Psychologisches Institut der Albert-Ludwigs-Universität Freiburg

On-Screen Videos as an Effective Learning Tool

The Effect of Instructional Design Variants and Practice on Learning Achievements, Retention, Transfer, and Motivation

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Für meine Familie:
Meine Ursprungsfamilie, Wahl-Familienmitglieder und zukünftige Familie.

Pour ma famille:
Naturelle, choisie et future

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1 General Abstract

This dissertation aims at investigating the potentials, the possibilities, and the limitations of dynamic visualisations, more specifically of on-screen videos, as a learning tool. On-screen videos are a special variant of videos that display what is happening on a computer screen. Examples of the use of on-screen videos might be a demonstration of how to use a new computer application or participate in a multimedia learning environment. The on-screen videos used in this dissertation were designed as modelled worked-out examples.

In two experiments the effects of certain instructional design features implemented in on-screen videos were analysed. Thereby, immediate and mid-term learning results, motivation and transfer were assessed. Both experiments used the 'acquisition of computer application skills' learning domain, for which on-screen videos are a highly convenient learning tool as they show how to perform tasks within an authentic environment. A common criticism of instructional videos is that a framework for designing and using visualisations is missing. As a result, knowledge may only be acquired on a short-term basis rather than maintained over time. The theoretical background used here builds on observational learning, research on example-based learning and on multimedia learning. These approaches were employed to determine the instructional procedures that foster learning. In Experiment 1 a special focus was put on investigating two different instructional design variants that intended to make the single solution steps in the computer application salient. These instructional design variants supported the learners in the acquisition of meaningful building-blocks for problem solving, instead of providing them with fixed chains of problem solving steps that can only be applied to similarly constructed problems. Within a 2x2 design, two different methods of segmentation were employed using the on-screen videos. One form of segmentation was content-related. A '*Label'* for every solution step within a task was presented and further indicated to the learner the following step. The second experimental condition, called *'Pacing',* was related to the application flow. This consisted of an interactive click-button set at the crucial point of each step. Learners had to pay attention and click there, or the video would stop. This was done in order to avoid the typical "couch potato" style of watching videos in which learning content is passively and superficially processed. The on-screen video conditions were also compared to the standard introduction to the computer application, which follows a learning-by-doing approach with few animations. 101 students took part in Experiment 1. Learning success was measured with a

declarative knowledge test (multiple choice/open questions) and a procedural knowledge test consisting of problems to be solved. The results showed that on-screen videos are a particularly successful learning tool in comparison to a standard introduction to the computer application. In other words, learning-by-observation was more effective than the standard introduction. However, a learning goal dependency was found: Those learning with *Labelling* substantially improved declarative learning outcomes, whereas those learning with *Pacing* enhanced procedural knowledge. Acceptance and motivation were about equal in all conditions. A very positive result was that learning outcomes could be maintained over time: At a follow-up test three days later, declarative knowledge was even better then at the post-test taken immediately following the experiment.

A restriction of the findings from Experiment 1 was that far transfer could not be fostered. Therefore, Experiment 2 was conducted in which short *Practices* were inserted in order to foster transfer. In terms of ACT-R theory (adaptive control of thought – rational) (Anderson, 1983) the compilation and autonomous stage should be fostered. *Practice* was implemented directly after each video and had the form of so-called guided exploration cards and was added to the 2x2 design with *Labelling* and *Pacing* of Experiment 1. These four with-*Practice* conditions were compared with a non-*Practice* condition. 103 learners took part in the experiment, where declarative and procedural knowledge were once again assessed. With respect to declarative knowledge, neither a significant effect for *Practice* nor for the instructional design variants was found. However, the *Labelling* group again showed the tendency to be the group demonstrating the most favourable results. With respect to procedural knowledge, significant effects for *Practice* and for *Labelling* on far transfer were found. With *Practice,* the effect of the interactive design variant *Pacing* was diminished; only *Labelling* had an additional positive effect on the procedural learning outcomes. In addition, procedural knowledge could be maintained over time. The time period until the delayed post-test was extended to one week. Like in Experiment 1, acceptance and motivation did not differ between the different learning conditions. However, interesting patterns between motivation and acceptance and the learning achievement variables were found: In Experiment 1, the best learners were not very motivated, whereas the worst performing learners were very motivated. With *Practice* in Experiment 2 another pattern was found: The best performing learners were the most motivated ones and the low achievers were not very motivated.

To summarise the findings, on-screen videos enriched with instructional design features constitute a very effective learning tool. The selection of an instructional design variant ideally depends on the learning goal. In any case, it is recommended to integrate *Labelling* and to name each meaningful solution step of the solution procedure. If learning takes place solely by observation, declarative knowledge will be fostered. In combination with *Practice*, procedural knowledge is generally, along with far transfer, enhanced. If *Practice* is not part of the learning environment, *Pacing* in the form of an interactive click button set at the crucial point of a step should be integrated to ensure general procedural knowledge is attained.

2 Introduction

2.1 What is Multimedia Learning?

Recent advances and developments in information and communication technologies (ICTs) offer a broad range of completely new learning tools (e.g., hypermedia, on-screen videos, virtual reality scenarios) and new applications of established media (i.e., using mobile phones as learning tools or turning mp3 players into learning devices using pod casts). The first phase of research on such tools usually displays great excitement about the potential of a new learning technology (Hegarty, 2004) and puts emphasis on its advantages. However, a more measured insight typically follows: Education cannot be improved simply by adopting a new technology. The situation can be summarised as in the following citation (Mayer, 1997, p. 4):

> *At this time, the technology for multimedia education is developing at a faster pace that a corresponding science of how people learn in multimedia environments. Technological advances in computer-based graphics including animation and text-based graphics including the use of animations have not been matched by corresponding scientific advances in understanding how people learn from pictures and words.*

This means that if attention is not turned to understanding how people actually learn, learners will get lost in these modern technological labyrinths (Greif, 1994), because they lack the necessary literacy to navigate them. Consequently, the challenging task and questions to be asked now include how instruction has to be designed and what conditions are playing a crucial role in capitalising on this new technology.

Against this background, the first matter to address is why learning with multimedia is seen as advantageous. Multimedia learning usually refers to the capacity of computers to provide real-time representations of nearly all existing media (Clark & Feldon, 2005). Multimedia learning takes place when learners build mental representations from words (spoken or written) and pictures (such as illustrations, photos, animations, or videos). It is important to distinguish here between *multimedia* as an instruction mode in the form of words or pictures and *learning* in the sense of actual knowledge building processes (Mayer, 2005).

2.2 What are the Necessary Prerequisites in Dealing with Multimedia Applications?

An often neglected aspect of multimedia learning is the learner's capabilities and foreknowledge: Do learners already have the necessary skills to use a multimedia learning tool? Or even more importantly, what *are* these necessary skills? Palincsar & Ladewski (2006) state that far too little research has been conducted to determine the literacies required to work and learn with new media, such as the Internet and other ICTs. The following definition tries to frame a conception of the required literacies:

> *The new literacies of the Internet and other ICTs include the skills, strategies, and dispositions necessary to successfully use and adapt to the rapidly changing information and communication technologies and contexts that continuously emerge in our world and influence all areas of our personal and professional lives. These new literacies allow us to use the Internet and other ICTs to identify important questions, locate information, critically evaluate the usefulness of that information, synthesize information to answer those questions, and then communicate the answers to others (Leu, Kinzer, Coiro, & Cammack, 2004).*

First and foremost, so-called *'visual literacy'* is an important prerequisite such that it makes the extraction of the learning content out of a visualisation possible. Visual literacy was first defined in psychology in the context of learning with pictures, or the learnt capacity to interpret visual messages and to build up messages by using visual symbols (Weidenmann, 1994). However, research has tended to focus on infants. Nevertheless, there is some evidence that learners in general already possess at least a rudimentary form of this competency. It has been shown that pictures can not only activate a mental model but can also provoke the learner to invest more time and mental effort into the learning material. This happens because attention is focused, context is given and prior knowledge is activated, all of which lead to improved interpretation and retention (Weidenmann, 1991). However, the parameters of this declaration must be made clear: It is not true for all kinds of pictures since experienced subjective easiness of encoding can cause an illusion of understanding

(Weidenmann, 1994) due to the reduced cognitive effort required (Salomon, 1984). This effect is also known as the illusion of knowing (Glenberg, Wilkinson, & Epstein, 1982) or the illusion of simplicity (Hansen, 2006; Nickerson, 1999). Hansen (2006) found the illusion of simplicity to be particularly dangerous when learners were already familiar with the learning material, for example, when they were shown concrete pictures. This led to reduced processing. Consequently in Hansen's experiment, existing differences between similar pictures were no longer found. Thus, a very prominent finding is that simple pictures stimulate a superficial processing, whereas challenging pictures indeed foster deep processing of learning material (Schnotz & Bannert, 1999). In the case of challenging pictures, guidance or prompting have been shown to be useful design variants for promoting learning. In sum, visual literacy and the perceived difficulty of pictures are closely related because they influence the nature of processing and thus, albeit indirectly, the learning achievements.

The situation concerning dynamic visualisations is comparable: Learners need an equivalent variant of visual literacy being similar as while learning with pictures. Furthermore, it is assumed that videos are a more powerful medium when they are designed and embedded in a larger context, such as a multimedia learning environment. Furthermore, the perceived level of difficulty of the dynamic visualisation is expected to play a role concerning the depth of processing. By implementing instructional design, it can be ensured that the learner's perception will be enhanced and their processing level will be stimulated. This is grounded in people's tendency to assimilate what is familiar to them rather than accommodate new subtleties (Schwartz & Hartman, in press). Realising an adequate instructional design requires identifying and taking the learning goals into account. This also involves a decision as to how the learning contents will be used. Schwartz and Hartman (in press) give a very clear example for this: If a person wants to learn the sport of cricket, is the primary goal (a) to teach the person how to play; (b) explain to him/her the history of the game; (c) enable his/her recognition of a good play; or, (d) to encourage him/her to want to learn more? The identification of a scenario and therein a learning goal is utterly important because it will ensure that the video-based learning medium is appropriately designed for each case. The authors suggest interesting distinctions to consider in this process: (1) classes of outcomes, (2) learning targets, (3) assessments, and (4) genres (see Figure 1). These distinctions help to identify the roots of a learner's perception and can influence the development of this perception.

The ring in the centre of Figure 1 shows four classes of possible learning outcomes: Seeing, saying, doing and engaging. These classes are intentionally broad and can be seen as approaches to introducing the learning outcomes. The next ring redefines the learning outcomes as possible ways of accomplishing the learning goals shown: For example, if the learning outcome is ‘seeing’, familiarity is an option. This means the ability of the learner to recognise what is new and what details are important (discernment approach). The third ring describes the behaviour learners show when they have successfully gained understanding and it provides a basis for assessment. The last ring gives examples of typical genres videos take on in addressing the corresponding learning outcomes.

Figure 1. A space of learning for the use of designed videos (Schwartz & Hartman, in press).

Another important construct in this context is *visual attention.* Visual attention is influenced by several factors, such as formal features (e.g., different types of voices, sound effects), and meaningfulness and comprehensibility of the presentation (Kozma, 1991). Visual attention is also directly related to the level of difficulty. Huston and Wright (1983) found an inverted-U relationship between comprehensibility and visual attention: Very simple or difficult content demands less attention than content of a medium range of difficulty (Huston & Wright, 1983). In addition to visual attention, active processing and the amount of invested mental effort are other important factors (Salomon, 1983).

To conclude, the present research relies on the findings that multimedia learning, as described in the studies above, has proven to be successful. Nonetheless, the processes on the learner's side, such as visual literacy, are still rather unclear, yet a deeper investigation into this matter is not the aim of this dissertation. What is, however, known so far is taken into consideration: (a) the dynamic visualisation should possess a medium level of difficulty in order to achieve a substantive visual attention and stimulate active processing. (b) The learning goal and the learning content have to be clearly defined for the instructional design to be successful.

Before turning the attention to the experiments performed (chapter 4 and 5), overviews of the video learning medium (chapter 3.1), the computer applications learning domain (chapter 3.2), and the theories behind instructional design variants are provided (chapter 3.3).

3 Theoretical Background

3.1 The Video Learning Medium

3.1.1 Different Types of Videos

Dynamic visualisations such as videos or animations are playing an increasingly important role in different learning contexts. However, both terms are widely used and thus constitute vague terminology. Videos are often defined in contrast to animated pictures. Mayer and Moreno (2002) distinguish videos as “a motion picture depicting movement of real objects, whereas animation refers to a simulated motion picture” (Mayer & Moreno, 2002).

The goals and the variants of dynamic visualisations are manifold: Starting with common applications, it can be stated that they can help learners to learn many kinds of skills and competencies. Do-it-yourself-shows, like cooking shows, (Schwartz & Hartman, in press) or educational videos, such as those shown in schools, are prominent examples. Furthermore, dynamic visualisation can be used to train and acquire (motor) skills because visual presentations provide a more direct way of communicating what is meant than aural or text-based instruction can (Wetzel, Radtke, & Stern, 1994). For more complex content, step-by-step demonstrations are an appropriate choice. Closely related are on-screen videos, which are the focus of this dissertation and combine the two of the stated application possibilities, namely to teach information and to acquire skills (see also chapter 4.1 for a more detailed overview).

Videos fulfil different functions, for example, they are deployed to generate meaningful learning environments by creating context. These “case-based” approaches should help learners to address problems by identifying their most important features and plausible solutions (Bransford, Sherwood, & Hasselbring, 1988). Evidently, videos are an appropriate choice when large amounts of information (Thomas & Thomas, 1984) are to be presented in a relatively short period of time. Videos can, accordingly, be characterised as a ‘dense’ medium. They can be used to picture realistic objects or scenes, to observe sequences in motion, and to view perspectives which are impossible or difficult to encounter in reality

(Wetzel et al., 1994). Another scope of use are simulations: They can be used to simulate experiments (Neuhoff, 2000) or machines to which access would otherwise be difficult to gain, like airplanes (Kearsley, 1990). On a more general level one can say that dynamic visualisations can be used for: (1) provoking the learners' interest in the learning content, (2) presenting information and teaching content, (3) enhancing practice by giving visual feedback or through an interactive experience, (4) motivating, and (5) for the purpose of cosmetic appeal (Rieber, 1994).

Videos have the inherent advantage of versatility as they can be used in both individual and collaborative learning settings. Despite their more common application as a group-focused learning tool, videos hold much promise in teaching individuals. As such, this dissertation explores their usage in individual learning. Videos can be used as a diagnostic instrument for individuals, for example, teachers can use them to self-diagnose competence (Schwindt, Rimmele, Seidel, & Prenzel, 2006). Another innovative application is a "hyper-video". Hereby, hyperlinks are implemented into the videos in order to stimulate knowledge acquisition through reflective learning and to enhance cognitive flexibility (Zahn, Barquero, & Schwan, 2004). Widely spread is the use of videos as educational films, but only recently has research been directed toward constructing mental models of a situation and knowledge acquisition (Tibus & Schwan, 2006). One of the most common uses of videos is the presentation of a model, from which learners acquire certain skills, such as arguing (Schworm & Renkl, 2005), or cooperating competencies (Rummel & Spada, 2005). Video desktop conferences illuminate the technical and communicative capacities of this medium. Several studies have investigated the optimal structure and components of video desktop conferences, such as the use of collaboration scripts to stimulate cooperative and collaborative approaches to complex tasks (Kopp, Ertl, & Mandl, 2004).

It is evident from the examples described above that: (1) the application possibilities of videos and their function are various; (2) videos can be used as a learning tool (intervention), a diagnostic instrument or a means of communication; and (3) the degree of reality of the videos can largely vary (e.g., if the heart is shown like it is in the human body or if a schematic version of its processes is shown). However, all approaches must enrich the medium by additional instructional design and pursue the goal of optimising the *'mental effort'* required to process the learning contents. The biggest challenge for the instructional design is to maximise the effort that learners place on elaborating content while minimizing the effort they must expend to make sense of that content (Cennamo, 1994). The examination of adequate instructional design has the additional function of stimulating research in a more productive direction. As mentioned in Chapter 2, the first phase of research compares the advantages of dynamic media over static media (Hegarty, 2004) or whether the decision for one media influences the effectiveness of instruction (Tabbers, 2002). This is naturally followed by an attempt to identify the instructional design that will best exploit the possibilities of the chosen media to its fullest extent.

3.1.2 Problems While Researching Videos

According to a review by Clark (1983), the investigation into the advantages of dynamic media has hitherto been senseless as most of the attempts have been methodologically confounded. The animated medium in most cases has not contained the same information as the static one (e.g., classroom condition). Either more information has been presented or it has been presented in a different way, both of which lead to an imbalance of information. Another issue is that the animated medium has been confounded with other factors, such as interactivity, which are known to improve learning when implemented appropriately (Tversky, Morrison Bauer, & Bétrancourt, 2002; cf. section 3.3.1.2). However, comparing different media without conducting so-called *"horse-race-research"* (varying the treatments to a great degree) (Weidenmann, 2001), has yet to be adequately executed. Differences between media can be found on three levels: The *medium* (e.g., paper versus computer), the *modus of presentation* (text with/without graphics versus videos) and the *sensory modalities* (visual versus visual and acoustic). If the learning contents and the treatment are controlled, potential differences might be evened out from the beginning, leading to a more suitable comparison of the advantages each medium actually offers. Further distinctions can be made between technologies, symbol system, and processing capabilities – the most obvious characteristic of a medium might be its technology or the technology's features. However, the cognitive effects of the previously mentioned subsequent characteristics are usually indirect (Kozma, 1991).

Another approach is to turn attention toward the instructional method. The same instructional method could be investigated in different media following the idea that if a certain method proved to be successful in one medium, it might do well in a related one (Mayer, 2003). Kozma (1994) renders this assumption moot as each medium has its own advantages as a result of its particular set of attributes, which influences the effectiveness of an implemented instructional design. Consequently, research should move beyond the superiority question and focus on examining the types of knowledge or skills learners gain through each medium (Mayer & Moreno, 2002).

In order to exploit the full potential of a medium, clear design guidelines are needed (Tabbers, 2002). So far there have been several approaches to introduce guidelines for the design of multimedia (e.g., Park & Hannafin, 1994), but an overall framework is missing. Unfortunately, some of the guidelines appear to be based on experience rather than theory. As such, a promising approach involves starting with theoretical considerations, such as can be found in *Multimedia Theory* (Mayer, 1997) or the *Cognitive Load Theory* (Sweller, 1999). Both theories take the working memory into account and can explain how the characteristics of the working memory influence learning processes. Since the instructional design features suggested in this dissertation build upon these theories (see chapter 3.3), effort is made in the following sections to describe these theories in greater detail.

3.1.3 The Multimedia Theory

Mayer defines multimedia learning as learning from words and pictures. The assumption is that learners learn more deeply from words and pictures than from words alone. Therefore, a multimedia instructional message contains both words and pictures. The theory is based on three assumptions about how the human mind works and how a multimedia instructional has to be designed in order to foster learning. The first assumption is the *dual-channel assumption*, which claims that humans have two different systems for processing verbal and pictorial material. This is also a central feature of the dual coding theory (Paivio, 1986) and the theory of working memory (Baddeley & Logie, 1999). The *limited-capacity assumption* postulates that each channel (auditory and visual) has a limited capacity. The *active processing assumption* implies that meaningful learning requires a substantial amount of cognitive processing and results finally in model building.

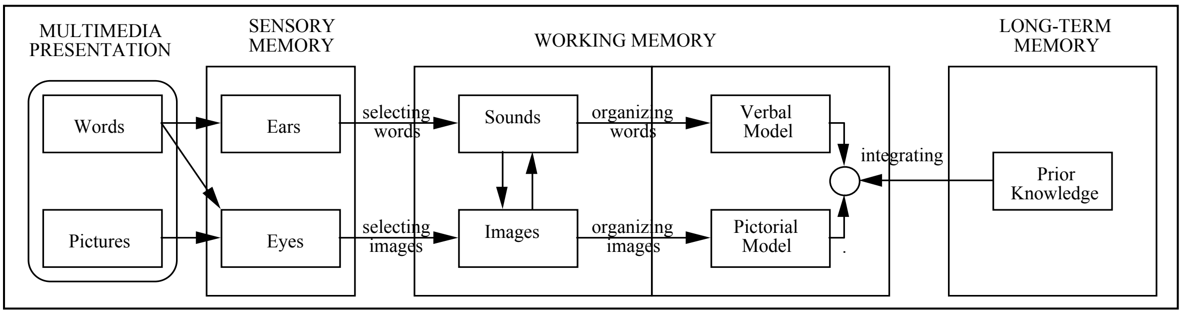

Figure 2. Cognitive theory of multimedia learning (Mayer, 2001).

