or computer instruction: 15 minutes; supervised and unsupervised physical practice: 15 minutes). The MI group received TI during the first five weeks and switched to CAI for another five weeks. A knowledge test and a skill test were performed before, immediately after and one week after the treatment, respectively. All three groups improved but again there were no significant group differences.
Vernadakis et al [33] compared TI, CAI and MI using the schedule of the first study. The subjects (48 pupils; age: 12–14 years) again had to learn the setting skill in volleyball within 10 weeks. Each session lasted 40 minutes and comprised 15 minutes of verbal or computer instruction and 15 minutes of supervised or unsupervised physical practice. Again, a knowledge test and a skill test were performed before, immediately and one week after the treatment, respectively. All groups improved skill and knowledge but there were no significant group differences.

To sum it up, there was no evidence in favour of multimedia skill learning of pupils aged from 12 to 14 years. In two studies there was a non-significant tendency towards a slight superiority of MI. Unfortunately all three studies suffer from a severe methodological problem: the CAI group does not only use MLS but practises unsupervised, i.e. without extrinsic feedback by the teacher. This is different from the TI group. Therefore there is a confounding of media and feedback effects. Furthermore, effective or net instruction time, i.e. pure teacher and pure computer instruction time (subtracting time for organization or starting the computer program), and computer experience were not controlled.

Research on multimedia skill learning is still in its beginnings. Further work has to be done in order to improve knowledge using more sophisticated research designs.

6 Learning with multimedia – a look into the future

In this section the future of multimedia as an educational tool for sport and sport science is discussed. Looking at the results of research and development projects there are two critical factors strongly influencing the success of multimedia learning: quality and sustainability. These issues will be discussed in the first part. In the second part selected possible scenarios of multimedia learning are proposed.

6.1 Quality and sustainability of multimedia learning

From the existing evidence concerning the effectivity and efficiency of multimedia learning, the conclusion can be drawn that multimedia learning is not effective in itself. Rather particular conditions have to be fulfilled in order to exploit the potentials and surplus values of multimedia learning. To ensure that multimedia is not just a mayfly, the aspects of quality management and sustainability have to be considered.

The term ‘sustainability’ means that multimedia learning is developed, implemented, used and improved in a systematic and enduring way. Sustainability pertains to five dimensions:

- Didactics and pedagogy
  The didactical and pedagogical surplus value of multimedia learning needs to be secured, e.g. by integrating multimedia learning into curricula.

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Economy
Additional financial resources are required for developing and maintaining MLS. A continuous cost–benefit calculation and allocation of financial resources for staff and material are indispensable. Sustainability needs to be ensured by appropriate business models.

Organization and administration
Multimedia learning projects require an efficient project management and a systematic integration into the respective working area.

Technology
Both provider and user of multimedia learning have to ensure that their equipment meets the requirements of stability and security. When standards of technology change, MLS have to follow.

Society and culture
Multimedia learning should be compatible to learning culture. As an alternative, multimedia learning can contribute to cultural and social innovations.

Sustainability implies quality. Multimedia learning systems can only be sustainable if they are of high quality. Therefore, quality has to be continuously ensured. Quality of multimedia learning means that ‘relevant content is appropriately processed according to the respective task and presented in a way that ensures good usability’ [34], translation by J.W.).

There are numerous norms and quality standards. Some of these standards pertain to software in general (e.g. ISO norm 9241) or to learning with electronic media (e.g. LOM and SCORM).

In order to ensure that multimedia systems fulfil these requirements a systematic development process is needed (for a review: see Ref. [35]).

6.2 Scenarios of an uncertain future

Because of the complex interactions of learners, teachers, learning tasks, learning system and learning environment many combinations are possible. These combinations range from the pure online learning using multimedia exclusively to pure traditional learning using no multimedia. We present three possible scenarios: learning with multimedia as support vs. the substitute of traditional education, and serious games.

6.2.1 Multimedia as support – digital lecture hall and digital gym
Monday, May 15, 8:30 a.m. – The lecture on ‘Basics of movement science’ takes place in lecture hall S1 01/054. The students enter the lecture hall. The teacher presents the topic ‘informational support of motor learning by means of instruction and feedback’. He complements his oral presentation by a multimedia presentation that is displayed by a beamer. The presentation contains texts, pictures (photos, animated diagrams and schemes), audios (samples of sonification) and videos (sport movements). The students use digital copies of the transparencies they have downloaded from the teacher’s website. They have brought their
notebook with them and may drop digital notes, e.g. a mind-map of the lecture. The teacher uses the ‘digital lecture-hall’, i.e. he can show also the previous transparency on the screen. Students can store these transparencies combined with their own notes on their own notebooks. The teacher can write notes onto the transparencies by using a touch-screen. These notes are also displayed on the screen and can be recorded for later access. By means of special interfaces (e.g. wireless LAN and Bluetooth), students can transfer spontaneous information to the teacher, for instance questions, comments, feedback or notes. The teacher can have a look at this information because his notebook is connected to a server. If it is necessary he can react to this information. Within the last five minutes of the lecture, the teacher tests the knowledge of the students by asking five comprehensive multiple-choice questions. The students can transmit their answers by notebook, cell phone, PDA or ‘Smartphone’. The teacher immediately gets the results and has the opportunity to give immediate comments to improve understanding.