Figure 2 gives an overview about how the human-information processing system works according to Mayer. It combines the three assumptions. Words and pictures come in the form of a multimedia presentation and enter the sensory memory via the eyes and ears. To transfer information to the working memory the learner has to pay attention, that is, he/she must select words or images. The working memory allows storing of sounds and images for a rather short period of time. The next step is to organise the selected words and pictures and different knowledge structures that are called verbal and pictorial models. Both can be described as a structured version of the working memory representation. These two models not only have to be integrated with each other to form one coherent representation with connections between the two models, but have also to consider prior knowledge. These five cognitive processes comprise active processing. Mayer also refers to the cognitive demands that compete during learning. When the demands of one channel or the sum of both exceeds the available cognitive capacity, learning is impeded. Mayer distinguishes between essential processing, incidental processing and representational holding. Essential processing is required to make sense out of essential material and refers to cognitive processing activities such as selecting, organising or integrating. Essential overload happens when the amount of essential cognitive processing needed to understand a multimedia content exceeds the limit of the available cognitive capacity. Therefore, Mayer (2005) uses the term essential processing as a synonym to Sweller's (1999) intrinsic cognitive overload. Incidental processing stems from the design of the learning task. Finally, representational holding is the cognitive demand imposed while holding a mental representation in working memory.

Similar to *Multimedia Theory*, the *Cognitive Load Theory* is based on two assumptions: The working memory posses a limited capacity (*limited working memory assumption*) and it includes partially independent subcomponents (cf. Baddeley, 1992).

Another premise assumes that the long-term memory is unlimited (*unlimited long-term memory assumption*) and holds schemata varying in their degree of automation (Chase & Simon, 1973; Chi, Glaser, & Rees, 1982; de Groot, 1966). Two means can overcome the limitations of working memory during learning. First, *automatic processing* of learning content unburdens working memory capacity for learning processes. Second, *schemata* increase the amount of information held in working memory because they constitute highly structured knowledge that consists of chunked elements. The interactivity between several schematic elements can cause so-called *intrinsic cognitive load*, which is defined in relation to the learning content and depends on the complexity and the basic interactivity of the learning contents. Existing knowledge is important in this context as it determines if learning contents are perceived as complex or not. *Extraneous cognitive load* originates from poorly designed instructional material. The described variants of cognitive load might influence learning in a negative sense as they can potentially hinder learning by drawing upon processing capacity. Thus, load *per se* is not something negative as load is also imposed when understanding or learning processes take place (*germane load).* In this case load is something positive and a prerequisite for learning. The three load measures described must be considered when designing a learning environment or deciding upon an instructional method. In terms of learner, existing knowledge is of particular importance. For example, an instructional method facilitating automatic processing and schema construction might be effective with inexperienced learners but not with experienced learners (Kalyuga, Ayres, Chandler, & Sweller, 2003).

An expansion of the cognitive theory of multimedia learning and an integration with the cognitive load theory is the cognitive-affective theory of learning with media (CTLM) (Moreno, 2005). It is based on seven assumptions: (1) dual-channel assumption (Baddeley, 1992); (2) limited capacity of working memory (Sweller, van Merriënboer, & Paas, 1998); (3) the assumption that meaningful learning can take place when the learner spends conscious cognitive effort in cognitive processes such as selection, organising, integrating etc. (Mayer & Moreno, 2003); and (4) the long-term memory consists of a vast number of hierarchically organised schemata, which can work automatically when they have been practiced and therefore reduce cognitive load on working memory (Paas, Renkl, & Swelller, 2003). New and innovative is the explicit incorporation of motivational and metacognitive factors by the following assumptions: (5) motivational factors either increase or decrease cognitive engagement and herein influence learning (Pintrich, 2003) and that (6) metacognitive factors regulate cognitive processing and affect (McGuiness, 1990 cited in Moreno, 2005). The last assumption states that (7) the level of prior knowledge and abilities influence how much is actually learnt within a specific medium (Kalyuga et al., 2003)

Chapter 4 describes how all dimensions (except the sixth) have been considered in the design of the learning environment [for further multimedia theories cf. Schnotz (2005) or for an overview compare Reed (2006)]. Prior to this the instructional design variants building on these theories are described and an overview on the approaches taken in the new computer applications learning domain is given.

3.2 The Computer Application Learning Domain

3.2.1 Introduction

The majority of people do not like learning how to use a new computer application because they feel incompetent until they are familiar with it. Users focus on *results* and not on the *process* of learning. This is called a *production paradox* and while it might be a successful strategy in the short-term, it fails to deliver in the long run (Carroll & Rosson, 1987). To make matters worse, as hardware and software become ever more complex and powerful, acquiring expertise in the computer domain remains a challenge even for the experienced computer user (Kiesler, Zdaniuk, Lundmark, & Kraut, 2000). However, traditional methods intended to foster learning a new computer application are often frustrating, given that they are difficult, time-consuming and thus disappointing (Atlas, Cornett, Lane, & Napier, 1997). Especially frustrating are the excessive manuals: Only 14% of users read manuals before using new software (Penrose & Seiford, 1988). A possible explanation for this finding might also be that users lack metaknowledge: Users seldom know exactly what it is that they do not know (Miyake & Norman, 1979). More specifically, they do not know what they should look for in the manual as they do not possess a mental model of the system (Briggs, 1988,1990). As a consequence, even experienced users employ only 10-15% of the program's given functionalities even when it would be more beneficial and easier for them to use the remaining possibilities (Süsser, 1998). Nonetheless, computer training is *the* training method in organisations. Of the 57 billion dollars spent annually on training activities by organizations in the United States, computer skill training constitutes the bulk of this investment (Yi & Davis, 2003). The same is true in Germany where computer training is the most popular course of studies in continuing education (Statistisches Bundesamt, 2001).

The first questions to arise are: What does learning a new computer application actually involve and what is the goal of learning? Leutner (2000) views learning to use a new computer application as a special case of skill acquisition. The ACT-R theory conceptualises skill acquisition as a process of acquiring and then automating domain-specific production rules in three phases: (1) *declarative phase*: step-by-step description in memory, (2) *compilation phase*: building and integration of steps as production rules and representation of larger units and (3) *procedural phase*: forming large units of steps which allows automatic performance (Anderson, 1993) (cf. also section 3.3.2 for more details). Errors are particularly likely in the first phase, if the steps are not followed consecutively – a very likely occurrence considering the tendency of users to "jump the gun" (Carroll, 1990a). The overall goal of systematically learning a new computer application is to foster the construction of an adequate mental model of the system that will ensure effective and efficient interaction with the system (Bannert, 1996; Bostrom & Olfman, 1990).

Until the 1980s, limited "systematic research ha[d] been devoted to discovering what learning conditions lead to improved learning of applications programs" (Allwood, 1990; p. 98). Presumably, the most prominent approach is the theory of minimalist instruction that was introduced by John Carroll (Carroll, 1990a, 1990b) and will be discussed in the next paragraph.

3.2.2 Carroll's Approach to Learning a new Computer Application

Carroll (1990a) observed that typical and serious problems occur when users learn a new computer application. These problems are partly based on the characteristics of the concrete application used, but to a large extent they are caused by certain attributes of the users themselves. These user attributes are clustered in problem classes, for which Carroll advises ideal learning behaviours. He also provides recommendations for the training design (see Table 1) that are based on an explorative approach.

Table 1. Overview of Minimalist Instruction Approach (Carroll, 1990)

Problem Class	Ideal Learning Behaviour	Training Design
Learners tend to jump the gun and start system without following the instructions	Learners learn by doing: They try to act in order to learn and they are interested in meaningful actions	Allow the user to get started quickly
Learners are not always careful planners and don't think about consequences or the relevance of actions and errors	Learners learn by thinking and by reasoning: They generate and test hypotheses in order to learn	Rely on the user to think and to improvise
Learners are not good at systematically following instructional steps if there is no information about interrelations between steps and possible constraints if not followed as directed	Learners seek to work in a meaningful context and toward meaningful goals	Direct training at real tasks
Learners' reasoning about situations is often subject to interference from what they superficially know about other similar situations	Learners rely on their prior knowledge when they try to manage and assimilate new experience	Exploit what people already know
Learners are often poor at recognizing, diagnosing and recovering from errors they make	Learners use error diagnosis and recovery episodes as a means of exploring the boundaries of what they know	Support error recognition and recovery

The biggest dividends of Carroll's approach are the systematic design and testing of different learning materials while learning different computer applications. Firstly, he introduced the so called *guided exploration cards*, which are task-orientated learning cards containing advice to solve a task and information on avoiding common mistakes. The information given on the card is incomplete in order to prompt the user toward explorative activities. Additionally, each card contains self-check clues to direct attention to potential errors (cf. also Experiment 2, chapter 5 where guided exploration cards are used). A further innovation was the *minimal manual* – a revised and shortened version of a conventional manual containing additional information supporting error recognition and error recovery. A third approach – named *training wheels* – is based on the assumption that even the best instructionally designed materials cannot prevent all user errors. The goal is to influence the learning behaviour by a re-designed version of the interface where negative consequences of common and typical errors are blocked. If a selected training wheel indicates a wrong or inappropriate solution step, users get feedback that this choice is not possible at the moment and a new selection must be made. These constraints are another form of guided exploration. Several studies have already proven the success of all three learning materials. In particular, the guided exploration cards have shown their potential as learners were not only faster than users learning with a common manual but also scored better test results. Despite these positive findings, Carroll (1990a) reckoned that "*guided exploration did not prove to be an instant solution for the many troubles associated with user training*" (p.134). The main reasons for this are that people continue to jump the gun in that they do not read the cards properly, or that they might have difficulties in understanding the structure of the guided exploration cards. However in more recent studies, success with guided exploration cards in combination with practice could be shown (Zapf, 2003). In the case of the *training wheels*, the positive findings of Carroll could not be replicated because the intervention was perceived as too restrictive and patronising by most learners and therefore did not lead to better training results (Bannert, 1996; Carroll, 1990a, 1990b). However, finding the balance between guided learning and explorative learning seems to be one of the crucial points in designing computer training, since users experience many problems when they have to set goals themselves (Charney, Reder, & Kusbit, 1990).

All in all, the minimal instruction theory provoked great interest within the scientific community because it was the first time that the attention was drawn to the learner and learning behaviour in that learning domain. Nevertheless, the experimental procedures (small samples, studies only with laypersons, training of old computer applications) have been riddled with criticisms. Furthermore, its theoretical foundation is not well grounded. It is cross-referenced to Jerome Bruner's concept of discovery learning, to John Dewey's task orientation and to Jean Piaget's view of learning as problem solving. Similarities have also been unsystematically cited with more recent theories like *Cognitive Load Theory*.

3.2.3 Further Developments – The Integration of Screenshots Into Manuals

Astonishingly, despite the scientific attention directed to Carroll's approach it failed to become *the* method used in practice. One reason might be that the development of the guided exploration cards and working with the training wheels or the minimal manual is rather time-consuming. Furthermore and in terms of the cognitive load theory, attention has to be toggled between the material and the computer and this *split-source format* causes a *split-attention effect* to be imposed (Chandler & Sweller, 1996; Kalyuga, Chandler, & Sweller, 1999; Sweller & Chandler, 1994).

> *Consider a person who must learn to use a new computer program. Probably the most common procedure is to begin by referring to the relevant manual. The instructions in the manual require use of the keyboard and attention to information on the screen. In most cases, neither the manual nor the screen information have been mentally integrated. As a consequence, we have a classic split-attention situation, with learning impossible until the elements of the manual and computer have been integrated. To learn the new computer application, students must split their attention among and mentally integrate information from the manual, screen, and keyboard. We might expect cognitive load to be reduced by an appropriate form of physical integration that obviates the need for mental integration. (Sweller & Chandler, 1994, p. 195).*

The *split-attention-effect* causes high cognitive load, or more specifically extraneous cognitive load, as the result of poorly designed instructional material. Load burdens the capacity of the working memory – a fatal fact as the capacity of working memory is limited. In contrast to the working memory, the long-term memory has unlimited capacity, and is highly structured and organised in schemata (Gick & Holyoak, 1983) or scripts (Schank & Abelson, 1977). If one wants to create a learning situation where schema acquisition and schema automating are possible, applied instructional intervention that: (1) avoids cognitive overload; (2) reduces extraneous cognitive load; and (3) stimulates deep cognitive processing of the learning content (germane cognitive load) is necessary. An approach which met this criterion was the integration of screen captures in the conventional manual (Carroll, 1998; Chandler & Sweller, 1996; Gellevij, van der Meij, De Jong, & Pieters, 2002; van der Meij, 2000; van der Meij & Gellevij, 1998). Sweller and Chandler (1994) demonstrated in their study that this variation of a picture-text-manual led to shortened training times and improved results. Van der Meij and Gellevij (1998) consider the advantages and role of screen captures in directing and switching attention, developing a mental model of the computer application to be learnt, verifying screen states, and identifying and locating window elements and objects. In Gellevij et al. (2002), screen captures prompted mental model building, identified and located window elements and allowed for the confirmation of task solving states.

A recent study compared three different forms of a manual: (1) manual and computer, (2) manual and juxtaposed screenshots, and (3) manual and integrated screenshots. No difference in a learning test could be found, but learners in the two versions with screenshots learnt twice as fast as with the conventional manual (Martin-Michiellot & Mendelsohn, 2000). Problems while working on tasks are likely, especially when the element interactivity is high. Element interactivity refers to the degree of interactivity between learning elements. An element is a learning item in its simplest form. For example, creating a table might involve clicking one key element so that interactivity and cognitive load are low. Whereas designing a table like given in a sample involves a higher level of element interactivity because different elements have to be considered simultaneously. Chandler and Sweller (1996) compared (1) a conventional manual and computer with (2) a modified manual and computer and with (3) a modified manual only-group. No differences were found between instructional formats when the learning material entailed low element interactivity. In contrast, when the level of element interactivity was high, the self-contained modified manual (3) led to dramatically better learning results (Chandler & Sweller, 1996). In other words, integrating screenshots in a manual is an improvement but does not yet constitute an optimal solution because a simple split-attention effect remains. Attention has to be toggled between the manual and the computer. If this split-attention effect is avoided, dramatically better learner results can be achieved (Chandler & Sweller, 1996).

3.2.4 Learning a new Computer Application With Worked-out Examples via Observation

How can the split-attention effect be avoided? Chandler and Sweller (1996) introduced a ‘static’ possibility, but what would a dynamic solution look like? A possibility is to draw upon theories of observational learning: Many behaviour patterns can be learnt via observation without immediate performance (Blandin, Lhuisset, & Proteau, 1999). This thought was implicitly applied in the two previously mentioned studies in the manual-only condition in a ‘static’ way. Watching an expert or another person performing a task resembles the method by which people normally learn procedures of a program and corresponds to the dynamic way of learning. Observational learning is also an effective way for learning a new application not only concerning learning outcomes (Simon & Werner, 1996): Participants in a modelling training condition reported more effective cognitive working styles, more ease with the task, more satisfaction with the training, and less frustration compared with participants in a tutorial training condition (Gist, Schwoerer, & Rosen, 1989). Learning-by-observation can be easily adapted to the computer in the form of a demonstration or a video, thus avoiding the split-attention effect (Atlas et al., 1997).

Learning with worked-out examples is another approach which meets the goal of reducing cognitive load (Renkl, 1997; Renkl & Atkinson, 2003). It can be compared to learning-by-observation. The difference is that learning-by-observation involves watching a model of task performance, whereas learning with a worked-out example shifts the focus from the model to the actual solution of the problem. Worked-out examples consist of a problem formulation, solution steps and the final solution. Thus, the learner is able to concentrate on the solution and establish understanding. Typical application domains for worked-out examples are mathematics, physics, and programming. In complex domains like mathematics or learning a new computer application, the learner lacks strong domain-specific problem solving strategies. In the initial phase of skill acquisition learners usually possess limited task- or domain-specific knowledge. Consequently, task- or domain-specific problem solving methods are not yet part of their repertoire. They have to rely on weak, unspecific strategies as means-end analyses impose cognitive load due to the simultaneous holding of the actual problem state, the goal state, the intermediate state and operators in the working memory. Consequently, such strategies burden the working memory immensely. Means-ends analysis can lead to a solution but is rather unlikely to promote understanding (Renkl, 2005). The positive effect of using examples (e.g., such as superior learning outcomes) could be shown in numerous studies which compared worked-out examples to traditional methods or problem solving (for an overview see Atkinson & Catrambone, 2000; Atkinson, Derry, Renkl, & Wortham, 2000). The success of examples is explained by Cognitive Load Theory (Sweller et al., 1998).

The same is true for the domain of learning a new application, more specifically learning procedures in the application Microsoft Word© (Catrambone, 1995). Beside this study, there is little empirical research about worked-out examples used in software learning (Bannert, 2000; Leutner, 2000; Reimann & Neubert, 2000; van der Meij, 2000). Although, there is plenty of evidence that learners not only attend to examples in instructional settings and often refer to them during problem solving (Chi, Bassok, Lewis, Reimann, & Glaser, 1989; van Lehn, 1986) but also prefer worked-out examples as information source (LeFevre & Dixon, 1986). The latter aspect is especially important in multimedia learning environments where use is dependent on the learner's interest (Renkl, 2005). In order to exploit the potential of a worked-out example Renkl (2005) proposes several design principles. Two principles are particularly important in the context of this study: The (1) *easy mapping guideline* suggests facilitating mapping between different learning sources by either integrating different sources or by guiding attention through signalling when textual representations have been put into an aural mode. Secondly, the (2) *meaningful building blocks guideline* places emphasis on making the sub-goals salient by assigning them a *Label* or by visually isolating them. The latter guideline is essential if the learning goal is the acquisition of conceptual understanding as it incorporates conceptually orientated solution procedures. Therefore, the sub-goals are named so that the learner knows what he/she is about to learn. These two principles are described in more detail in the following section and in section 4.2.2.

3.2.5 Learning a new Computer Application With On-screen Videos

Considering the positive findings concerning worked-out examples, observational learning and avoiding the split-attention effect, it seems sensible to convert the on-screen manual to an *on-screen-video*. On-screen videos provide the opportunity to demonstrate application possibilities within a multimedia learning environment. Thereby, the learning content is featured within an authentic context. In other words, on-screen videos are not only a further development of integrating screenshots into manuals but they are also the multimedia version of a worked-out example. The idea of teaching procedural knowledge through demonstrations in an authentic context is not new (cf. *Cognitive Apprenticeship*, Collins, Brown, & Newman, 1987). It is often suggested in the new computer application learning domain to use on-screen videos as a learning tool. A synonymous term to on-screen videos is 'animated demonstrations', which was originally defined by Palmiter and Elkerton (1991) as a real-time instantiation of computer-based procedures. It is regarded as the most direct way for novices to learn the basic functionality of and steps necessary to execute commands using an application. The common view on animation is that it should facilitate comprehension, learning, memory, and inference (Morrison & Tversky, 2001). Several studies are reported in the instructional literature that evaluates the use of videos or demonstrations (for an overview see chapter 3 and 4). Together the studies confirm that videos might be an interesting alternative method to learning a new computer application. At the same time they caution that success is highly dependent on the features of task instruction and on the instructional setting (Kerr & Payne, 1994).

Ensuring that the control group is fair from the perspective of the medium and the learning domain is a key attribute to consider (see section 3.1.2). It has been criticised that in many such studies the conditions for the control group were rather unfair or were engineered to satisfy certain ends, such as being an a control manual for the experiment, and therefore was not a good example of its kind (Lazonder & van der Meij, 1993; Nickerson, 1991).

3.3 The Need to Instructionally Design On-screen Videos

3.3.1 Video Design

Against the background of the previous considerations, videos might be an interesting alternative for learning a new computer application via observation. At the same time, videos are no panacea and the state-of-the-art of science and technology within the domain make clear that adding instructional design to the videos is absolutely mandatory.

Several authors recommend strategies to using or designing dynamic visualisations. If dynamic visualisations are used to improve users' performance and attitude, five influencing factors have to be considered: (1) animated content; (2) the level of interactivity; (3) objective of animation, (4) design of animated interface, and (5) individual differences (Bétrancourt & Tversky, 2000). Other models distinguish only between the nature of the animation (meaning the description of its characteristics and purposes) and the nature of the subject matter (Weiss, Knowlton, & Morrison, 2002). The two approaches taken by Bétrancourt & Tversky (2000) and Weiss et al. (2002) remain on a very abstract level. Slightly more grounded is the suggestion of Plaisant and Shneidermann (2005, September) who recommend ten guidelines to be taken into consideration while designing animations:

(1) provide procedural or instructional information rather than conceptual information[1]; (2) keep segments short; (3) ensure that tasks are clear and simple; (4) coordinate demonstrations with text documentation; (5) use spoken narration; (6) be faithful to the actual user interface: do not shrink the screen; (7) use highlighting to guide attention; (8) ensure user control; (9) keep file sizes small; and (10) strive for universal usability.

Most of the aforementioned approaches are plausible and possess a high level of face validity. Some of the principles can even be explained by *Multimedia Theory*, *Cognitive Load Theory*, or the *Theory of Worked-out Examples*. However, the important fact is that the majority of these principles have shown only moderate success or have yet to be evaluated. Even more sophisticated studies that have tested, either explicitly or implicitly, the ability of animations to foster and aid learning (Kehoe, Stasko, & Taylor, 2001) have failed to demonstrate significant benefits. Kehoe et al. (2001) suggest three plausible explanations: (1) there are no or only very limited advantages of using animations; (2) there are benefits, but the used measurements were not sensitive enough; (3) something in the experimental design hinders learners from benefiting from animations. Therefore, a re-examination of how dynamic visualisations can be exploited as a learning tool is suggested. This dissertation will concentrate on the third idea, namely that dynamic visualisations have often been applied without sufficient consideration into the appropriateness of use, the larger context, the learning domain or the learning goals. As stated previously, videos should not be a stand-alone learning tool but should be embedded in a larger context (Schwartz & Hartman, in press). Furthermore, it must be considered if video is the optimal learning tool for a given learning scenario and actual learning goals must be determined.

3.3.1.1 Learning Theories Related to Design

The reason why videos are assumed to be the optimal learning tool for learning a new computer application is based on the finding that behaviour modelling leads to better results than other training methods like lecture-based instruction (Bolt, Killough, & Koh, 2001, 2001b; Compeau & Higgins, 1995; Simon & Werner, 1996). Behavioural modelling is the

[1] In this context procedural information is described as the steps required to complete a given specific task. Thereby, the goal is to complete the task successfully and immediately. Conceptual information is defined as background or theory information which is not necessarily needed to complete the task. Instructional information is a hybrid of the procedural and conceptual information that lead to better comprehension.

process in which a live or videotaped model demonstrates the behaviour required for performance (Gist, Rosen, & Schwoerer, 1988; Gist et al., 1989).

The theoretical basis of behaviour modelling originates from social cognitive theory (Bandura, 1977b, 1986) and is explained in more detail in section 4.2.1. Its success can be explained by the fact that through observation one forms a conception of how new behaviour patterns are performed, and symbolic construction serves as a guide for action on future occasions (Bandura, 1971). Several studies suggest that observation engages the learner in cognitive processes similar to those occurring during physical practice (Blandin & Proteau, 2000). These findings also serve to explain why even motor skills can be learnt by observing a model (Blandin et al., 1999). It is particularly interesting to note that videos containing a verbal description of desired behaviour increase the effect of the modelling component (Decker & Nathan, 1985). It is important to state that in the case of on-screen videos no model is visible, but the solution of a worked-out example is modelled.

On a rather general level instructional design aims to provide learners with a conceptual model of the content to be learnt; in this case a new computer application program (Moody, Ellis Blanton, & Augustine, 1996). One could also call it a mental model that can only be built if people know the names of all the relevant components, which combined in proper relation, allow them to build a causal model. Since knowing the components' names is important, the so-called *Labelling* intervention was implemented to provide the learner with a name (*Label*) of the learnt component (for a more detailed rationale see section 4.2.3.2). This is also in line with the already introduced *meaningful building blocks guideline* which puts emphasis on making the sub-goals salient by assigning a *Label* in the context of learning with worked-out examples. Additionally, schema construction is to be stimulated. According to information processing theory, a schema is an organised network of knowledge that includes concepts, facts, skills, and action sequences organised in such a way, that its individual elements can be stored and retrieved in terms of a more inclusive concept (Gagné & Glaser, 1987). This means that the learner not only learns how to use certain program features but *when* to use them. Through elaboration connections are made between prior knowledge in form of schemata and new information that requires mental effort. The application of examples, ideally different examples, can illicit elaboration (Quilici & Mayer, 1996). It is conducive is to implement real and authentic tasks and to foster task-orientation. Especially in the new computer application learning domain, task orientation is an important instructional concept as users need context to build mental models (Gong & Elkerton, 1990). Many researchers accentuate the method of a complete task that should be segmented into part-tasks (Dicks, 1994). This is also important from a cognitive load perspective (for a more elaborated explanation see section 3.1.3). However, it is important that the material requires the learners to draw inferences (Black, Carroll, & McGuigan, 1987) and thus enough time is a necessary prerequisite for drawing inferences. For this purpose the pace of the learning material needs to be adapted. This can be realised by implementing short pauses into the learning material until the learner has processed the given information. In this case, the phrase '*Pacing*' is used (see section 4.2.3.2 for more information).

3.3.1.2 Interactivity

Pacing might be seen as a special variant of interactivity; however both terms are ambiguous. Starting with *Pacing*, different definitions can be found (see Table 2 in the following).

Table 2. Different Definitions of Pacing

	(Ertelt, Renkl, & Spada, 2006)	(Moreno, 2005)	(Wouters, Paas, & van Merriënboer, 2006, April)
Pacing	Pacing in the form of integrating an inter-active click-button at the crucial point of a solution step avoids excessive demands and fosters active process-ing of the learning contents.	Pacing is control over the pace of present-ation. Students learn better because repre-sentational holding is reduced as smaller chunks have to be processed in working memory	Pacing involves control over the continuation of the presentation of instructional material, which can be exerted by either the learner or the system

All definitions share the postulate that imposed load on processing facilities should be reduced by taking the pace of presentation into account. Kozma (1991) already put emphasis on the fact that dynamic visualisations, such as television, have a transient nature. In this way, the effect of pace might be *the* crucial variable, especially in comparison to stable media like books. Surprisingly, little research has so far been conducted. However, the situation is just about to change. An interesting result concerning *Pacing* is that when it was the manipulated factor, meaning it was distinguished between *learner Pacing* and *computer Pacing*, no difference was found for transfer on learning (Moreno & Valdez, 2005). Hence, the important factor seems to be to adapt the pace of the presentation somehow, but whether it is done by the learner or by the system seems to make no difference.

Turning the attention to the broader concept of *interactivity*, one will quickly recognise the difficulty in identifying a single definition of the concept. It is often used synonymously with segmenting, learner control, or interaction. Definitions of interactivity can be rather simple, such as starting and stopping, to more sophisticated techniques like distinguishing between starting, stopping, repeating, zooming, taking different perspectives and regulating time (Tversky et al., 2002), or be very complex, multi-faceted descriptions. More important is the instructional meaning of interactivity, which is utterly complex. To put it simply, implementing interactivity aims to foster active learning, such as ensuring the learner deals with information and therein restructures its meaning (Campbell, 1999). Consequently, most instructional designers try to foster deep learning by integrating interactivity. Deep learning is defined as cognitive activities, such as selecting relevant information, mentally organizing them into a coherent knowledge structure and integrating new knowledge with existing knowledge (Moreno & Mayer, in press). Many of the expressions have several features of definition in common: Thus, it is important to distinguish between *interaction* and *interactivity*. *Interaction* is the exchange between individuals and groups. *Interactivity,* in contrast, is defined as the property of allowing exchange between (technological) media and users (Wagner, 1994). In the latter case, the benefits and constraints of the media can significantly influence the type of interactivity (Tversky et al., 2002). For example, “text interactivity” could mean scanning, rereading, annotating, or page turning (Narayanan & Hegarty, 2002). Hence the media constrains the dimension of interactivity. Nonetheless, this is not a disadvantage *per se* because interactivity always has to be seen in the context of the instructional design of the learning situation (Hannon & Atkins, 2002). Furthermore, it must be considered that the term covers a broad range of meanings independent of the learning scenario and the author. For example, Oliver, Omari, and Ring, (1998) put the focus on learner control and engagement that involves making decisions and learning from their consequences, whereas Schaverien and Cosgrove, (1997) promote a ‘generate-test-regenerate’ form of interactivity. McLoughlin and Oliver, (1995) argue for interaction in the sense of giving the learner control over the pace, sequence, and form of the instruction. Consequently, interactivity can be an important factor in a variety of learning scenarios, including web-based scenarios and simulation-based discovery situations (Swaak & de Jong, 2001). Additional definitions and taxonomies of interactivity can be found, for example, in Kettanurak, Ramamurthy, and Haseman (2001) who classified variants of interactivity according to behaviourist, cognitivist and constructivist theory. A complete review of interactivity that is independent of a certain medium is missing. However, all approaches have one thing in common: They emphasise interactivity as a crucial factor for knowledge acquisition.

It can be summed up that there is no single, explicitly stated version of an *interactivity principle* although several related effects are reported under labels such as 'interactivity effect' (Mayer, 2001 p., 188) or 'segmentation effect' (Mayer & Moreno, 2003, p. 47). On a rather general level, one could characterise the interactivity principle as follows: Students learn better from multimedia presentations if they can interact with the learning material [cf. e. g., (Bétrancourt, 2005)]. It is hypothesised, however, that some kinds and higher degrees of interactivity only benefit more experienced learners or that the use of interactivity needs to be prompted, too (Bétrancourt, 2005). In this sense what is meant by 'interactivity' can differ greatly. Therefore, it seems to be appropriate to first distinguish the different meanings of 'interactivity' in this learning setting.

In the context of dynamic representations, interactivity can be conceptualised in a multidimensional nature rather than seeing it as different degrees of one dimension. Bétrancourt (2005) distinguishes three different conceptualisations:

1) Interactivity as *control over pace and direction* of the succession of frames (e.g., VCR-such as controls as pause, play, (fast) rewind, (fast) forward, step-by-step, etc.).

2) Interactivity as the *capability to act on the appearance* of content on the next frame by action on parameters. In this case the presentation is rather a simulation of a dynamic system than an animation.

3) Interactivity as a possibility of *changing the viewpoint*, so that phenomena can be explored from different perspectives.

The first conceptualisation is explored in the following. The concept of interactivity has been integrated in multimedia learning environments for the purpose of reducing extraneous cognitive load on working memory, which can improve learning outcomes (Bodemer, Ploetzner, Feuerlein, & Spada, 2004). At the same time, implementing interactivity runs the risk of overloading the learner with too many interactive activities. To sum up, interactivity might be most successful if it is carefully related to the learning activities and takes the learner's prior knowledge into account (Kalyuga et al., 2003).

3.3.2 Practice as the Crucial Factor for Transfer

A related concept to interactivity is *Practice*. This concept is taken up in the second experiment in order to foster near and far transfer. *Practice* is seen as *one*, if not *the* crucial component, in improving transfer and application of knowledge (see also ACT-R theory later in this chapter). Acquired knowledge that is not used to solve similar or new problems is common and is referred to as inert knowledge (Renkl, Mandl, & Gruber, 1996). Renkl (1996) gives three explanations for the emergence of inert knowledge: (1) meta-process explanations, (2) structure deficit explanations and (3) situated explanations. Meta-process explanations are related to the meta-cognitive control procedures such as motivational deficits or dysfunctional epistemological beliefs. It is assumed that the knowledge is available *per se* but the access processes are prone to malfunction. Structure deficit explanations refer to the knowledge itself. The most prominent explanation in this context is the one of inadequate compilation of knowledge based on Anderson's ACT-R theory. The situated explanation rests on the fact that knowledge always is bound to a particular context and questions the traditional perspective of knowledge and transfer altogether. In this study, the second explanation is used to explain lack of transfer. In Experiment 1, the root for a lack of transfer was seen in knowledge deficits caused by an inadequate compilation due to a lack of *Practice*. Therefore, the ACT-R theory is introduced and followed by a general discussion of transfer.

ACT-R is a model of the human cognitive process and the acronym stands for 'adaptive control of thought – rational'. The theory can also be characterised as a *production system theory* meaning that a cognitive skill can be described with conditional sentences known as production rules. A production rule consists of condition-action pairs. The condition has to be met before the action can take place. Most important in this context are the memory modules. In ACT-R there are two separate long-term memory modules: declarative and procedural. The declarative memory consists of knowledge about facts and things (e.g., Berlin is the capital of Germany) and is represented by units called chunks. Procedural knowledge, in contrast, refers to knowledge about how to perform various cognitive activities (e.g., how to drive or perform a calculation). Procedural knowledge, such as mathematical problem solving, is represented by a large number of rule-like units called production rules. The term ‘production’ is important because it offers a connection between declarative and procedural knowledge (Anderson, 1983). It can be broken down into two levels of abstraction: the symbolic level and the sub-symbolic level. The symbolic level deals with productions and chunks as described above and learning happens via knowledge compilation from declarative to procedural knowledge. The sub-symbolic elements consist of multiple parallel processes affecting the high-level chunks and productions. These processes can be conceptualised as a set of mathematical equations that model neurological information processing units. This framework allows a description of learning skills (Anderson & Schunn, 2000). Anderson (e.g., 2000) describes three steps: (1) cognitive stage, in which a description of the procedure is learnt (in his earlier taxonomy this stage was called ‘generalization process’); (2) an associative stage in which a method for performing the skill is worked out (‘discrimination stage’) and (3) an autonomous stage, in which the skill becomes more and more rapid and automatic (‘strengthening process’) (Anderson, 2000). The working memory in this model can be described by activated declarative units. Information processing happens via the firing of a production rule. Thereby, declarative knowledge is retrieved and used to advance the problem solution (Anderson & Schunn, 2000). This retrieval process, and more specifically its speed and success, depend on the chunks’ activation level and the strength of the production rule. This production rule also contains conditioned knowledge. Through generalisation, discrimination and strengthening processes knowledge gets conditioned to specific applications situations. Conditioned knowledge is directly connected to the application conditions with the production rules. With *Practice* these application possibilities are taught directly in the application domain in an authentic context.

Practice and the retention interval have a multiplicative effect on this retrieval and it was found that performance continuously improved with *Practice* and consistently worsened with the retention interval. The learning mechanism on the symbolic level can be described as a compilation of declarative knowledge to procedural knowledge. In contrast to computer compilation, human compilation is gradual and occurs as a result of *Practice*, (Anderson, 1983, p.240). Consequently, inert knowledge or a lack of transfer might not only be explained by inadequate compilation of knowledge but also by a lack of *Practice*.

In practical skill training a common assumption is that learnt skills are transferred to new skill development insofar as the skills share facts, production and patterns. Success depends on the amount of *Practice*. Regarding procedural knowledge, forgetting procedural tasks is a function of the number of steps needed to perform the tasks. Steps are even more likely to be forgotten if they are not prompted by the environment or proceeding steps (Druckman & Bjork, 1991). There are several findings modulating the effects of *Practice*: (1) spacing of *Practice* increases learning. It is one of the most reliable phenomena in psychology that *Practice* sessions spaced in time are superior to massed practices in terms of long-term retention. (2) Furthermore, skills can be learnt better if independent parts are taught or practiced separately and if understanding is fostered. This requires repeated *Practice* and use of the to-be-learnt material. (3) Understanding is fostered if the learners are continuously encouraged to elaborate during *Practice* and when they learn with *Practice*. This effect is also used while learning with worked-out examples (Renkl, 1997). (4) *Practice* has a further effect on the time to perform a task in the sense that continued *Practice* is of continuous but ever diminishing benefit to the task performance. All these issues lead to the following question: Is transfer possible without *Practice*?

In Experiment 1 the focus is placed on optimizing learning with on-screen videos by implementing instructional design features. In Experiment 2, the focus is on the improvement of transfer by implementing *Practice*.

4 Experiment 1: Instructionally Designed On-screen Videos as an Effective Learning Tool

Starting points for Experiment 1 are (a) the inherent advantages on-screen videos provide, such as learning from a modelled worked-out example via observation (compare section 4.1.1) and (b) the problems while learning with them (compare section 4.1.2) that have to be solved (3) by introducing instructional design features (compare section 4.1.3).

4.1 On-Screen Videos as a Variant of Dynamic Visualisations

As introduced in section 3.1.1 and section 3.2.5, a further domain where video can be applied is learning a new computer application like software visualisation or so-called on-screen video (Baecker, 1998). This is a compelling medium for the display of computer application behaviour as it provides the opportunity to demonstrate application possibilities within a multimedia learning environment. Furthermore, learning contents are explored within an authentic context. A synonym for on-screen videos used by Atlas et al. (1997) is animated demonstrations. They define it a full-motion recording of the computer-screen or as a ‘show-me-how’ instruction. This has been an area of research since the 1980s (e.g., “Getting Started” tours in Apple Computers, Palmiter, Elkerton, & Baggett, 1991).

4.1.1 Advantages of On-Screen Videos

Several studies examining on-screen videos as learning tools have already demonstrated that these videos are highly accepted by learners and that they possess motivational potential (Atlas et al., 1997; Hegarty, 2004). Learning with videos resembles the way people normally learn: By visually observing others. Thereby, the linking of input action and interface results is facilitated. This gives the learner the chance to rehearse and plan while watching (Palmiter & Elkerton, 1993; Palmiter et al., 1991). In addition, videos have the capacity to convey multiple forms of information by using both the verbal and the visual channels (Wetzel et al., 1994). Dynamic visualisations are also believed to aid the retrieval process because they facilitate initial encoding (Rieber, Boyce, & Assad, 1990). Besides fostering initial encoding, studies also report a positive effect on first-time exploratory learning (Payne, Chesworth, & Hill, 1992). A common optimistic assumption about dynamic visualisations used in instruction is that they facilitate comprehension, learning, memory, and inference (Morrison & Tversky, 2000).

4.1.2 Problems With On-Screen Videos

Despite the obvious positive elements of learning with videos, there are some typical problems that make instructional design necessary for effective learning. Two variants of the split-attention effect play a particularly crucial role: The *temporal* and the *spatial split-attention effect*, which are differentiated in the following.

A severe problem in all kinds of dynamic visualisations is the difficulties people have in accurately perceiving and conceiving of real-time animations (Proffitt, Kaiser, & Whelan, 1990). It remains to be determined if this reflects a lack of specific literacy or if it is a question of visual attention. Extracting the message contained in an animated visual is problematic and may need direct prompting (Rieber, 1989). The excessive demands are due to the so-called *temporal split-attention effect*. This variant of a split-attention effect can be divided into an *intra-representation split-attention effect* (Lowe, 2003) and a *video-specific split-attention effect*:

The intra-representation split-attention effect: Occasionally there are multiple activities occurring at several locations simultaneously, which requires a distribution of attention and causes the intra-representation split-attention effect. The same is true when a number of changes have to be mentally integrated. The imposed extraneous cognitive load negatively influences learning. Lowe (2003) calls this imposition of processing demands the *overwhelming* effect of dynamic visualisations.

The video-specific split-attention effect: Videos are a transient medium that places heavy demands on the working memory as the presentations have a continuous flow and learners have a limited amount of time to study each video-segment. This can cause problems if new segments of information are being introduced faster than the earlier segment can be processed and transferred to long-term memory. Interference or retroactive inhibition (Baddeley, 1997) is likely and ineffective cognitive load may inhibit learning. This effect is called video-specific split-attention effect and leads to major problems, such as shallow processing of the central contents due to excessive demands. Consequentially, learners only mimic and do not deeply process the learning contents (Atlas et al., 1997); thus potentially hindering the acquisition of procedural knowledge.

In addition to the two described variants of the *temporal split-attention* effect, the more common *spatial split-attention effect* also plays a crucial role when turning the attention to the learning domain ‘learning a new computer application’. In most cases, it is learnt with a paper source (e.g., manual, tasks-to-be-done) and the computer. Learning is impossible until all sources, that is, information from the screen, the manual and the keyboard have been mentally integrated (Sweller & Chandler, 1994). However, the solution for this is rather easy: By using on-screen videos the “manual can be brought onto the computer-screen” and attention need no longer be divided between several sources of information.

It is also important to note that the learning or training methods learners enjoy and prefer are not necessarily the ones that lead to the best learning results (Schmidt & Bjork, 1992). Learners might like videos as a learning tool because they associate them with television. A possible consequence can be that learners do not process the learning contents deeply but instead show the tendency to mimic behaviour superficially (Palmiter et al., 1991). The reduction of engagement in valuable processing activities is also called the *underwhelming* effect of dynamic visualisations (Lowe, 2003). However, television as a medium of entertainment might also foster a passive viewing attitude without any mental effort (Wetzel et al., 1994). The consequence is that learners just blindly mimic the seen procedures because they have been engaged only in very little processing and encoding (LeFevre & Dixon, 1986). This behaviour could be also characterised as “couch potato attitude” (Schwan & Riempp, 2004). Another consequence of suboptimal learning behaviour is the deterioration of performance outcomes over even a short period of time, such as a week (Palmiter & Elkerton, 1993; Palmiter et al., 1991). Therefore, two important questions arise: How can mid-term performance be improved and how can the learner’s cognitive engagement be ensured? The effectiveness of video as a learning tool depends on the learner, who is expected to recognise critical features and engage in cognitive processing strategies. Unfortunately, learners rarely demonstrate this behaviour on their own.

Interestingly, a majority of studies featuring the topic ‘learning from television’ were conducted in the learning domain ‘watching the news’ and led to disappointing recall results. This was explained by the continuous stream of information challenging the learner’s comprehension. A further explanation of the low recall results could be found in the combination of the mentioned presentation format and an experimental ‘flaw’ such as the fact that learners are often engaged in other activities while watching the news and are not used to actually “learning” the contents (Wetzel et al., 1994).

What can be concluded about the advantages of new media like videos? First of all, there are still very few empirical evaluations on the use of videos for learning (Schwartz & Hartman, in press; Tversky et al., 2002), see also chapter 3.1. Second, an early phase of research was devoted to the search for advantages of animated over static learning scenarios (see section 3.1.2). So far the conclusion is that animations more or less failed to demonstrate ground-breaking success. Its effects, if any, are subtle. Furthermore, learners definitely require significant instruction or coaching in order to learn the presented contents – even if many of the studies leading to these results dealt mainly with the learning content ‘watching the news’ and were flawed (Rieber, 1989). As a result, it is necessary for research to focus on the conditions that make dynamic visualisations successful. Therefore, emphasis should be put on: (1) the possibilities dynamic visualisations actually provide (e.g., learning-by-observation, learning from worked-out examples); (2) successful instructional settings (e.g., instructional design through *Labelling* and *Pacing*); (3) the prerequisites learners already bring to the situation (e.g., knowledge in the learning domain); and (4) the methods used to measure learning outcomes.