In this scenario – despite all technology – students are required to be present because the transparencies are not self-explanatory. Illness and other obstacles raise the problem that students have to get the information they missed. Reading the literature, talking to fellow students or studying the notes of fellow studies is only a poor substitute of the lecture having been presented by multimedia with high informational and didactic quality. In order to participate in the technology-based interactions with the teacher, the respective technical devices need to be available. There is no mutual communication of the students within the lecture hall because everyone is engaged in listening, dropping notes and controlling the tools for interaction and communication. Hopefully all devices work well and there is no loss of power.

Wednesday, May 17, 9:50 a.m. – The education of apparatus gymnastics for female students takes place in the gym. Today, students have to practise the flic-flac on the floor. The female teacher works with notebook and beamer. She delivers various information concerning the flic-flac: verbal cues, videos taken from different perspectives, applying different presentation speeds, demonstrations of physical guidance, information concerning the biomechanical structure of the movement and didactical information. After this phase of detailed instruction and a warm-up phase physical practice starts. The teacher adopts a coupling of video camera and notebook. The movements of the students are recorded for later analysis during the phase of reflection (errors and reasons, critical phases, didactical implications, etc.). The whole material is stored and after the lesson it will be available on the server. In this scenario the physical presence of the students is also required.

The two scenarios illustrate on the one hand the potentials of multimedia for education that have been discussed. Numerous didactical options are available that need to be chosen appropriately (which is not at all trivial!). On the other hand, the physical presence of the teacher and the students is a ‘sine qua non’. This prerequisite is not always fulfilled. And even if it were the ‘volatility’ of present education always raises the problem that essential information may be missed or misunderstood.
6.2.2 Virtual multimedia – online course presented by a LMS

Monday, May 15, 8:30 a.m. – No student enters the lecture hall. The lecture ‘Basics of movement science’ is presented exclusively via internet. Students can get all the necessary information by means of a learning management system (LMS):

- The lectures have been recorded in a studio. They can be downloaded and displayed using a specific plug-in (see Figure 3).
- Further material is available: transparencies, interactive simulations and animations, videos, etc. By using this material students can confirm, transfer and deepen their knowledge and understanding.
- By means of interactive tests, students can check their knowledge. Different tasks like multiple-choice questions, cloze, drag-and-drop and assignment tasks have to be solved. With every task they get helpful comments.
- The LMS offers several options for synchronous and asynchronous communication: forum, chat rooms, videoconference and e-mail.

The options of this scenario for education are evident: Independent of space and time, the students can use the numerous offers. On the other hand, this kind of learning requires students’ ability and readiness to self-control their own learning because there is no external force like time-table that guides them.

![Figure 3: Example of a pre-recorded lecture with transparency navigation (top left), video (bottom left), transparency with notes (right) and control buttons (bottom).](image)
Furthermore, financial resources for staff and technology are required in order to
develop, maintain, offer and use multimedia online systems.

The scenario of a learning that takes place exclusively online is not yet used
by a great number of students. Most students prefer a dual-mode or ‘blended’
learning strategy combining being present and using online material.

### 6.2.3 Playing virtual learning games – ‘serious games’

Every human being is fond of playing. Games are (usually) demanding, motivating,
instantaneous, open, and free of extrinsic goals and purposes. And every human being has to perform lifelong learning to adapt to the dynamically changing
requirements of work, leisure, etc. Therefore, it seems reasonable to combine education and playing games. This is meant by the term ‘serious games’.

**VirtualTeacher – Level 1.** The virtual PE teacher enters the virtual gym. In front of her, the virtual gym floor extends. The pupils stand together in groups or sit on the bench. In this lesson, the flop technique in high jump will be physically practised. The teacher has to gather the pupils, organize the practice, and give instructions and feedback. Level 1 is easy (beginner level). The pupils readily carry out instructions, organization is simple and the movement errors can easily be observed and removed. If all the tasks are solved, the final score is determined. Depending on this score, the teacher reaches level 2 or has to solve another level 1 task that is of the same difficulty as the first task but happens in a different context, e.g. teaching the crawl technique in swimming. With increasing level, the tasks gradually become more difficult and complex. Disturbances can occur, injuries require fast reactions, sport devices are missing or defect and the movement errors are more difficult to detect and correct.

The virtual PE teacher is confronted with increasingly complex and difficult tasks. Finally, if all the tasks have been solved successfully (and – as a side effect – all required competencies have been acquired) the ‘high-score’ may be beaten and the player may be awarded ‘master of teaching PE’. And of course the player gets the respective credit points and grade. Serious games are just in their infancy. If they are applied appropriately, they may improve multimedia education due to the motivating combination of education and game. On the other hand, developing serious games of good quality is expensive. The normal budget of a commercial game project is approximately 15 million Euros.