4.2 Theoretical Background of On-Screen Videos

4.2.1 Observational Learning

A principal advantage of dynamic visualisation is the chance it offers to learn via observation. Some studies argue, therefore, that learning through videos is superior to other methods because modelling is a vicarious experience. It allows one to observe a model performing a task and reaching the goal state. A video serves as a coherent reference that might generally facilitate recall. In the context of computer training behaviour, modelling has already revealed its superiority to other methods like tutorials (Gist et al., 1988; Gist et al., 1989) or self-study from a manual (Simon & Werner, 1996). The range of scenarios where video-based modelling of behaviour is an option is diverse. It has been shown to be effective within collaborative problem-solving settings (Rummel & Spada, 2005) or learning to argue (Schworm & Renkl, 2005).

Behaviour modelling originates from social cognitive theory (Bandura, 1977b, 1986), which claims that modelling-based training affects outcomes by influencing one or more of the following processes: (1) *Attention*: People can only learn from models when they are attentive during observation; (2) *Retention*: Actions must be stored as symbolic representations in memory to provide the possibility to regulate future behaviour; (3) *Production*: The stored symbolic representations must be convertible into actions; (4) *Motivation*: The symbolic memory of actions will decrease unless the perceived consequences are favourable enough to cause repetition of the performance. A path-model testing the four aforementioned processes revealed the following results (Yi & Davis, 2003): All four dimensions significantly influenced the observational learning process. Observational learning processes had also great impact on declarative knowledge, which in turn influenced immediate and delayed task performance. Task performance can also be called 'procedural knowledge'. However, there was no direct influence of declarative knowledge on delayed task performance, only intermediated by the immediate task performance. In regards to the learning domain 'learning a new computer application', the first process '*attention*' might be the crucial point for learning success and the instructional methods needed to foster the learners' attention. However, the '*retention'* phase is also very important as learners often get the feeling with videos that they have understood everything. In reality, they do not understand the solution procedures, thus they do not store the function of and rationality behind each solution step (Catrambone & Holyoak, 1990) but rather learn whole solution chains that cannot be transferred to a new problem situation that differs in any way. The result is an 'illusion of knowing' – a well-known concept in research on text comprehension (Glenberg et al., 1982). This has consequences for the *production* phase as the mentioned solution chains make transfer rather unlikely. Therefore, it was assumed that the production of the learnt behaviour is more likely if learners possess prior knowledge in the learning domain and are made aware of the function and sensibility of each solution step. As the observed actions always consisted of the completion of a whole task it was thought that this could increase the motivation of in fact performing the behaviour oneself.

4.2.2 Theoretical Background: Worked-out Examples

A model presented by a video can also be regarded as a worked-out example demonstrating the steps experts use in solving authentic, complex problems. Ideally, these examples are designed and implemented according to an instructional model of example-based learning as suggested by Renkl and Atkinson (in press; Renkl, 2005) among others. However, what is a worked-out example? On a general level it can be summarised as a step-by-step demonstration of how to perform a task or solve a problem. It consists of a problem formulation, solution steps, and the final solution (as it was already introduced in section 3.2.4). Recently it has been considered for learning new computer applications (van der Meij, Vogels, & Cromwijk, 2005, August). E-learning scenarios have been recognised as potential fields for their application (Clark & Mayer, 2003). Providing learners with worked-out examples avoids an overload of working memory and enhance capacity for learning and understanding. Therefore, the effect of a worked-out example can be characterised in a positive sense as a carefully guided form of learning. This is valuable since it is well-known that unguided learning generally does not work (Kirschner, Sweller, & Clark, 2006). That said, it might only be successful if the learners have sufficient prior knowledge that provides internal guidance. Furthermore, minimal guidance can not only be ineffective but also harmful (Clark, 1989). Unfortunately, simply implementing worked-out examples is not enough. More instructional design is necessary to exploit their full potential. Renkl (2005) proposes the consideration of several principles (see also section 3.2.4). The most important of these principles for this dissertation are the *easy-mapping guideline* and the *meaningful building block guideline*. The easy mapping guideline refers to the integration of different representations that can be achieved by putting text into an auditory mode or guiding attention by using, for example, signalling. The second guideline brings one of the primary objectives of all kinds of learning situations into account: *Transfer*. Transfer means that the learnt learning procedures can be applied to new problem situations. This implies a modification of the already known problem solving procedure(s). However, as already mentioned, learners show the tendency to learn a problem solving procedure as a fixed chain of steps that has to be applied as a whole. Learners show great difficulties in solving problems requiring changes to solutions demonstrated in worked-out examples (Catrambone, 1998). In the majority of cases they are unaware of the individual solution steps that make up the learnt solution chain. For the purpose of solving this dilemma, Catrambone (e.g., (Catrambone, 1995, 1996; Catrambone & Holyoak, 1990) suggests making the sub-goals (or the individual solution steps) salient by giving them a *Label* or by visually separating them. The idea is that making the sub-goals and the single meaningful building blocks explicit leads to an enhanced transfer problem solving capability. This idea has been confirmed in several experiments (Atkinson et al., 2000; Catrambone, 1995, 1996). Gerjets et al. (2004) introduced the term 'modular solutions' for the individual solution steps and were able to prove their effectiveness in terms of test performance and transfer problem solving capabilities (Gerjets, Scheiter, & Catrambone, 2004).

4.2.3 The Necessity of Instructional Design

It can be concluded from the aforementioned potential problems inherent in videos and from the described theoretical background that instructional design is indispensable to effective learning and knowledge retention. Starting with the videos, the underlying idea is that instructional design can only be fruitful if it is implemented in videos that exhibit sophisticated multi-media principles. Therefore, the videos were designed by implementing the principles of Mayer's *Theory of Multimedia Learning* (Mayer, 1997, 2005; Mayer & Moreno, 2003). For example, the signalling principle (or easy-mapping guideline in the context of a worked-out example, Renkl, 2005) was implemented, which signifies that the integration of cues highlighting the organisation of learning material leads to deeper learning. In this case green highlights were integrated. The theoretical rationale for this principle is that it directs the learners' attention to the essential material and helps to ignore extraneous material that can distract learning. Thus, any available cognitive capacity can be used for learning. Until now several empirical studies have supported the signalling principles (Mayer, 2005). However, there seems to be some restrictions: It was found that cueing had an effect on the retention test, but no implication for the transfer test (Tabbers, Martens, & van Merriënboer, 2004). For a complete overview of the principles and their use in this learning scenario compare section 4.4.2. Besides neglecting the quality of the learning material *per se*, another common mistake is neglect the user who is actually going to be learning within the learning environment.

4.2.3.1 Importance of Prior Knowledge

An important question to be considered is for whom the learning environment is created. Learners or students do not enter a learning situation as an empty vessel, waiting to be filled. On the contrary, they already possess at least some prior knowledge, half-formed ideas or even misconceptions (Sawyer, 2006). As such, prior knowledge is a crucial factor in the designing of an effective learning environment. As it is known from the *expertise reversal effect* (Kalyuga et al., 2003), the effectiveness of an instructional technique depends very much on the level of the learner's expertise. Thus, instructional methods that have shown success with inexperienced learners can have a negative effect on experienced learners. If a learner has high prior knowledge, animations with additional information might initiate deep and thorough cognitive processing (enabling function). In contrast, learners with low prior knowledge could make use of the animation for building up an image of the processes (facilitating function) (Salomon, 1994). In the case of learning a new computer application it could be realised by starting with known tasks or by referring to common applications and showing similarities or differences (Price & Korman, 1993). There is evidence that observational learning is best suited to intermediates (Jentsch, Bowers, & Salas, 2001). According to this finding, the learners taking part in this experiment possessed intermediate-level prior knowledge within the domain. To sum it up and relate it to Ausubel's tradition, prior knowledge is a necessary prerequisite (Mayer, Mathias, & Wetzell, 2002) that requires stimulation.

4.2.3.2 Instructional Design Variants Labelling and Pacing

Once the videos were of generally high quality, in terms of multi-media design, and the decision to include intermediate learners was made, attention could be turned to the instructional design. This was done to address the aforementioned potential problems of dynamic visualisations. As it has been repeatedly shown, learners often lack the ability to extract relevant information from videos. This falls in line with the finding that during self-regulated or exploratory learning learners often lack the ability to set personal objectives or determine overarching learning goals (Charney et al., 1990; de Jong et al., 1998). Hence, prompting or coaching functions are sensible techniques to ensure a positive learning attitude (Rieber, 1989). However, what kind of information extraction should be fostered? Without special cueing, it has been shown that information extraction is mainly motivated by perceptual features of the dynamic visualisation (Lowe, 1999). Even when information is important, from a thematic point of view, it is often neglected when the perceptual salience is low (Lowe, 2003). In the context of on-screen videos, it is assumed that learners need prompting to extract relevant declarative information (facts) and require assistance to construct a basis of procedural knowledge from which to apply practical knowledge.

A solution to foster the extraction of declarative and the construction of procedural knowledge is segmentation or sub-goal learning. This means dividing the solution process of a complex task into small, meaningful building blocks. Segmentation of solutions through worked-out examples has been very successful in other settings, for example, in learning probability calculation (Catrambone, 1998). In the following, two different variants of segmentation are introduced: *Labelling* and *Pacing*.

Labelling: By segmenting a complex solution procedure into meaningful building blocks each adorned with heading in the sense of a *Label* for each sub-goal, learners are made aware of what they are about to learn. This prevents the tendency among learners to form representations of a solution procedure that consist of a linear series of steps rather than a more structured hierarchy (Catrambone & Holyoak, 1990; Reimann & Schult, 1996). The headings might solve another problem that arises while learning with animations: Learners often lack the appropriate vocabulary to describe the learning contents they see. This is an issue even in the case when the learners already possess some domain-specific knowledge. Thus, *Labelling* (i.e., naming the meaningful building blocks) should foster declarative knowledge acquisition because learners are directly prompted to extract the relevant sub-goals – it was already demonstrated that *Labels* indeed serve as cue for creating sub-goals (Catrambone, 1996). Being aware of the relevant sub-goals is, in turn, important for developing effective procedural knowledge. It can be assumed that knowledge acquisition proceeds from a declarative to a procedural, compiled form (Anderson, 1993, 1995b). Acquiring knowledge about single steps and their function (i.e., the sub-goals to be achieved) facilitates the construction of procedural knowledge. Furthermore, mental model construction is boosted as learners become familiar with each step while recognizing how it fits into the whole solution chain. It is, therefore, important to carefully consider the number and granularity of each step: If there are too many single steps, excessive demands are induced (Mayer et al., 2002).

On that account a pre-requisite to determining sub-goals involves a detailed task-analysis (Catrambone, 1994). Providing observers with an external mental model prior to viewing has been found to positively affect transfer performance because such models allow observers to classify and organise their expectations (Trimble, Nathan, & Decker, 1991) and act as an advanced organiser (Ausubel, 1960). It is expected that *Labels* counteract the tendency of learners to represent problem solving procedures of training problems or worked-out examples as a set of linear steps (Atkinson & Catrambone, 2000). At the same time *Labels* are expected to foster the formation of a hierarchical representation that allows learners to successfully solve novel problems (Singley & Anderson, 1989). This is especially important as several studies have shown that learners show a tendency to form representations of a solution procedure that consist of a linear series of steps rather than a more structured hierarchy; making transfer rather unlikely (Catrambone, 1996).

Pacing: The second mentioned variant of segmentation, *Pacing*, brings the issue of passive viewing into account. A possible disadvantage of dynamic representations like videos is that learners do not put enough effort into active learning activities because they perceive it as an “easy” media (Salomon, 1984). An approach to avoiding this kind of passivity is to actively engage learners in the on-screen video by introducing *Pacing* in the form of an interactive push button. The push button appears at the key point of a segment. Consequently, the learners’ attention should be drawn towards the relevant content and the steps leading to a solution. Without participation from the learner, the video simply stops until the button has been clicked. This fosters enhanced perception and conceptualisation of solution procedures and should, therein, boost learning outcomes; particularly of the procedural variety. *Pacing* in this case could be classified as a form of computer control, but at the same time it gives the learner time to consider the material. However, it is difficult to define proper pace parameters. With *Pacing* information is presented at a rate determined by the particular content in relation to the viewer’s needs and current skill level (Wetzel et al., 1994). It is expected that by integrating these variants of segmentation the temporal split-attention effect is less likely to occur. *Pacing* ensures a continuous flow of information unless a learner is inattentive or overwhelmed with the processing of an earlier segment.

In order to test the two described instructional design features and the overall effectiveness of on-screen videos, participants had to work with a new computer application. The previously mentioned advantages of this particular media demonstrated substantial merit– namely; it was possible to demonstrate the task’s solutions within the software application to be learnt.

4.2.3.3 The Motivation Factor while Learning with Dynamic Visualisations

Final aspects of interest were *motivation* and *acceptance* as several studies addressed the motivational potential (Waterson & O`Malley, 1992) inherent in animations or videos and their use as an extrinsic motivator. Furthermore, animations are considered to enjoy very high user acceptance (Weiss et al., 2002). Other studies are more precise and report a high acceptance among users and learning efficacy only while learning complex command sequences (Jung, 1994). The motivational potential is important because it influences a learner's level of interest and sustained concentration (Rieber, 1991). This falls in line with CTLM (cognitive-affective theory of learning with media, see 3.1.3), which assumes learning outcomes are affected by the design of a learning environment and motivational factors (Moreno, 2005).

Nevertheless, the latest research challenges the postulation that dynamic visualisations are superior to other learning materials (Narayanan & Hegarty, 2002). One reason for this might be the inverse relation between interest and achievement: While learners are generally very interested in learning with new media and may be motivated by the assumption that this new technology will simplify the learning process, a reduction in effort and engagement in processing activities can result. Consequently, less is learnt (Salomon, 1984).

4.3 Research Questions

The current study aimed to investigate the impact of a learning-by-observation approach on performance, motivation and acceptance values in comparison to a learning-by-doing approach. The videos (learning-by-observation method) were instructionally designed according to the above mentioned instructional theories. The following research questions were addressed:

1. **Do instructionally designed on-screen videos lead to more favourable learning outcomes when they are compared to the enriched standard introduction to a computer application and when they are compared to the video-control group?**

Providing learners with a modelled worked-out solution in the form of a video should facilitate learning because the content is demonstrated in a step-by-step manner. What is more, more content can be shown within the same amount of time and one can watch how an expert solves a task. Hence, it was predicted that learning with videos would lead to better results in declarative and procedural knowledge than learning in the enriched standard introduction. It also was predicted that the three instructionally designed video groups would reach better results in declarative and procedural knowledge as the video control group without *Labelling* or *Pacing*. Furthermore, the effects on near and far transfer tasks concerning procedural knowledge were of interest.

2. Does Labelling and/or learner-controlled Pacing in instructionally designed on-screen videos foster learning?

The aim of the study was to analyse the effect of the two experimental design features alone and in combination. It was predicted that *Labels* would improve the acquisition of declarative knowledge in particular, while *Pacing* would enhance the acquisition of procedural knowledge. Additionally, the effects of the instructional design variants on near and far transfer (procedural knowledge) were examined.

3. Do the experimental conditions differ with respect to motivation and acceptance?

Results of other studies concerning videos as a learning tool found that videos are perceived as a very motivational learning tool and are thus highly accepted among learners. Consequently, it was expected that these findings would be re-confirmed in this study. An explorative question asked if there is a correlation pattern between performance values and motivation/acceptance.

4. Are there certain types of learners?

Based on the question regarding performance values and motivation/acceptance, it was asked if there are certain types of learners who show a specific pattern regarding the previously mentioned variables, which are to a certain extent independent of the experimental condition to which they belong. To answer this question a cluster analysis was conducted.

5. Do the direct ratings of the experimental variations differ?

It was of interest to examine how *Pacing* and *Labels* were perceived during the course of the experiment. Furthermore, were they rated differently when presented alone or in combination?

6. How do learners conceive of the learning environment?

This explorative question sought to determine the spontaneous reactions of learners to the learning environment. Being open-ended, learners had a certain degree of freedom in their responses. It was expected that answers to this question would not only give additional insights but also serve as a source for post-hoc explanations as to the successfulness, or lack thereof, of the learning environment.

4.4 Method

4.4.1 Participants

This experiment included N = 101 students (61 females, 40 males, mean age: 25.08 years, SD = 5.14) from different departments at the University of Freiburg. 16.8% of the students were from natural sciences departments, 37.6% from the humanities, 41.6% from business and behavioural sciences and 2% from other departments. Students were selected if they had at least some general computer knowledge and no prior knowledge of the application to be learnt (i.e., RagTime®). The computer application RagTime® was chosen because it was widely unknown and available at that time as freeware. It provided an opportunity to make use of general transfer abilities (good general computer knowledge) and was seen as having intrinsic potential as a valuable tool for students.

The pre-test on general computer and Internet knowledge will be described in section 4.4.4.1. The average time to complete this test was approximately 25 minutes (M = 25.25; SD = 8.31). 152 students wrote the test (M = 168.73, SD = 49.64). The minimal score to be reached for taking part in the study was 140 points. This score was calculated by dividing the maximal possible point into three category groups: laymen, intermediates and experts. All eligible persons belonged to the intermediate group. 101 students reached that threshold (M =

186.67, *SD* = 45.45). Furthermore, all students had been using computers for a reasonable time span, that is, about 8 years on average (*M* = 8.05, *SD* = 3.41).

Participants were randomly assigned to the five different experimental conditions, each of which contained up to 21 people (see Figure 3). They received 21 EURO, the freeware version of the application RagTime® and the on-screen videos on CD as compensation for their participation.

4.4.2 Design and Material

Of the five experimental conditions, four used video and one, the so-called enriched standard introduction condition, did not. The design might be best characterised as a 2x2 plus one design. The distinction of a ‘2x2 plus one design’ was made to avoid a media comparison. Nonetheless, it is of interest to anchor the findings of observational learning with a different learning approach, such as a learning-by-doing learning variant.

Enriched Standard Introduction			**Labelling**	
			with	**without**
20	**Pacing**	**with**	21	20
		without	20	20

Figure 3. Overview of the design.

4.4.2.1 On-Screen Videos (4 Conditions)

The learners were provided with four different on-screen video conditions containing the same learning content (2x2 factorial design). The objective was to create excellent on-screen videos for two main reasons: First, it was expected that the design variants would improve learning results if they were implemented in well-designed videos. Second, it was important to avoid the critique other studies related to software tutorials had faced, namely the creation of unfair conditions for the control group (Lazonder & van der Meij, 1993; Nickerson, 1991).

The first design principle proved to be a contra-intuitive insight considering the videos’ level of reality: A naïve assumption is that the more realistic a video is, the more effective it will be. Actually, in many cases abstractions or ‘deformations’ of reality are preferable and lead to successful outcomes (Rieber, 1991). Therefore, and as a result of a preliminary study, the on-screen videos were slightly abbreviated and did not show the mouse cursor. Time-consuming and potentially boring processes were also accelerated in order to condense the given information. These efforts were made in response to findings from the above mentioned preliminary study concerning the instructional design features.

All four videos were designed according to the principles of Mayer's *Theory of Multimedia Learning* (Mayer, 1997, 2005; Mayer & Moreno, 2003). Taking into account, for example, the modality principle, which states that learning is enhanced by using animation and spoken text rather than using animation and written text. Other studies have also confirmed that relating visual material to audio significantly improves performance than visual material presented alone. However, it must be ensured that the audio track is not redundant to the visual material (Leahy, Chandler, & Sweller, 2003). Consequently, this form of dual mode presentation does not reduce the extraneous cognitive load, but increases effective working memory capacity (Kalyuga et al., 1999). Hence, all videos contained the same spoken explanations instead of written explanations. A female voice was chosen, because of findings that learners are more motivated and perform better when listening to female voices (Linek & Gerjets, 2005; Linek, Gerjets, & Scheiter, 2005, August). Furthermore, all videos contained green highlights which are in line with the signalling principle and VCR-like control as aforementioned. These highlights or so-called colour codes boost the processing efficiency and lead to better integration of new content. Especially with complex material, colour codes guide attention and reduce search processes; yet this is not the case if the material is too easy. Instead of 'highlights', Gellevij et al. (2002) use the term 'cueing', which means circling the important features in hopes this will demarcate importance (Gellevij, van der Meij, de Jong, & Pieters, 2002). Another influencing factor is the level of expertise: Processing efficiency increases with level of expertise because experts can organise their viewing behaviour more efficiently (Folker, Ritter, & Sichelschmidt, 2003). That should be the case in this study as only participants with intermediate pre-knowledge in the domain were included.

For a detailed overview of all principles, see Table 3 in the following. All these design features were kept consistent in the four video conditions.