### 7 Multimedia as a research tool – (still) unused potentials

So far we have discussed multimedia as an educational tool that has been the subject of research. In this section we address the option of multimedia to be used as a research tool.

Before multimedia came up, computers could only be used as devices for acquisition and processing of (predominantly numerical) data. The computer offered methods to analyse data and to present the results in an appropriate way, e.g. using diagrams.
Now, multimedia computers offer new options for research. Numerous combinations of dynamic and static media are available that can serve as research tools. These options range from new forms of dynamic and interactive instruction to complete control of experiments. In this section we present three examples of how multimedia can be used to support research: assessing the image of a movement, manipulating the visual input and instructing the learners.

7.1 Assessing the mental image of a movement

When performing experiments on motor learning, it is important to assess the current status of the internal representation, because particularly in the initial learning phase it changes constantly [36].

Conscious internal representations of movement consist of different components: visual, auditory, proprioceptive and verbal representations. Most of the existing methods to assess internal representations either use verbal or visual tests (see Figure 4).

The main disadvantage of these methods is that only the results of the test can be analysed. We developed a method that allows to record the process of reconstructing the internal representations [37], see Figure 5).

By means of the computer-assisted picture selection test much more information can be acquired compared to other procedures:

- Separate assessment of decision and movement time
- Errors and corrections
- Order of selection (e.g. primacy and recency effects in short-term memory)
- Partial and total time.

This testing program is only a first step towards a more sophisticated assessment of mental images of movement. Multimedia allows us to use dynamic presentations like audios, animations, simulations or video. One option is a multimedia program that displays synthetic movements based on the reconstructions of the users. Users only determine the key postures and the system will calculate the intermediate frames.

![Figure 4: Options for assessing internal representations (from Ref. [36]).](image-url)
In general, multimedia has the potential to enhance practicability, objectivity and reliability of many research methods:

- Psychological tests of cognition, perception, emotion, motivation, volition, etc. can be completely performed and controlled by a multimedia system: instruction, testing procedure, feedback and evaluation.
- Multimedia features like auditory instructions or auditory feedback can complement online questionnaires to improve completion.
- Interviews can be performed by a multimedia system. The system asks questions and records the answers. Based on the progress in Natural Language Processing (NLP), a sophisticated analysis will soon be possible.

### 7.2 Manipulating sensory input

A further interesting research area for multimedia applications is manipulating sensory input: Virtual or Augment Reality (AR) systems, e.g. simulate sensory (especially visual) worlds. AR systems overlay real world perception with artificial stimuli. This method can be used to instruct learners and to direct their attention. Kahrs et al [38] have developed an AR device (head-mounted display) that illustrates the trajectory of the ball travelling to the basket to support basketball players in free-throw situations (see Figure 6).

By using VR or AR systems many issues of basic research can be addressed, e.g. focus of attention (external vs. internal) or optic flow field in relation to human motor control and learning. The great advantage of these technologies is the strict control of visual stimuli. This cannot be achieved by other techniques. One problem that has to be solved is that such sensor-based systems (still) have
a latency of at least 50 milliseconds. For fast movements like in soccer, tennis or table tennis this latency is too long to adjust the visual image to changes of the environment fast enough. For a ball velocity of 30 metres per second, this would mean that the ball has travelled 1.5 metres before the new image is displayed. This is the reason why currently only slow changes of position and environment can be efficiently processed.

### 7.3 Multimedia instruction

Another purpose multimedia can be used for is instruction. Researchers can apply simple multimedia instruction or complex interactive information systems. Visual, auditory and verbal information can easily be combined and presented in an interactive way. An interesting issue that has recently been addressed is ‘sonification’, i.e. the production of multi-dimensional sound based on selected biomechanical parameters of the movement [39].

### 8 Conclusions

Multimedia has much to offer to research and education in sport and sport science. However, there are numerous conditions that have to be considered to really tap the full potential.

Concerning multimedia education, research has revealed many factors influencing the effects of multimedia learning. At first glance, this situation might look disappointing. On the other hand, the detailed body of knowledge helps to select particular promising combinations based on solid scientific evidence. Research on multimedia learning tells us whether or why particular combinations work and others do not. Sport and sport science have not tapped the full potential of multimedia learning yet. Particularly motor learning in sport has been investigated only in very few experiments.

Furthermore, the numerous potentials of multimedia as research tools are also very promising. Multimedia may help to enhance objectivity of instruction,
perform assessments (interviews, questionnaires, tests) automatically and control experimental manipulations of perception in a more systematic way.

Finally as is the case with all technology, there is no easy way to adopt multimedia for enhancing education and research. Multimedia is neither the panacea nor the Pandora’s Box – it is just a particular progress of technology opening new potentials but also posing new problems. Multimedia requires deliberate use and critical reflection. But these demands have always been the strengths of science.

References