Table 3. Overview of Multimedia Learning Principles

1.	Multimedia Principle	*Deeper learning from words + pictures than from words alone* ☑ Spoken text (words) + animation (pictures)
2.	Spatial Contiguity/ Split-Attention Principle	*Deeper learning when on-screen text is presented next to the corresponding action in the animation* ☑ Label is placed before and after the corresponding action
3.	Temporal Contiguity/ Split-Attention Principle	*Deeper learning when corresponding portions of the narration and animation are presented at the same time than when they are separated in time* ☑ Spoken text always refers to the action in progress
4.	Coherence Principle	*Deeper learning from animation and narration when extraneous material is excluded rather than included* ☑ No inclusion of unnecessary material in the animation, such as sounds, etc.
5.	Modality Principle	*Deeper learning from animation and narration than from animation and on-screen text* ☑ Spoken text instead of on-screen text
6.	Redundancy Principle	*Deeper learning from animation and narration, than from animation, narration and on-screen-text* ☑ Only spoken text
7.	Personalization Principle	*Deeper learning from a multimedia presentation when the narration is in conversational rather than formal style* ☑ Learner addressed directly by using “you”
8.	Voice Principle	*Deeper learning from a multimedia message when the words are spoken in a human voice rather than in a machine voice* ☑ Female human voice is used
9.	Image Principle	*Not necessarily deeper learning from a multimedia message when the speaker’s image is on the screen.* ☑ Only the voice of the speaker is audible; she is not visible

10.	Segmenting Principle	*Deeper learning from a multimedia message when it is presented in learner-paced segments rather than as a continuous unit* ☑ Presentation in segments, possibility of using VCR-control
11.	Signalling Principle	*Deeper learning from a multimedia message when cues are added that highlight the organization of the material* ☑ Green highlights in order to guide the learner's attention to the important features
12.	Worked-out Example Principle	*Deeper understanding sought in certain circumstances when learners receive worked-out examples* ☑ Videos serve as a worked-out example *per se*
13.	Animation & Interactivity Principle	*Deeper learning when the apprehension of the animation is easy & when the learner is interactively integrated in the animation* ☑ VCR-control implemented in all videos
14.	Prior Knowledge Principle	*Deeper learning when instructional procedures are optimal for the level of expertise* ☑ Instructions tailored to learners with intermediate computer & Internet knowledge

In regards to the experimental variations (see section 4.2.3.2), the learners in the *Labelling condition* (*Label*: with; *Pacing*: without) saw a slide at the very beginning with all the labelled steps that were going to be presented. This slide was thought to work as an advanced organiser (Ausubel, 1960), thus facilitating the construction of a mental model (see section 4.2.3.1). The beginning of each step was indicated by providing a *Label* (e.g., "Opening a file") presented in the so-called '*cameo performance approach'* (Mayer et al., 2002). This means that everything on the slide is black except of the things which should be in the focus of attention – in this case the *Label*, which was written in white. At the end of each segment the *Label* was repeated (e.g., "This was opening a file") in order to emphasise the end of a segment (see Figure 4). In the *Pacing condition* (*Label*: without; *Pacing*: with) the learners were instructed that at the beginning of each important new step the video would stop until the user clicked on the interactive push button situated at the key point of each step. Thereby, it was expected that participants would briefly consider this step before moving onto the next. Within the *Labelling & Pacing condition (Label*: with; *Pacing*: with) both instructional procedures were realised, whereas in the *video-control group* (*Label*: without; *Pacing*: without) learners had to watch the animated instructionally designed video condition without the instructional design variants *Labels* and *Pacing*.

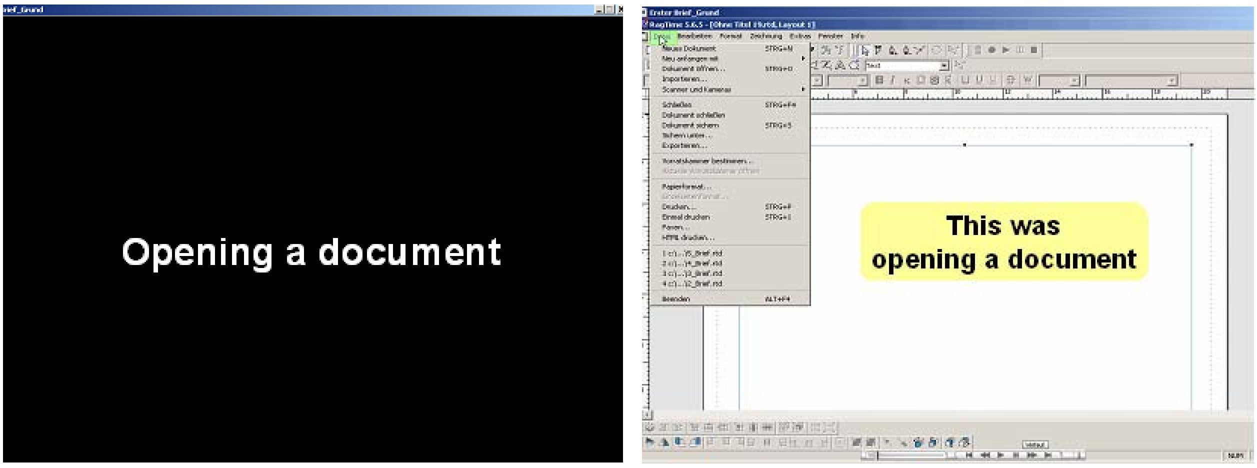

Figure 4. Label condition.

4.4.2.2 Enriched Standard Introduction Condition (Non-Video Control Group)

Special emphasis was placed on creating a high-quality control group in order to generate meaningful comparison with the video conditions; although this comparison was not the primary focus of the experiment. The standard introduction of the desktop publishing program RagTime® consists of short animations that seek to integrate the learner actively into the computer application. Since these animations do not have narration. After working with these animations, learners received two additional ‘learning cards’ (Carroll, 1990a, 1998) that indicated important features to be explored and learnt. These features were the same as in the on-screen video conditions. Thus, a ‘fair’ control group in the sense of equivalent learning contents and goals was created. However, the control group differed from the four video conditions in terms of theoretical background. The control group was designed using results of learning-by-doing and of learning-by-exploration experiments, (for example Dutke, 1994). In the following it is referred to as a learning-by-doing approach. In contrast, the videos were designed according to the learning-by-observation approach. As the comparison of different media typically leads to problems like so-called *”horse-race-research”* (Weidenmann, 2001) (see section 3.1.2), the main focus of this research was not to compare the four video-conditions with the non-video control group, but instead to compare the effect of different learning approaches on the learning outcomes. Thus the 2x2 plus 1 design was created.

4.4.3 Procedure

The learning environment was designed and framed as a software tutorial for experienced computer users in which participants could learn a new computer application over two sessions. First of all, interested participants had to complete an online test on existing computer knowledge. If they were eligible (see section 4.4.1, 4.4.3.1. or section 4.4.4.1 for more information), they would receive an invitation for the first session that included the date, time and their personal identification number (for reasons of anonymity) (see 4.4.3.2). The first session lasted about two hours. The second session took part three days later and lasted one hour (see section 4.4.3.3).

4.4.3.1 Pre-Test

To evaluate existing computer knowledge for the purpose of selecting participants, an extensive net-based test directly accessible from the worldwide web was programmed using the software Globalpark®. This software ensured that all questions were answered completely before responses could be registered and offered the possibility of saving all data in an enclosed database. Therein, a complete dataset was achieved. Working on the pre-test, students not only answered declarative and procedural knowledge questions, but also self-assessed their knowledge (see 4.4.4.1). In the case the set score was reached, they got a confirmation email with details on the timing and location of the test and their identification number. If they did not reach the set score, they got an email explaining a lack of capacity in consideration of their level of knowledge. However, they were offered a self-learn CD including the videos and the program after the study was finished. 95% of the persons in this category accepted the offer.

4.4.3.2 First Session

The experimental conditions were assigned randomly to each day of study so that only people in the same condition would be working at the same time. This was done to avoid experimental artefacts such as motivational problems that can occur when learners see another experimental condition on the screen of the learner sitting next to them. The experiment took place in the computer room at the Department of Psychology, University of Freiburg. After a short introduction participants worked individually on a personal computer (Microsoft Windows XP®) equipped with the application software required. Learners used the computer marked with their identification number. Learners watched seven videos about the computer application RagTime® or worked with the *enriched standard introduction* plus a guided exploration with two learning cards. The videos lasted between 5 and 14 minutes. Additionally, learners in the *Labelling and Pacing conditions* started by watching a very short video of 1min 30s in order to introduce the specifics of their conditions (e.g., how to handle the interactive push button). Once the videos were started, learners had to follow a pre-determined order of lessons. All tests and questionnaires were provided online.

Learners started by watching three videos. The participants in the video conditions had to rate on a 7-point rating scale (1=*absolutely not true*; 7=*absolutely true*) after each video, if the video/ the *Labels*/ the clicking/ the *Labels* and the clicking supported their learning. As the learners were not familiar with the term '*Pacing*, it was referred to it as clicking because that was the action they actually had to perform. After the third video they had to work on the first part of the declarative knowledge questions (open questions and multiple-choice questions). Then video 4 and 5 had to be watched followed by the procedural test task 1 and 2. Time on-task was limited to 9 minutes. In a pilot study, a RagTime® expert was able to solve the task within this time limit. The participants in this study, novices with this particular application, were not supposed to solve the whole task within the time limit. For this study, it was expected that the scores would be distributed normally[2]. Figure 5 shows what a procedural task looked like. It consisted of two instruction sheets. The first sheet gave information related to the task. The second sheet was a print-out and demonstrated

[2] The Kolmogorov-Smirnow Test proved this assumption – the test of bivariate normality was not significant.

how the solved task should ideally look. This was followed by videos 6 and 7, the second part of the declarative knowledge questions, and test tasks 3 and 4. Together the four tasks constituted the immediate post-test. Finally, the motivation and acceptance questionnaire was administered.

Information for Task 2

Please make a **copy** of the following print-out.

Important Clues:

- You have **9 minutes** to work on the task. After 9 minutes you will hear a beep.
- Never change the name of the document or the storage location.
- You don't have to imitate "Task 2"
- You are finished, if your paper looks similar to the original paper.
- If you are finished the task before the beep, save the document, close the application and continue with the course.

Make a Flyer (Las Vegas)

- Font: Times New Roman, 48 pt, sometimes bold
- Colours

Hasenfuß	yellow
Star inside	red
Star outside	green
Around tower	blue

- You can find the picture:
  C:\Computercourse\materials\tower.jpg

When you hear to the **beep**, press  (save) and close the application.

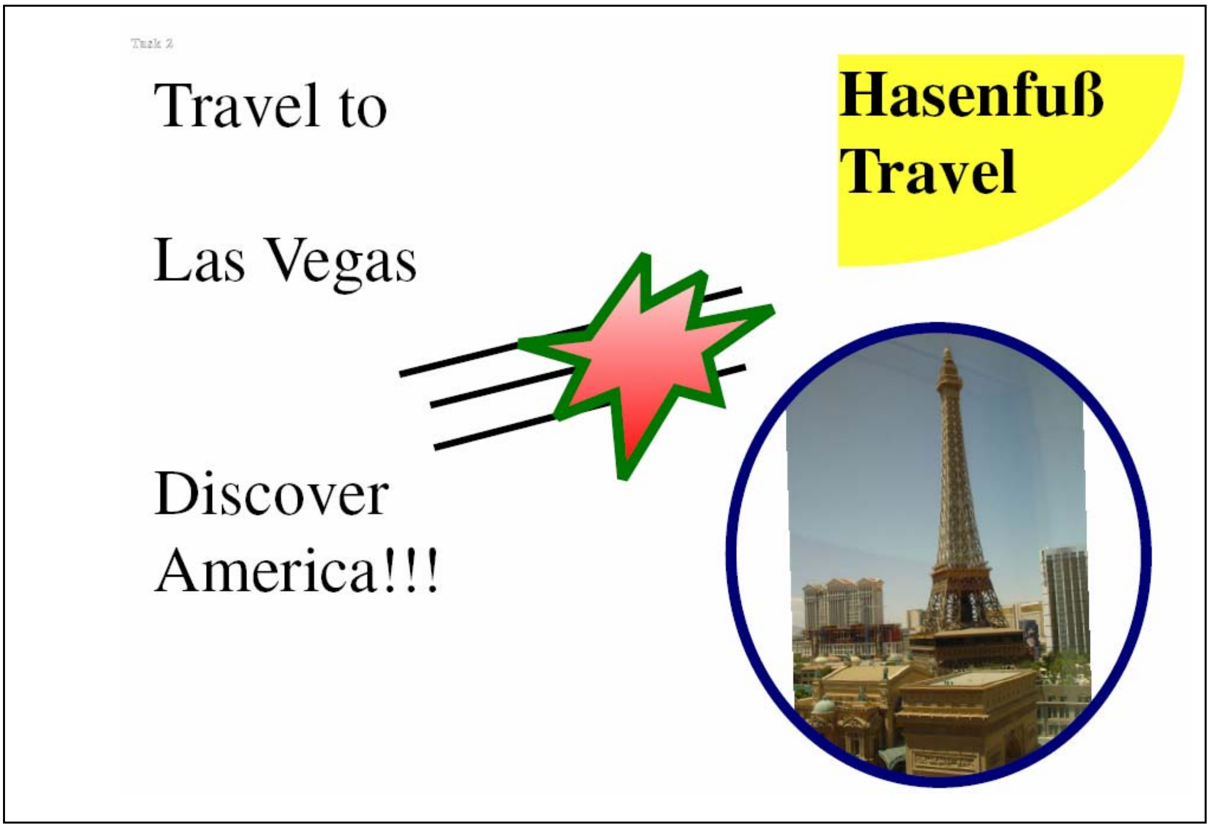

Figure 5. Procedural task consisting of instruction and task.

4.4.3.3 Second Session

In the second session (lasting an hour), three days later, a delayed post-experiment test on declarative and procedural knowledge was administered. With respect to procedural knowledge, an overall score for both testing sessions was used because different test items at each occasion were employed in order to be able to cover an appropriate range of skills (the number of problem-solving items at the first measurement point was very restricted due to the length of the experimental sessions and corresponding effects of fatigue). After this test, all learners saw two additional videos, which summarised the learning contents. This was done for the purpose of pleasing the subjects. Learning during this phase was neither tested nor did it influence any of the outcomes' variables. At the very end an optional feedback questionnaire with open-ended questions was provided. Before leaving, learners received the financial compensation for their participation and the freeware application on CD.

4.4.4 Instruments and Coding of the Knowledge Variables

4.4.4.1 Pre-Test

An existing questionnaire was adapted for the pre-test on computer and Internet knowledge (Richter, Naumann, & Groeben, 2000). This questionnaire has proven to be successful in distinguishing between different knowledge levels in other settings, such as in net-based communication between computer experts and laymen (Nueckles & Ertelt, 2006; Wittwer, 2005). The extensive net-based test consisted of declarative and procedural knowledge questions. An example for a declarative knowledge question is "What is a cache?". Four answer possibilities were given and an "I don't know" option. The same was true for the procedural knowledge question (e.g., "You are on website you want to save. What do you do?").

Additionally, users were asked to self-assess their experience in using computers on several dimensions. Frequency-of-use ratings and direct self-assessments of competence have shown to be valid and reliable predictors of actual computer expertise (Richter et al., 2000). In particular, participants were asked how long they had been using computers and how frequently they use a broad range of software applications and operating systems (4-point rating scale: 3 = *daily*, 2 = *one or two times a week*, 1 = *less than once a week*, 0 = *very rarely*). Among them were widely used applications such as Microsoft PowerPoint®, different Internet browsers and graphic applications. The participants also self-assessed their competence in each of the software applications on a 6-point rating scale (1 = *low competence level*, 6 = *high competence level*). It should be noted that existing knowledge *and* self-assessed competence were used to determine eligibility; many other studies use merely user competence. Existing knowledge was assessed by the knowledge questions described above. User competence was self-assessed as one's potential to utilise the given application to its fullest possible extent so as to maximise performance in the completion of tasks (Marcolin, Compeau, Munro, & Huff, 2000).

4.4.4.2 Declarative Knowledge Test

The post-experiment test measured the acquired declarative knowledge by multiple-choice (i.e., "Where do I find the function 'object coordinates'?" – four answer possibilities plus an "I do not know" option were provided) and open-ended knowledge questions (i.e., "What are the advantages of a circular pipeline?" – three facts could be named). Each response to the open questions was rated and compared with an ideal solution containing a list of all possible answers. Learners received one point for each correct answer given. The ratio of points received in relation to total possible points was calculated. This was done because the number of possible points varied between tasks.

4.4.4.3 Procedural Knowledge Tasks

Procedural knowledge was assessed by working on tasks. It was tested by problems to be solved (learners got a printout of the final solution and the materials required to reproduce it, see Figure 5). For each problem, a rating scheme with all necessary steps to be taken in order to solve the task was created. Therefore, each step could be coded whether it was carried out or not. Additionally, each step was identified as involving near or far transfer in accordance to the scheme that will be introduced in section 5.2.2

4.4.4.4 Motivation and Acceptance

Motivation and acceptance were assessed by a test derived from the instruments of Deci and Ryan (1985) and Rheinberg and Vollmeyer (Rheinberg, Vollmeyer, & Burns, 2001; Rheinberg, Vollmeyer, & Engeser, 2003). Motivation was measured with different scales, such as *interest* (e.g., "I would describe this activity as very interesting"), *challenge*, *effort* (e.g., "I put a lot of effort into this"), perceived competence (e.g., "I think I did pretty well at this activity, compared to other students") and *flow*. As all scales were substantially inter-correlated, an overall score of motivation was determined.

4.5 Results

The results are presented in accordance to the different dependent variables: Declarative knowledge, procedural knowledge, and motivation. Within each section, the analyses are presented in the order of the research questions.

4.5.1 Declarative Knowledge

1. Do instructionally designed on-screen videos lead to more favourable learning outcomes when they are compared to the enriched standard introduction to a computer application and when they are compared to the video-control group?

As mentioned before, declarative knowledge was assessed by open-ended and multiple-choice questions. To test the hypothesis that instructionally designed on-screen videos lead to more favourable immediate and mid-term learning outcomes than does the enriched standard introduction, an *a priori* contrast was calculated that compared the mean of the control group with the video conditions (see Table 4 for the descriptive statistics). The two post-tests were included in an ANOVA model with repeated measurements with the factor time. The video conditions out-performed the enriched standard introduction (main effect), $F(1, 96) = 152.82$, $p < .01$, $\eta^2 = .61$ (very strong effect). This result shows that the video conditions reached higher scores than the *enriched standard introduction (non-video control group)*. The second contrast comparing the *video-control group* (*Label*: without, *Pacing*: without) with the three instructionally designed video groups indicated no significant difference in declarative knowledge between groups (see also Figure 6).

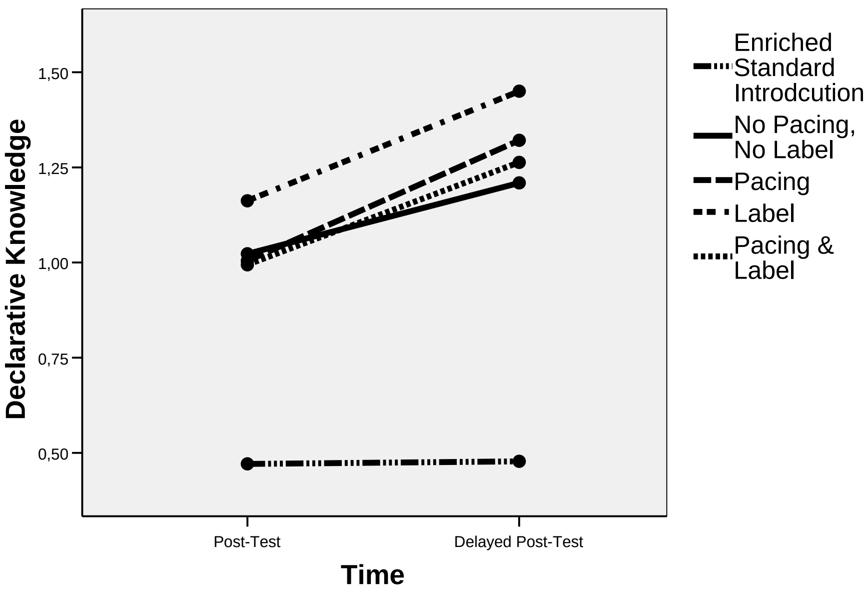

Figure 6. Declarative knowledge (2x2 plus 1 design).

The increase of learning outcomes between the two testing sessions was, however, significant, $F(1, 96) = 50.75$, $p < .01$, $\eta^2 = .35$ (very strong effect). This is a very surprising effect as it meant that the groups performed better at the second point of measurement than at the first. The effects of time had to be qualified by a significant interaction between the different groups and the factor time, $F(4, 96) = 3.48$, $p < .05$, $\eta^2 = .13$ (medium effect), indicating that the increase of knowledge from the immediate post-experiment test to the delayed post-experiment test is due to the video conditions.

Table 4. Means and Standard Deviations (in Parentheses) of Declarative Knowledge

	Experimental condition				
Dependent variable	Control Group	No Pacing, no Label	Pacing	Label	Pacing & Label
Post-test: Declarative	.47 (.28)	1.02 (.22)	1.00 (.22)	1.16 (.15)	.99 (.22)
Delayed post-test: Declarative	.48 (.39)	1.21 (.29)	1.32 (.34)	1.45 (.17)	1.26 (.34)

2. Does *Labelling* and/or learner-controlled *Pacing* in instructionally designed on-screen videos foster learning?

In order to answer the second research question the learning effects of the instructional design variants of the on-screen videos were tested with a 2x2 design (see Figure 7) – without the *enriched standard introduction*, but with the factor time. An ANOVA indicated an increase of learning outcomes across the two testing sessions, $F(1, 77) = 79.62$, $p < .01$, $\eta^2 = .51$ (very strong effect). In other words a very strong effect of improvement from the post-test to the delayed post-test was found. This enhancement of learning was found in all four conditions (no significant interactions with time). Neither the main effect for *Labelling* nor for *Pacing* reached the level of significance. However, the interaction between the two experimental conditions *Label* and *Pacing* was significant, $F(1, 77) = 5.50$, $p < .05$, $\eta^2 = .07$ (medium effect). *Labelling* without learner-controlled *Pacing* was the most favourable learning condition in comparison to the other experimental groups with respect to post-test and delayed post-test performance.

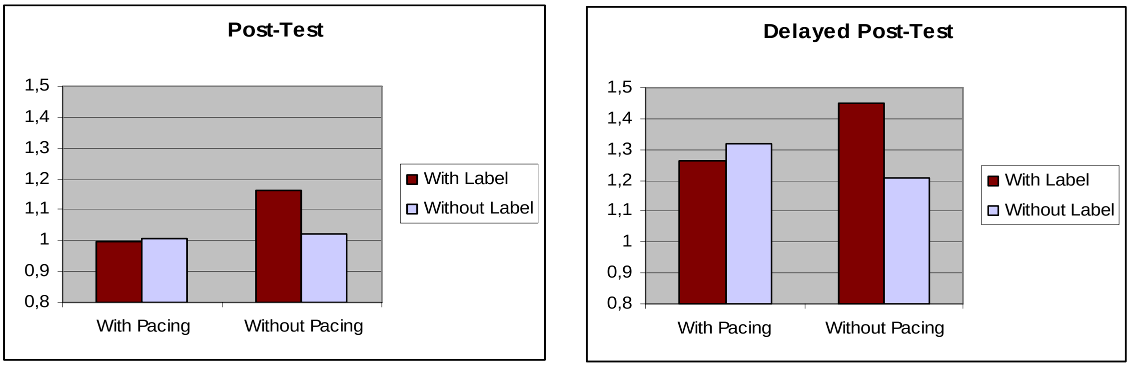

Figure 7. Declarative knowledge (2x2 design) at the post-test and the delayed post-test.

4.5.2 Procedural Knowledge

1. Do instructionally designed on-screen videos lead to more favourable learning outcomes when they are compared to the enriched standard introduction to a computer application and when they are compared to the video-control group?

The planned contrast comparing the control group with the video conditions revealed that learning with videos leads to more favourable procedural learning outcomes than learning with an enriched standard introduction, $F(1, 95) = 13.70$, $p < .01$, $\eta^2 = .13$ (medium effect), see Table 5. For this calculation no distinction was made between the two testing sessions, but it was calculated with an overall score for both sessions as different test items were employed at each occasion in order to be able to cover an appropriate range of skills (see 4.4.3.3). Computer knowledge (assessed by the knowledge questions) was integrated as a covariate in order to control the difference in knowledge between the groups; however, as the covariance analysis revealed, this difference was only of importance in terms of procedural knowledge and not declarative knowledge.

Table 5. Means and Standard Deviations (in Parentheses) of Procedural Knowledge

	Experimental condition				
Dependent variable	Control Group	No Pacing, no Label	Pacing	Label	Pacing & Label
Procedural knowledge	18.03 (5.15)	23.68 (6.11)	28.37 (5.66)	27.79 (5.70)	27.35 (7.96)
Procedural knowledge (Near transfer)	11.55 (2.99)	15.58 (3.46)	18.51 (3.04)	18.02 (3.27)	17.59 (4.14)
Procedural knowledge (Far transfer)	6.48 (2.66)	8.10 (3.03)	9.86 (3.48)	9.77 (3.33)	9.76 (4.25)

Additionally, the significant difference found, F (1, 95) = 4.32, $p < .05$, $\eta^2 = .04$ (small effect) in the second contrast comparing the video-control group (*Label*: without, *Pacing*: without) with the remaining three instructionally designed video conditions, is in line with the hypothesis that the effect of the video medium can be significantly enhanced by introducing instructional design features, such as *Labels* or *Pacing*. It can be concluded that adding instructional design features such as *Labelling* or *Pacing* can additionally improve the achievements in procedural knowledge.

To answer this question if there are any differences in near and far, the described two contrasts within near transfer procedural knowledge and within far transfer procedural knowledge were calculated. A significant difference in *near transfer* was found between the *enriched standard introduction* and the *video conditions*, F(1, 95) = 25.20, $p < .05$, $\eta^2 = .21$ (large effect), and between the *video-control group* and the three experimental video conditions, F(1, 95) = 5.33, $p < .05$, $\eta^2 = .05$ (small effect). No differences were found regarding *far transfer*.

2. Does *Labelling* and/ or learner-controlled *Pacing* in instructionally designed on-screen videos foster learning?

Regarding the effects of the video design features, a significant main effect for *Pacing* was found at the first measuring point, F(1, 76) = 4.44, $p < .05$, $\eta^2 = .06$ (medium effect). This means that *Pacing* yielded the best learning outcomes in procedural knowledge acquisition at the immediate post-test. This test also saw a significant main effect for *Pacing* in the case of *near transfer* $F(1, 76) = 6.38$, $p < .05$, $\eta^2 = .08$ (medium effect). No differences were found for *far transfer* at this point. At the delayed post-test, no differences between the instructional design variants were found either for procedural knowledge in general or for near and far transfer.

4.5.3 Motivation and Acceptance

Previous findings that videos are highly accepted by learners as motivating in comparison to other learning mediums could not be replicated (see Table 6). An overall score of motivation was determined by measuring the composite of various and highly inter-correlated scales, such as interest, challenge, flow, effort and perceived competence. The number of questions measuring each scale (e.g., interest or challenge) differed. A question could be rated between 1 (not true at all) and 7 (absolutely true). Therefore, the final score took into account the number of rated points in ratio to the number of possible rating points. Consequentially, a maximum of one point per scale could be reached. For motivation, a maximum of five points could be achieved if every item was rated with 7. For acceptance the maximum was two points. An *a priori* contrast compared the enriched standard introduction with the four video conditions and found no difference in motivation (ANOVA; $F < 1$). The same was true with respect to acceptance (ANOVA; $F < 1$). Subjects in all groups experienced roughly the same degree of motivation and acceptance of learning conditions. Furthermore, no differences were found by gender.

Table 6. Means and Standard Deviations (in Parentheses) of Motivation and Acceptance

	Experimental condition				
Dependent variable	Control Group	No Pacing, no Label	Pacing	Label	Pacing & Label
Motivation	2.88 (.70)	2.94 (.47)	3.08 (.46)	2.98 (.49)	2.94 (.47)
Acceptance	1.27 (.31)	1.27 (.25)	1.33 (.21)	1.31 (.26)	1.28 (.30)
Motivation (Interest)	.63 (.19)	.62 (.13)	.63 (.13)	.62 (.18)	.57 (.14)
Motivation (Challenge)	.59 (.16)	.58 (.15)	.62 (.13)	.58 (.13)	.60 (.15)

Motivation (Flow)	.56 (.18)	.53 (.13)	.59 (.16)	.55 (.16)	.56 (.10)
Motivation (Effort)	.76 (.16)	.79 (.10)	.84 (.11)	.79 (.13)	.79 (.11)
Motivation (Perceived Competence)	.34 (.19)	.42 (.15)	.40 (.15)	.43 (.11)	.42 (.19)

Motivation correlated significantly with procedural knowledge (r = .219, p < .05). Acceptance did not correlate significantly with any performance value. The question then arose: Are there different types of learners? In other words, how did motivated learners perform in comparison to those less motivated? Did learners in of the successful group(s) belong to the experimental groups?

4.5.4 Cluster Analysis for Different Learning Types

A cluster analysis was performed to investigate the possibility of different types of learners. More specifically, learners were grouped according to similarities in the performance variables and motivation and acceptance values. In order to give all performance variables the same weight, both declarative and procedural knowledge variables were calculated at the post-test and at the delayed post-test. Z-standardised variables were used to prevent the influence of certain variables over others due to larger variances. The Ward procedure with squared Euclidian distances was employed. The dendrogram favoured a four cluster solution, as other solutions with less clusters would have dramatically increased the intra-cluster variance. The identified clusters were relatively unequal in size (Cluster 1: N = 49, Cluster 2: N = 13, Cluster 3: N = 17, Cluster 4: N = 22). A chi-square test showed a significant difference in distribution ($\chi^2(12, N = 101) = 75.42, p < .01$). For an overview see Table 7.

Table 7. Cross Table: Person per Cluster in Dependence of the Group

		C1	C2	C3	C4	Total
	Enriched Standard Introduction	7	13	0	0	20
	No pacing, no label	13	0	4	3	20
	Pacing	11	0	5	4	20
	Label	7	0	4	9	20
	Pacing, label	11	0	4	6	21
Total		49	13	17	22	101

Cluster 1 is the largest group and can be described as not very motivated and achieving rather limited success (see also Figure 8). Learners from all conditions can be found in this cluster. Cluster 2 is the worst performing cluster with very poor scores in both procedural performance values and the declarative knowledge tests; nonetheless they scored second in motivation levels. All persons in this cluster descended from the control group (enriched standard introduction). Learners in Cluster 3 performed very well in the procedural tests but achieved “only” good values in those testing declarative knowledge. They also had the highest motivation and acceptance scores. Finally, everyone in Cluster 3 learnt with videos. Cluster 4 was the most successful from both a procedural learning perspective as well as from a declarative point of view. The majority of learners in this cluster belong to the three instructionally designed video conditions. Interestingly, learners seemed not to be very motivated while learning and did not readily accept the learning environment.

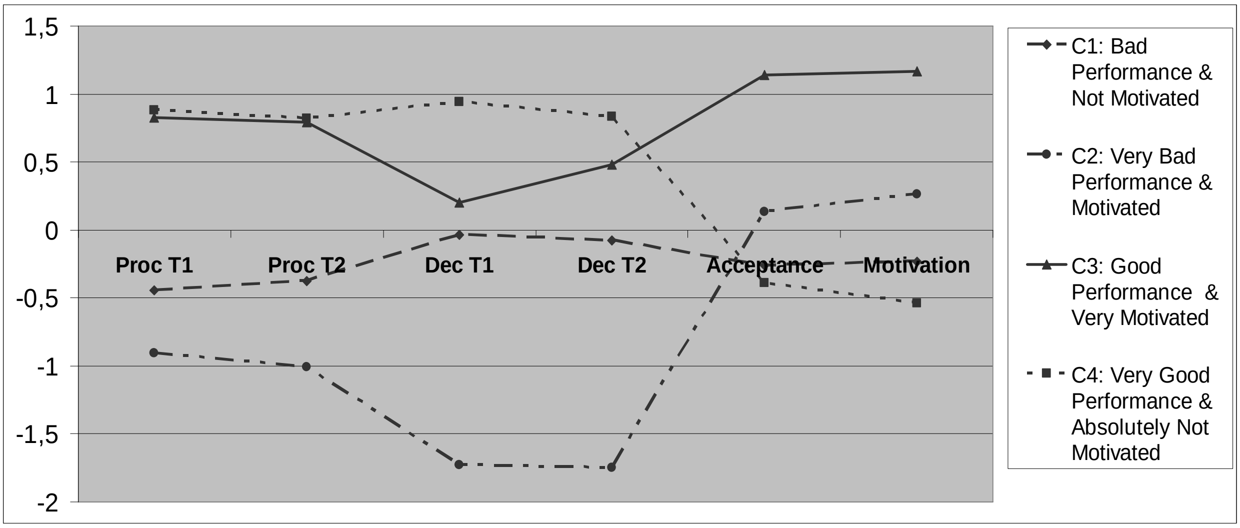

Figure 8. Cluster analysis.

In concrete terms, there were motivated learners who performed both well and poorly and unmotivated learners who did the same. Interestingly, high motivation does not necessarily mean good learning results as is indicated in several studies. The most interesting result, however, is that the best performing learners were the least motivated.

4.5.5 Rating of the Design Variants Labelling and Pacing

After each video, learners had to assess on a 7-point rating scale (1=*absolutely not true*; 7=*absolutely true*), if the video/ the *Labels*/ the clicking/ the *Labels* and the clicking supported their learning. In Table 8 the means of all 4 video conditions according to the single videos are diagrammed. All learners assessed their learning conditions as helpful for the learning process with 5 out of 7 possible points on average. In the 'with *Label* and with *Pacing* condition' both design variants were rated separately. In the first learning session, ratings for the *Pacing* condition declined gradually (from $M_{Video1} = 5.50$ to $M_{Video7} = 3.85$ with $M_{All\_Videos} = 4.72$; $F(1, 19) = 15.93$, $p < .05$). In combination with *Labels*, *Pacing* was generally rated a bit higher ($M_{Pacing\ in\ the\ with\ Label,\ with\ Pacing\ condition\ all\ videos} = 5.27$). However, there was no significant difference between the rating of *Pacing* and *Pacing* in the 'with *Label*, with *Pacing* condition'. If *Pacing* is rated in the 'with *Label*, with *Pacing* condition' the rating also declines gradually ($M_{Video1;Pacing\ in\ the\ with\ Label,\ with\ Pacing\ condition} = 5.42$ to $M_{Video7\ Pacing\ in\ the\ with\ Label,\ with\ Pacing\ condition} = 4.63$; ($F(1, 18) = 5.94$, $p < .05$). However, the reverse pattern was found in terms of *Labels*: *Labels* were perceived more positively when presented without *Pacing* ($M_{Label} = 4.89$), whereas in the combination condition the average rating score was $M_{Label\ in\ the\ with\ Label,\ with\ Pacing\ condition} = 4.23$. No significant difference was found between these two ratings. When *Labels* were presented without *Pacing* a significant time effect was found: They were rated less positively over the course of the first experiment, $F(1, 19) = 8.02$, $p < .05$.

In the second session subjects saw two videos at the very end of the experiment that summarised the learning contents and showed further application possibilities. For this purpose, the videos were presented without *Labels* or *Pacing*. These videos were evaluated very positively with a mean of about 5.5 points.

Table 8. Means and Standard Deviations (in Parentheses) of the Video's Ratings

		Video Number									
		Session 1 **1**	Session 1 **2**	Session 1 **3**	Session 1 **4**	Session 1 **5**	Session 1 **6**	Session 1 **7**	**Average**	Session 2 **1**	Session 2 **2**
No Label, no Pacing		5.15 (1.31)	5.70 (0.80)	4.85 (1.14)	4.95 (1.00)	5.20 (1.06)	4.35 (1.27)	4.55 (1.36)	**4.96** **(0.88)**	5.53 (1.19)	5.48 (1.17)
Pacing (Clicking)		5.50 (1.36)	5.05 (1.47)	4.80 (1.36)	4.85 (1.63)	4.95 (1.76)	4.10 (1.52)	3.85 (1.66)	**4.72** **(1.29)**		
Label		5.30 (1.42)	5.40 (1.64)	4.95 (1.54)	5.00 (1.26)	4.85 (1.42)	4.30 (1.49)	4.40 (1.43)	**4.89** **(1.17)**		
Label & Pacing	Label	4.37 (1.71)	4.37 (1.71)	4.42 (1.64)	4.16 (1.86)	4.11 (1.88)	4.26 (1.88)	3.95 (1.81)	**4.23** **(1.71)**		
	Pacing	5.42 (1.54)	5.47 (1.47)	5.63 (1.42)	5.26 (1.63)	5.21 (1.51)	5.26 (1.37)	4.63 (1.50)	**5.27** **(1.29)**		

In other words, as can be seen in Figure 9, a decline in the ratings over time can be observed in all conditions. *Pacing* in the with *Label*, with *Pacing* condition was rated the highest, whereas *Label* in the with *Label*, with *Pacing* condition received the lowest ratings.

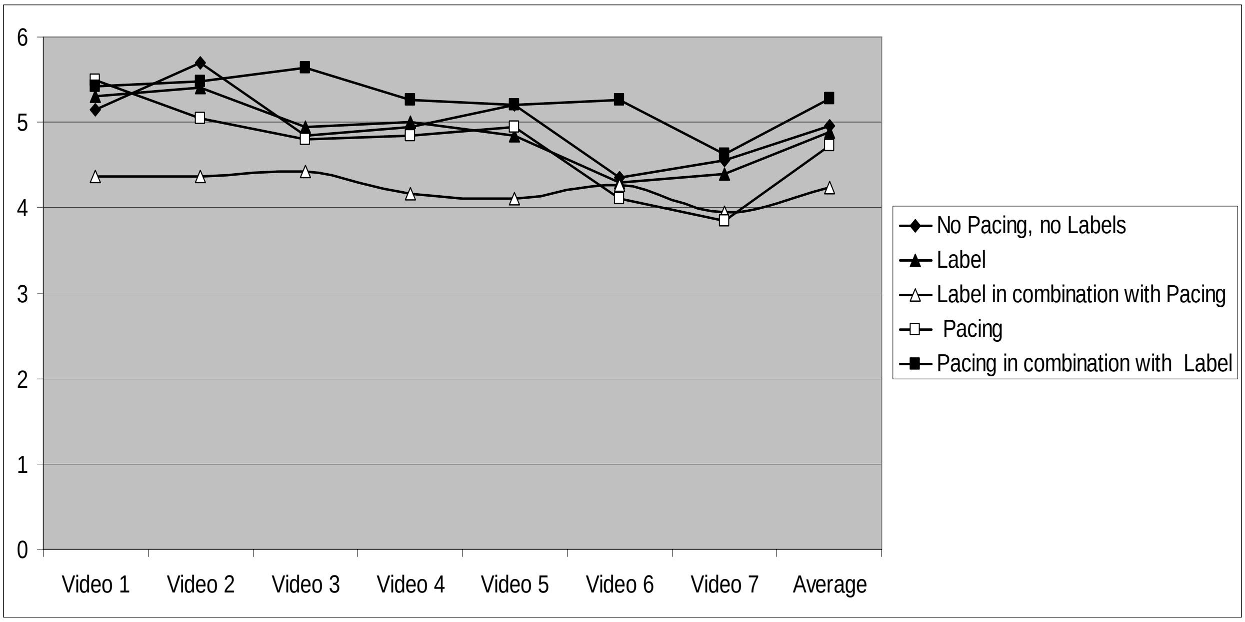

Figure 9. Video ratings.

4.5.6 Open Feedback Questionnaire

At the end of the second session, learners were provided with an optional feedback questionnaire containing three open-ended questions: (1) What didn't you like about your learning method?; (2) What did you like about your learning method?; (3) What would you improve? This questionnaire was administered in order to get a better idea of how the learners actually perceived the learning environment. These questions, numbers 1 and 3 in particular, were thought to be interesting as the learner's opinion on a learning environment in a non-experimental setting, where it is learnt individually and voluntarily, normally defines if learning takes place at all.

Although the questionnaire was optional, 95% of the learners filled it out. They did so in a reasonable amount of time (M = 7.53; SD = 3.63). The following presents the percentage of learners who mentioned certain topics. It has to be noted that these percentages have to be seen in relation to the assessment method, namely open-ended questions. In other words, the topics presented here represent the spontaneous ideas of the learners. 33.3% said they did not like this way of learning via "watching" very much and that there was no opportunity to practice. 44.8% lamented the volume of information given at one time. That said, 34.4% found that the content was presented in very plausible terms and 27.1% liked the structure of the tutorial. More than half (53.1%) reckoned that on-screen videos were an adequate tool for learning a new computer application. Suggested improvements include the incorporation of more learning-by-observation and learning-by-doing (24.0%) and enhanced interactive features, rather than simple clicking (26.0%). 10% to 20% of the learners pointed out the following topics as both positive and negative: *Pacing* (liked/ not liked) and the speed of the video (just right/ too slow or too fast or too long). However, the same amount of people disliked the given time restrictions, and commended at the same time the step-by-step-instruction and given explanations. Very few learners (less than 10 %) mentioned their support or distaste for the *Labels*/ the voice of the speaker/ the number of repetitions (too few or too many).

4.6 Discussion

The first goal of this study was to test the usefulness of on-screen videos as a learning medium. Secondly, it sought to analyse the effects of certain instructional design features for on-screen videos with respect to knowledge acquisition, maintenance of knowledge and transfer. Therefore, the videos were created according to findings from social learning theory (Bandura, 1977b), the instructional model of example-based learning (Renkl, 2005; Renkl & Atkinson, in press) and multi-media theory (Mayer, 2005). The research questions can be answered as follows: Instructionally designed on-screen videos are indeed a very effective learning medium in comparison to an enriched standard introduction of a computer application. This applies for the acquisition of declarative knowledge as well as procedural knowledge. In both cases, substantial effects were found. This finding is not trivial as previous findings showed that learners are often unable to extract the essential information from a dynamic visualisation (Rieber, 1989). Furthermore, the first phase of research in previous studies often failed to show any advantages of dynamic visualisations over static visualisations (Schwartz & Hartman, in press; Tversky et al., 2002).

4.6.1 The Effectiveness of the Instructional Design Variants

With respect to the question about the effects of the instructional design features, it was found that *Labelling* without *Pacing* is particularly advantageous in fostering declarative knowledge, not only in an immediate test but also in the medium-term. Presumably, the sub-goal oriented learning (Catrambone, 1996) brought structure into the presentation that supported the acquisition of declarative knowledge. However, without practice there was not enough time for declarative knowledge to transform into corresponding procedural knowledge (e.g., Anderson, 1995b).

With respect to *Pacing* in the form of an interactive push button, a significant positive effect was found in the immediate post-test on problem solving performance but not on declarative knowledge. A potential explanation for this is that learner *Pacing* involves the learner in a "procedural" way. If the learner does not pay attention and click at the right time, video progress is halted. The chance that the learner is unfocused and misses an important step while watching is thereby reduced.

4.6.2 Further Findings

4.6.2.1 Does Declarative Knowledge Increase over Time?

A rather astonishing finding here is the increase of knowledge over time in the video conditions as research shows that learning by video is ineffective in the medium and long-term or that little has been acquired at all (Atlas et al., 1997). The results at the immediate post-test could partially be explained by the demanding experimental setting: Subjects had to watch videos for over one hour and then, without any practice, apply their knowledge in the tests and tasks. Learners reported in the feedback questionnaire that they felt slightly overwhelmed with this arrangement. Even though performance might not have been optimal due to fatigue in the immediate test, it is noteworthy that the learning outcomes were maintained in the medium-term and did not vanish as reported in other studies. These results support the assumption that well-designed videos can significantly influence the quality of learning – even in the medium-term. The effect of poor initial performance but better delayed performance values was also found in several other studies where the contents to-be-learnt were rather difficult (Catrambone, 1989; Charney & Reder, 1986).

A rather speculative explanation for the improvement at the second point of measurement might be the so-called *Zeigarnik effect* which states that learner remembers uncompleted or interrupted tasks better than completed ones (Zeigarnik, 1967). As learners in this study could not finish their task within the given 9 minutes, the delayed post-test may have provided them the chance to examine more closely those steps of the task they were unable to get to the first time around. However, the effect of ‘the longer the time interval between learning and testing the better the retention’ is not an uncommon one and was found in the context of research on over-learning (Driskell, Willis, & Copper, 1992).

Another speculative explanation might be a sleep-related gain of insight. Insight is defined as mental restructuring leading to a sudden gain of explicit knowledge that results in qualitatively changed behaviour. Sleep, in this case, consolidates recent memories by reactivating autoassociative hippocampal networks during rest. This mechanism is assumed to be responsible for the temporary storage of recently encoded material. During sleep this area feeds the information back into the neocortex, where the information is incorporated into prior knowledge. This process is crucial for fostering memory representations and traces and, hence, for restructuring knowledge that can foster insight gain (Wagner, Gais, Haider, Verlegrer, & Born, 2004). As there were several days between testing points, this might be a logical explanation for the sudden surge in declarative knowledge at the second measuring point. This is in line with the finding that delayed performance tests might be also an indicator for knowledge integration (Linn & Eylon, in press); a measure rarely taken. Nevertheless, the goal of most learning scenarios is to create long-term knowledge. Unfortunately, progress during learning has proven to be a poor indicator of long-term retention (Bjork, 1994). Research on training and tutoring (Aleven & Koedinger, 2002) indicates that skills are more successfully developed and can be maintained when they have been mentally integrated in a coherent understanding of the learning domain. These findings demonstrate the importance of integrating information in order to recall it (Linn & Eylon, 2000). The need for integration is even more important in scientific domains, where students might be overloaded by details that they have not organised around principles (Larkin, McDermott, Simon, & Simon, 1980).

4.6.2.2 No Effect on Far Transfer?

An unexpected finding was that no effect on far transfer was found. According to the behaviour modelling theory (Bandura, 1977b), which claims that modelling influences four processes: 1) attention, 2) retention, 3) production and 4) motivation, it is clear that the third process, in particular, was not realised in this study. This means that without an opportunity to practice, the symbolic representations were never actually reconverted into actions in a non-testing situation. As the production process plays a crucial role in transfer (Manz & Sims Jr., 1981), it can be concluded that fostering far transfer requires the integration of practice in training. Interestingly, learners suggested the inclusion of a practice component in future learning environments (see section 4.5.6).

4.6.2.3 No Effect on Motivation?

The expectation that videos should lead to more favourable levels of motivation and acceptance could not be shown. Although motivation and acceptance values are all located in the upper part of the scales – a finding which resembles the experience that following the learning science principles (e.g., authenticity, inquiry, collaboration, and technology) makes it more likely that learners experience the learning environment as motivating (Blumenfeld, Kempler, & Karjcik, 2006). However, this finding suggests that the experimental conditions have been regarded as equally fair with respect to their motivational potential. Another possible explanation might be that the length of the experiment had an influence by diminishing possible differences in motivation.

A further interesting approach that shed light on motivational processes and their relation to performance measures was the cluster analysis conducted. The results showed that the best performing learners were also the least motivated. This resembles the results of Salomon (1984) who pointed out that very motivated learners often lack engagement in learning activities. However, there is no correlation between motivation and knowledge; this is interesting as one could have assumed that the more knowledge one possesses, the more motivated he/she would be.

4.6.3 Conclusion and Future Research

To summarise, instructionally designed videos are a powerful learning tool in general and in comparison to the exploratory learning-by-doing approach. Rather than declaring a fixed list of design features, it is more useful to select the particular design features that best assist the attainment of particular learning goals. More specifically, if declarative knowledge acquisition is the primary goal, only *Labels* should be used. On the other hand, if the objective is to enhance procedural knowledge, interactive click-buttons at the key point of each step help reach this goal and integrate users. Furthermore, it can be stated that with both kinds of prompting, learners are able to extract the relevant message out of a dynamic visual and learn-by-observation in a quick and effective manner. In order to enhance far transfer, *Practice* needs to be integrated.

Last but not least, future research should also explore the possibility of generalising findings on design to other learning settings, learning materials or presentation modes. While the presented design concept might easily apply to slightly different presentation modes, such as animations, using it for other learning materials is also imaginable; especially, when the material to-be-learnt consists of declarative and procedural knowledge. Despite the fact that the design concept was successful here, it would likely be even more effective if applied in learning settings where on-screen videos are used in combination with other methods like guided exploration or *Practice* (Kehoe et al., 2001). Future research is needed to investigate this combination approach. To this end, the second study will be done in order to exploit the full potential of dynamic visualisations.

5 Experiment 2: Fostering Transfer With Instructionally Designed On-Screen Videos and Integrated Practice

5.1 Starting Point for Experiment 2

In Experiment 1 the success of observational learning with worked-out examples in form of on-screen videos was shown in comparison to a learning-by-doing approach. What is more, the on-screen videos allowed the presentation of quantitatively and qualitatively demanding material. There is evidence accumulating for a neurological basis for observational learning. For example, so-called “mirror neurons” are activated regardless of whether a subject sees an action being performed or if they perform the action themselves (e.g., Meltzoff & Prinz, 2002 in Bransford et al., 2006). Besides the neurological basis and preparedness for observation, imitating an observed behaviour involves perspective-taking and transforming the observed action into behaviour. Furthermore, the observed behaviour has to be remembered – this is facilitated when examples are used in the learning situation (Renkl, 2005) as they promote the retrieval of learnt solutions (Ross, 1984, 1989a, 1989b; Ross & Kennedy, 1990).

Nonetheless, learning with videos seems to have its limitations, too. The results of Experiment 1 revealed no effect on far transfer. However, the critical question is if stimulating transfer is possible solely by observation or if other learning principles, such as *Practice*, also hold promise in this regard (see section 3.3.2) and should be integrated into the learning environment in order to reach the set goals.

To answer these questions, examinations of the crucial aspects of transfer and *Practice* are made below.

5.2 The Transfer Concept

5.2.1 What is Transfer?

Can we use the skills we learnt at school in real life? Can we apply the new computer skills we learnt with videos when we have to solve tasks on our own in a new context? These two questions have the same thing in common: They deal with transfer. This concept, along with the idea that *Practice* has a general effect on learning, lay at the heart of psychological research at the beginning of the 20th century. The most prominent idea of this early research was that so-called "formal discipline", learning Latin for example, would enhance general learning and attention skills (e.g. Binet, 1908, cited in Gould, 1981, p. 154). Thorndike and his colleagues were among the first to challenge and to test the doctrine of formal discipline using transfer tests (Thorndike & Woodworth, 1901). Thorndike formulated the "Theory of Identical Elements". The underlying idea was that previous learning facilitates new learning to the extent the new learning tasks contain elements identical to those in the previous task (Thorndike, 1913). Besides the differentiation between general versus specific transfer, popular topics of early research include lateral versus vertical transfer and meaningful versus rote learning (for an overview see Singley & Anderson, 1989).

100 years of research later, there is still consensus about the importance of transfer. However, a meta-analysis is yet lacking due to the simple facts that the plethora of studies on transfer do not share a common structure and that confusion concerning the definition of transfer persists (Barnett & Ceci, 2002). Transfer is often defined in very general terms, for example, as the "ability to extend what has been learnt in one context to a new context" (Bransford, Brown, & Cocking, 1999, p. 39) or as whether and how students access and apply their learning in novel contexts (Pugh & Bergin, 2006). A distinction is commonly made between near and far transfer: *Near transfer* is transfer to a similar context, whereas *far transfer* is transfer to a dissimilar context and involves a generalization of skills (Barnett & Ceci, 2002; Royer, 1979). Generally, two different views of transfer can be distinguished (Bransford & Schwartz, 1999): Either transfer refers to how learning skill A influences the learning of skill B; or, and more recently, transfer is defined as the transfer of knowledge from one situation to another by a process of mapping (Gick & Holyoak, 1980, 1983). Transfer via analogy also plays an important role when learning with worked-out examples. By comparing examples a learner notices similarities and differences. Similar examples induce schema construction because learners are taught to directly abstract from surface features. Dissimilar examples should invoke distinction between problem types in order to avoid being misled by surface features (Renkl, 2005).

5.2.2 Transfer Taxonomies

The transfer taxonomy of Barnett and Ceci (2002) was used as a basis for characterisations of transfer. It differentiates between *what* is transferred (content) and *when* and *where* the transfer occurs (context) (see Table 9 for an overview).

The content factor can be divided into three dimensions: (1) the specificity – generality of the learned skill; (2) the nature of the performance change assessed; and (3) the memory demands of the transfer task. They are not universally applicable: Not all of them can be used for all situations. In Experiment 2, to characterise the learning content this means the following: procedures' was the skill to-be-learned and accurately recalled, recognised and executed.

Table 9. Transfer Taxonomy (Barnett & Ceci, 2002)

CONTENT: WHAT IS TRANSFERRED			
Learnt skill	procedure	representation	principle or heuristic
Performance change	speed	accuracy	approach
Memory demands	execute only	recognise and execute	recall, recognise and execute

CONTEXT: WHEN AND WHERE TRANSFERRED FROM AND TO					
	Near Transfer ←→ Far Transfer				
Knowledge Domain	mouse vs. rat	biology vs. botany	biology vs. economics	science vs. history	science vs. art
Physical Context	same room at school	different room at school	school vs. research lab	school vs. home	school vs. the beach
Temporal Context	same session	next day	weeks later	months later	years later
Functional Context	both clearly academic	both academic but non-evaluative	academic vs. filling in tax forms	academic vs. informal questionnaire	academic vs. at a play
Social Context	both individual	individual vs. pair	individual vs. small group	individual vs. large group	individual vs. society

Modality	both written, same format	both written, multiple choice vs. essay	book learning vs. oral exam	lecture vs. wine tasting	lecture vs. wood carving

The context, which resembles the second category of this taxonomy, gives information about when and where something is transferred from and to, and differentiates between near and far transfer on a general continuum. Taken into account are the knowledge domain, physical context, temporal context, functional context, social context and modality (Barnett & Ceci, 2002). Applied to this experiment, learning a new computer application was the chosen *knowledge domain*, the *physical context* was the computer room, and there was one week between the two sessions (*temporal context*). The *functional context* was framed as a learning situation and learners worked individually on the program. It made use of on-screen videos and practices in form of guided exploration cards, both of which used the to-be-learnt computer application. The test situation consisted of online-questionnaires and tasks in which the same computer application was used (*modality*).

Furthermore, and in addition to this taxonomy, the definition of transfer was enlarged: Learners had to decide which procedure was appropriate to solve the tasks at hand. This was implemented because “telling subjects to use a principle is not transfer. It is following instructions” (Detterman, 1993, p.10). In the terms of ACT-R (Anderson, 1983; Anderson & Schunn, 2000), the kind of transfer to be reached in this study can be described best by *procedural-to-procedural transfer*. However, it does not embody the full extent of this definition because procedural-to-procedural transfer occurs when productions acquired in the training phase apply directly to the transfer situation. Transfer, according to this definition, is automatic as long as the acquired production rules are also applicable to the transfer task (Wiedenbeck, Zila, & McConnell, 1995). In the context of this study, the learner has to make inferences. In concrete terms, a procedure belonging to content A was learnt. In the transfer task the procedure had to be applied in a similar context with the same structure but a different cover story (near transfer), or applied to a dissimilar context with a different structure (far transfer) or a new procedure had to be inferred for another unknown feature of the content area A (far transfer). The conceptualisation of transfer for this experiment is visualised in Table 10.

Table 10. Understanding of Near and Far Transfer.

	Content/ task in the learning situation	**Content/ task in the transfer situation**	**Procedure in the learning situation**	**Procedure in the transfer situation**	**Explanation**
Near transfer	AA	AA	P	P	Content AA is learnt using procedure P. In the transfer situation the content AA remains the same (different cover story) using the learnt procedure P
	Same Structure		**Same Procedure**		
Far transfer	AA	**AA***	P	P	Content AA is learnt using procedure P. In the transfer situation the content AA* is different (different structure),using the learnt procedure P
	Different Structure		**Same Procedure**		
	AA	**AB**	P	**P***	Content AA is learnt using procedure P. In the transfer situation the content AB* is unknown, but in the same content area. Procedure P* was not learnt but has to be inferred
	Unknown Structure		**Procedure-to-be-interfered**		

5.2.3 Preconditions for Transfer

The framework of the ACT-R theory is used to explain missing transfer (see section 3.3.2). Skill acquisition is explained using three stages: (1) *the cognitive stage* in which a declarative description of the procedure is learnt; (2) *the associative stage*, in which the facts are compiled and integrated with the method to perform the stage; and (3) *the autonomous stage*, in which the learnt skill becomes more fluent and automatic. Typically, most training material neglects the autonomous phase, in which component skills become compiled and more automatic through *Practice*; thereby resulting in the development of attention capacity to be devoted to more complex aspects of a task. Several studies confirm the finding that this last stage is the crucial one for competent performance (Shiffrin & Schneider, 1977). Furthermore, to ensure competent performance, the last phase has to be focused (May & Kahnweiler, 2000). Anderson (1995b) proposes elaborate processing to satisfy this purpose. The strength of encoding knowledge in memory is seen as the critical factor for the accessibility of declarative knowledge and for the performance of procedural knowledge. Memory, however, is improved by processing more elaborate learning material (Anderson, 1995b). This depends on the amount and type of *Practice*. Elaborate processing incorporates repetition (*Practice)* with augmentation of the items that have to be remembered. This includes: (a) connections to prior knowledge: (b) incorporating contextual factors; and (c) imaging and inferring from the material. Evidently, this is a successful approach as interconnections between the to-be-learnt material increase, information is organised (which is beneficial for retrieval), and there is a greater number of overlapping elements between the learning and the transfer situation (Anderson, 1995a). A similar conception is pursued by Salomon and Perkins (1989), which contends that active learning and deep level processing are advantageous for “high-road transfer” (Salomon & Perkins, 1989). High road transfer is defined as “an explicit conscious formulation of abstraction in one situation that allows making a connection to another” (p.118). Furthermore, awareness of meta-cognition and any related processes have to be created so that successful transfer is possible (Mayer & Wittrock, 1996).

It can be summed up that transfer becomes more likely if there is *Practice* available and if the learning takes place actively. Both of these measures stimulate deep processing. Decker and Nathan (1985) add *Labelling* as a method of enhancing transfer because it helps the learner identify important features. It is further used as a technique in behaviour modelling where important features of a task are repeatedly labelled. *Labels* also influence transfer in a positive way when they are presented with illustrations. It is claimed that they play two roles: (1) guiding students’ attention; and (2) helping them build internal connections (Mayer, 1989). The use of labels stimulates transfer as the learner understands the general principles needed to solve a task (Decker & Nathan, 1985). This can also be referred to as discrimination: Retrieval depends largely on whether the to-be-recalled information was labelled as relevant or not (Sternberg & Frensch, 1993).

5.2.4 Transfer and Worked-out Examples

Labelling and putting emphasis on (1) generalisation and (2) *Practice* are important design features to facilitate transfer in the context of learning with (animated) worked-out examples. Starting with *Labelling*, there is evidence that learners sometimes process worked-out examples in a suboptimal way, for example, they show a tendency to form representations of a solution procedure that consist of a linear series of steps rather than a more structured hierarchy (Catrambone & Holyoak, 1990; Reimann & Schult, 1996). In other words, transfer problems often stem from the fact that learners try to memorise rather than deeply process the steps. Deep processing of worked-out examples can be stimulated by various methods. For example, by self-explanations (Renkl & Atkinson, 2002) or by the sub-goal learning method (Catrambone, 1996). If the overall solution consists of several sub-goals, it is easier for the learner to apply the learnt procedure in a more flexible way. The sub-goals indicate to learners which pieces of their prior knowledge might be relevant for achieving the goal of a particular step. It is especially advantageous if the sub-goal is labelled. It has been proposed that *Labels* facilitate transfer because learners show the tendency to group sub-goals in a set of steps and explain to themselves why these steps belong together (Catrambone, 1996). This allows learners to discriminate if the learnt step is relevant or not. This is valuable since novices often have problems deciding which solution steps are important (Catrambone & Holyoak, 1990; Reimann & Schult, 1996). Evidence is accumulating that sub-goals and learning with worked-out examples indeed foster transfer on new problems (Atkinson & Catrambone, 2000; Atkinson, Catrambone, & Merrill, 2003; Catrambone & Holyoak, 1989).

5.3 The Practice Concept

Numerous studies already have shown that incorporating *Practice* is a central strategy in realizing transfer (see section 3.3.2). Indeed, motor skills can be learnt solely by observing a model practising; however, incorporating a practical element improves achievements and maintenance significantly (Blandin et al., 1999). Similar results were found in another series of studies showing the importance of hands-on *Practice* in procedural learning. With *Practice* less time was needed in the performance test and performance itself was enhanced (Swezey, Perez, & Allen, 1988). To quote the well-known adage and to put it in Anderson’s word: *Practice* makes perfect: almost always *Practice* brings improvement and more

Practice brings greater improvement (Anderson, 1981). *Practice* is still a part of modelling based training programs, which consist of four phases: (1) the attention process, in which a presentation of the model is built; (2) the retention process, in which the modelled behaviour is symbolically represented (either verbally or visually) in memory and behaviourally rehearsed; (3) the motor reproduction phase, in which the learnt skill is used in various procedures to enhance transfer; and (4) the motivational processes of feedback and social reinforcement lead to the execution of the desired behaviour (Bandura, 1977a; Manz & Sims Jr., 1981). In the second and third phases *Practice* comes into account and leads to improved performance.

What about the effect of *Practice* when it comes to the medium of video? Several studies already have demonstrated that practising during a film can be effective when the learner is allowed enough time to participate without missing any information (Ash & Jaspen, 1953 as described in Allen, 1957). The factor time for *Practice* is also a crucial point in other studies: If *Practice* is given simultaneously with audiovisual instruction, the motor elements are not learnt properly. *Practice* only has an effect when it is extensive or when it is given sequentially rather than simultaneously (Baggett, 1988). Even in approaches that have a very optimistic attitude toward videos the importance of *Practice* is stressed: it is alluded to the fact that when skill acquisition is the goal, typically intentional effort and *Practice* on the learner's part is involved (Schwartz & Hartman, in press). Furthermore, Schwartz and Hartman (in press) emphasise that complex skills should be decomposed into sub-skills and learnt separately. In addition, for some skills it is important to help people see the critical components of the behaviour. Good instructional design ensures that learners can discern relevant behaviours (for example, via *Labelling*) so that they can imitate them. Before *doing* something, one must correctly *see* it performed. Afterwards, attention can be shifted to the doing-part through practice (Schenkel, 2000).

Practice has proven to be a helpful method when learning a new computer application as it has been repeatedly shown that groups learning with *Practice* fare better in terms of time and errors in comparison to other methods, such as those of an explorative nature (Wiedenbeck et al., 1995). Following Anderson (1993), learning is defined by the acquired productions, not by the *Practice* method used to arrive at those productions. *Practice* methods are the means to the end of acquiring the necessary productions. Consequently, they have to be well-designed and appropriate (Wiedenbeck & Zila, 1997).

For example, practices must have a defined goal and not to be too exploratory, otherwise they lose efficiency and learners fail to systematically explore the procedures needed to gain basic productions (Anderson, 1993). Guided exploration cards (Carroll, 1990a) are one possibility for realising effective *Practice*. They cultivate a task-orientated approach and give hints on how to reach a set goal rather than provide step-by-step instruction (see also section 3.2.2 and section 5.5.2.1). Other advantages include being a follow-up to the video, containing a sub-skill to be learnt and identifying a goal to be reached.

For the second experiment the following can be concluded:

- Enhancing transfer without integrated *Practice* seems quite unlikely
- *Practice* is needed to improve the compilation of declarative and procedural knowledge from a skill acquisition perspective
- Working on different examples fosters schema acquisition from a worked-out example point of view
- *Labelling* important features and sub-goals is important because transfer can be fostered by *Practice* from a behaviour modelling and worked-out example perspective and when seen as a means to instructionally design practices.

5.4 Research Questions

The aim of the current study is to investigate the impact of *Practice* on the acquisition of declarative and procedural knowledge while learning with instructionally designed videos. Near and far transfer are particularly expected to be fostered by integrating *Practice* and not by watching on-screen videos alone. Motivation and acceptance values are assessed. The videos were instructionally designed as in a first study (see also section 4.4.2.1).

The following six main research questions were addressed.

1. **Do instructionally designed on-screen videos in combination with Practice have an additional effect on the acquisition of procedural knowledge?**

Hands-on *Practice* is expected to lead to even deeper processing of learning contents and therein improved learning results in comparison to the without *Practice* condition (Anderson, 1981).

2. **Do instructionally designed on-screen videos in combination with Practice foster near and far transfer?**

In addition to the videos that provide learners with a modelled worked-out solution in the form of a task, learners actually work with the program in question. The practices, in the form of so-called guided exploration cards, are integrated directly after each film. The cards assist learners practise important features being explained in the preceding on-screen video. Thus, it is predicted that learners having additional *Practice* should show better learning results in near and far transfer (procedural knowledge) than learners viewing videos without *Practice*.

3. **Do instructionally designed on-screen videos in combination with Practice lead to mid-term retention in procedural and declarative knowledge?**

It is expected that *Practice* not only has a beneficial effect on learning but also on the maintenance of knowledge over time. Even though the time span in the second experiment has been extended from three to eight days, the same retention of knowledge in both performance values is expected; especially in the case of the with *Practice* groups.

4. **What are the effects of our instructional design variants Labels and Pacing in combination with Practice on procedural and declarative knowledge?**

In the first study, it was found that *Labelling* was especially suitable to fostering declarative knowledge acquisition, whereas *Pacing* enhanced the acquisition of procedural knowledge. Consequently, the question arose as to whether and how this result is influenced by *Practice*. On the one hand, it is expected that *Labelling* in combination with *Practice* has a positive effect on learning results. On the other hand, it is anticipated that *Practice* diminishes the effect of *Pacing* so that no substantial effect for *Pacing* is expected.

5. **Do the experimental conditions differ with respect to motivation and acceptance?**

In Experiment 1, no differences in motivation and acceptance were found between groups. It is expected that *Practice* has a motivating effect and leads to more satisfaction with the learning environment.

A cluster analysis was conducted to answer a further question that is not directly related to the experimental conditions:

6. **Are there certain types of learners?**

Based on the findings in Experiment 1 that showed an interesting pattern between learning success and the motivational variables, an attempt was made to gauge the relationship between performance values and motivation/acceptance in Experiment 2. However, these patterns might, to a certain extent, be independent of the experimental conditions.

5.5 Method

5.5.1 Participants

One hundred and three students (46 females, 57 males, mean age: 22.4 years, *SD* = 3.8) from the University of Freiburg participated in the experiment. 31.1% of the students were from the natural sciences departments, 25.2% from the humanities, 27.2% from business and behavioural sciences and 16.5% from other departments. Students were eligible if they had at least some general computer knowledge and no prior knowledge of the application to be learnt (i.e., RagTime®). Computer knowledge (declarative and procedural) was assessed by an extensive net-based test, which consisted of an updated version of the computer and Internet knowledge test developed by Richter and colleagues (Richter et al., 2000) and which proved to be successful in the first experiment (Ertelt, Renkl & Spada, 2006) (see section 4.4.4.1).

The time to complete the test was approximately 27 minutes (*M* = 27.32; *SD* = 13.58). 190 students finished the test (*M* = 190.05, *SD* = 58.16). The minimal score to be reached for taking part in the study was 140 points, 103 students reached that threshold (*M* = 212.3, *SD* =

49.66). All students had been using the computer for a reasonable length of time, that is, about 10 years (*M* = 10.36, *SD* = 3.89).

Participants were randomly assigned to the eight different experimental conditions. They received 21 EURO, the freeware version of the application RagTime® and the on-screen videos on CD as compensation for their participation.

5.5.2 Design and Materials

The design consisted of eight experimental conditions (see Table 11): four conditions *with Practice* and four conditions *without Practice*.

Table 11. Overview of the Design (with 8 groups)

		WITH PRACTICE		WITHOUT PRACTICE	
		Labelling		Labelling	
		with	without	with	without
Pacing	with	20	22	5	5
	without	20	21	5	5

For all calculations, statistical analyses were performed with five groups, as the cells in the *without Practice* conditions only contained five learners. In the *without Practice* condition the 2x2 was pursued in order to have basis of comparison with Experiment 1. The five group design is visualised in Table 12.

Table 12. Overview of the Design (With 5 Groups, Used for Most Calculations)

		WITH PRACTICE		WITHOUT PRACTICE
		Labelling		
		with	without	20
Pacing	with	20	22	
	without	20	21	

All learners had to study the same computer application, namely RagTime 5.6.5®, by watching the same five on-screen videos. These videos, each of varying length, were the same as in Experiment 1 (see section 4.4.2.1). As in the previous study, all videos were designed according to Mayer’s Multimedia theory. They also contained green highlights and spoken text. The experimental variations, *Labelling* and *Pacing*, were also kept constant across experiments. *Practice* existed in the variant *with Practice* and *without Practice*. However, as *Practice* was integrated, the number of videos shown to the learner had to be reduced from seven (Experiment 1) to five (Experiment 2) and thereby learning time was also reduced in order not to exceed the learner’s concentration span. In the case of the *with Practice* condition the videos contained seven short *Practice* units for which the solution time was restricted. In the case of *without Practice*, small videos showing the solution steps were shown if the guided exploration cards were administered. These *Practices-videos* had the same length as the maximal solution time of the cards.

5.5.2.1 The Practice Conditions

In the *with Practice* condition, short little *Practices* in form of so-called guided exploration cards (Carroll, 1990a) were integrated directly after each video and participants learnt in four different conditions: (1) without *Labelling*/without *Pacing with Practice*, (2) with *Labelling*/without *Pacing with Practice*, (3) without *Labelling*/with *Pacing with Practice* and in the condition (4) with *Labelling*/with *Pacing with Practice*. This also resembled the experimental variation of the first experiment. Figure 10 shows one such guided exploration card.

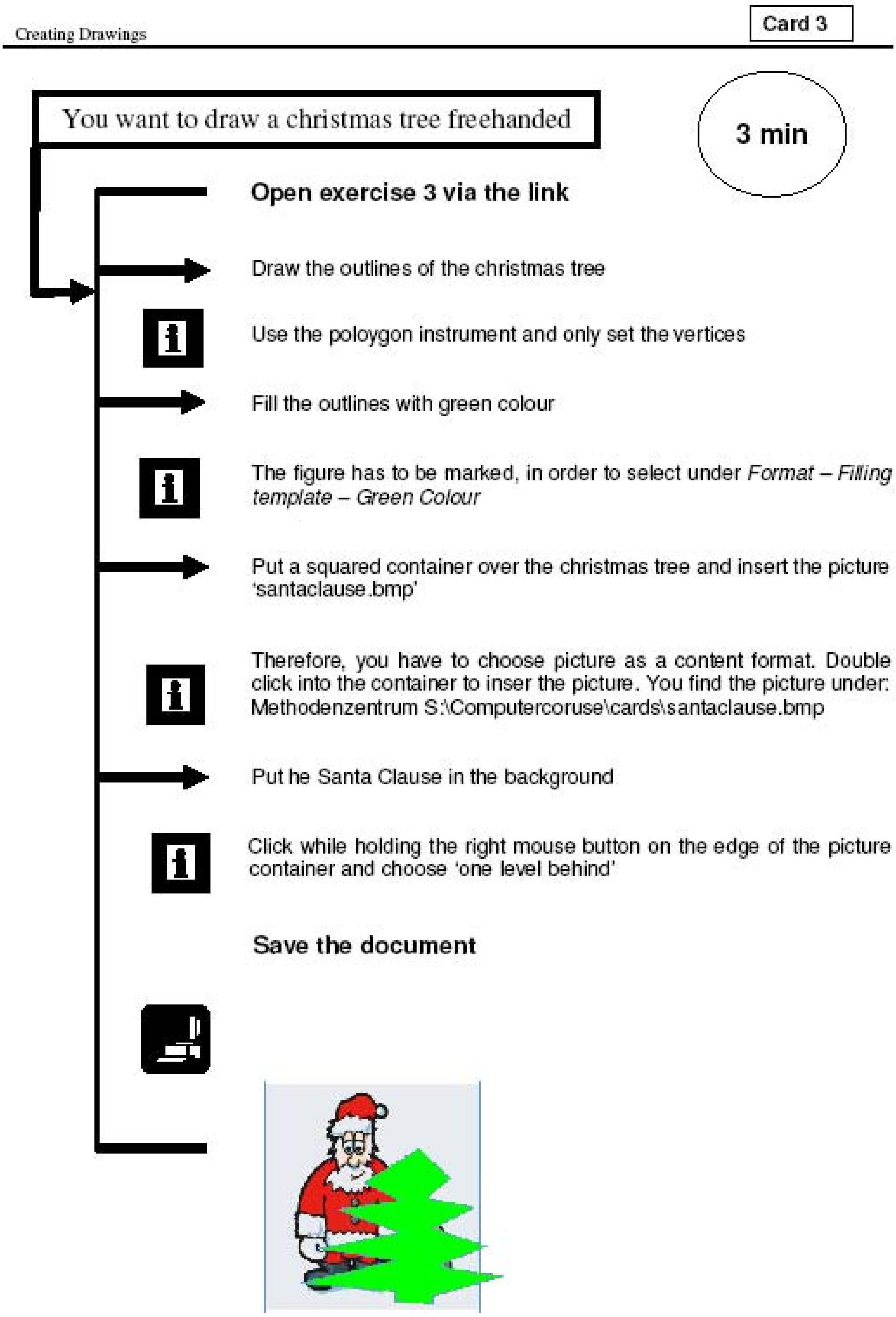

Figure 10. Guided exploration card.

Guided exploration cards were developed within the theory of minimal instruction (Carroll, 1990a, 1998). These cards embarked on the strategy of task orientation. The user was guided in his explorative behaviour by the cards, but he did not have to search for the goal on his own as it was given. However, there was no step-by-step description of what had to been done next. Instead the cards just gave hints of what to do (symbolised by arrows). If the user was uncertain how to reach that goal he could read the small information boxes. However, the information boxes also offered small hints rather than the whole solution. At the bottom of each card one could find the final solution, so that a comparison with the self-produced solution could be made. Furthermore, the time restriction was indicated in the upper right circle. In the upper left part over the line a small description to which category the card belongs could be found. In the upper right part over the line, the card number was given. In the box under the line the task was summed up. In two cases where the movies were somewhat longer, two guided exploration cards were given. The time of each *Practice* was restricted from 1:30 to 4:00 minutes. In general, the guided exploration cards proved to be very successful. In cases where they were not successful, the learners either did not read the cards thoroughly enough or the unconventional structure of the cards was not understood. In order to avoid these problems, an overview card was created to explain all the symbols and how to use them. The overview card was present throughout the experiment.

5.5.2.2 The Control Group

The control group consisted of four sub-groups that were variations of the experimental conditions *Labelling* and *Pacing*: (1) without *Labelling*/without *Pacing without Practice*; (2) with *Labelling*/without *Pacing without Practice*; (3) without *Labelling*/with *Pacing without Practice*; and the condition (4) with *Labelling* /with *Pacing without Practice*. These four groups can be equated with the experimental conditions of the first experiment, the difference being the short ‘filler video’ displaying the solution of the guided exploration card that was shown to all groups after the ‘learning video’. Thus, seven additional, though shorter, videos had to be watched. The rationale behind this was to keep time-on-task constant in the experimental and in the control conditions. The filler videos were designed according to the experimental conditions. If the condition was with *Labelling*/without *Pacing*, the filler video also contained *Labelling*/without *Pacing*.

5.5.3 Procedure

As in the previous experiment, the learning environment was framed as a software tutorial for experienced users testing a new learning method. All interested participants had to fill in an online test on existing computer knowledge. Eligible participants took part in the first session lasting about two hours and 30 minutes. The second session took part exactly one week later and lasted about 45 minutes.

5.5.3.1 Pre-Test

In order to select the experienced users, an extensive online test (directly accessible on the worldwide web) had to be filled out before taking part in the software tutorial (for more details see section 4.4.3.1). The test consisted of declarative and procedural knowledge questions and a self-assessment of prior computer knowledge. If the preset score was reached, a confirmation email was sent indicating directions and a personal identification number (done for reasons of anonymity) that participants should bring to the session. In the case they failed to reach the preset score, learners got an email explaining the lack of space for participants with their level of knowledge. Nonetheless, they were offered a free self-learn CD after the study was finished. Approximately 15% of the persons who were ineligible for the study gladly accepted this offer. Additionally, ten vouchers for the cinema (worth 10 Euros) were raffled between all those who completed the online test.

5.5.3.2 First Session

Eligible students were randomly assigned to the eight experimental conditions. They participated in groups of up to seventeen people. The experiment took place in the computer room at the Department of Psychology, University of Freiburg. All computers there were equipped with Microsoft Windows XP®, the application software and headphones. The learners were seated in front of the computer according to their personal identification number and worked individually in the learning environment. The order of the experiment was predetermined and once it had started it was not possible to re-view played sections. Participants watched a total of five videos about the application to be learnt. In the *with Practice* condition, they worked directly after each video on small *Practices* realised in the form of guided exploration cards (seven in total). In the *without Practice* condition, they saw a video about the contents of the guided exploration card. These little videos lasted between 1:30 and 4:00 minutes. Additionally, learners in the *Labelling* and *Pacing* conditions started by watching a very short video (1:30 minutes) that introduced the specificities of their conditions (e.g., how to use the interactive push button). After all videos and guided exploration cards (or short filler videos), the declarative knowledge test had to be filled out. This test was conducted online and contained multiple-choice questions and open questions. Following this test, learners had to work on four procedural test tasks. The time for each task was limited to 9 minutes. The procedural test tasks were the same as in the first session at the first experiment. Finally, they had to fill out an online questionnaire on motivation and acceptance (see also section 4.4.3.2). Figure 11 shows how the learning environment appeared. The instructions were given on the computer screen but were also present in paper form throughout the experiment. The chronological sequence was visible on the left part of the screen and indicated where the learner was located at any given time. Yet it was impossible to go backwards.

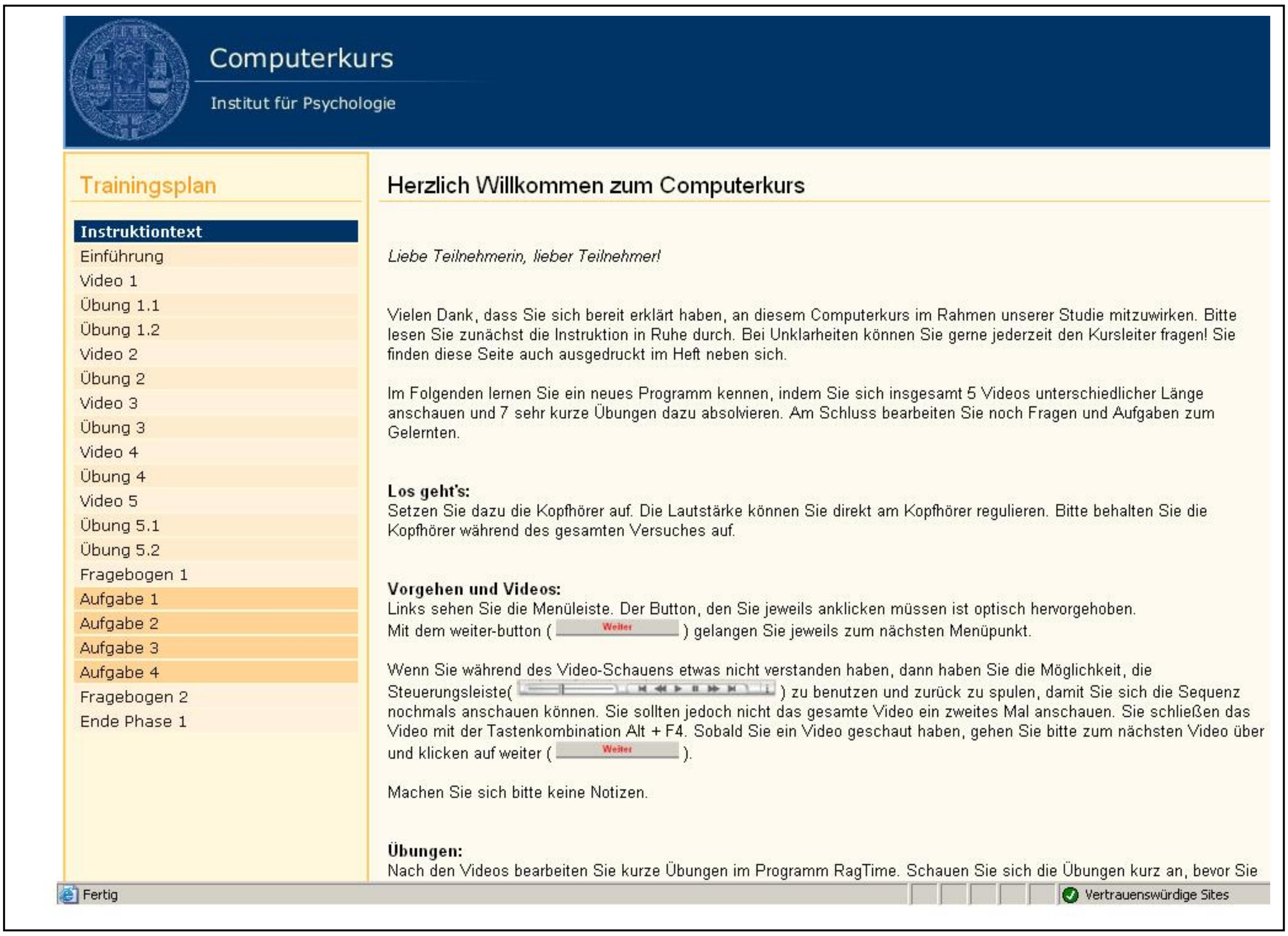

Figure 11. The learning environment in study 2 (with practice condition).

5.5.3.3 Second Session

The second follow-up session took place one week later and lasted 45 minutes. Learners completed the declarative knowledge test. However, the sequence of questions was changed. Afterwards learners worked on the same four procedural tasks they encountered at the immediate post-test. Lastly the learners received the money, information about the experiment and the freeware application on CD for their participation.

5.5.4 Instruments and Coding of the Knowledge Variables

The computer & Internet knowledge pre-test was derived from an existing questionnaire (Richter et al., 2000) and already showed its usefulness at distinguishing between several ability levels in other studies (Nueckles & Ertelt, 2006; Wittwer, 2005) (compare section 4.4.4.1).

The post- and delayed-post test on declarative knowledge corresponded to those from Experiment 1. In this experiment, however, the sequence of questions in the delayed post-test was modified. The answers were rated according to an ideal solution and the ratio of points participants received in relation to total possible points was calculated (for more information see section 4.4.4.2).

The procedural knowledge tasks were identical to the tasks administered at the immediate post-test in the first study. In Experiment 2 the same four tasks were given at both measuring points. For each problem, a rating scheme with all necessary steps to be taken in order to solve the task was available. Therefore, each single step could be rated regardless of whether it was carried out or not. Additionally, each step-to-be-done was identified as supporting near or far transfer according to the scheme in section 5.2.2. The calculations were made with the ratio measures described above because each task contained a different number of steps.

Motivation and assessment were assessed by the instruments derived from Deci and Ryan (1985) and Rheinberg and Vollmeyer (Rheinberg et al., 2001; Rheinberg et al., 2003). Motivation was measured with different scales, such as interest, challenge, effort, perceived competence and flow. As all scales were substantially inter-correlated, an overall score of motivation was determined. For a more detailed description of the instruments and coding, see section 4.4.4.

5.6 Results

In the following the results are presented according to the six research questions introduced in chapter 5.4. This begins with the results related to effects the variable *Practice* has on procedural knowledge. The second question examines results related to near and far transfer. The third question is connected to the effect of time on both performance values. The forth question addresses the effects of the instructional design variants *Pacing* and *Labelling*. The last two questions deal with the effects on motivation and acceptance and if there are certain types of learners.

5.6.1 The Effect of Practice

1. Do Instructionally Designed On-Screen Videos in Combination *With Practice* have an Additional Effect on the Acquisition of Procedural Knowledge?

The comparison of the *without Practice control group* with the four *with Practice* conditions revealed that learning *with Practice* significantly increases procedural knowledge $F(1, 98) = 3.97$, $p < .05$, $\eta^2 = .03$ (small effect). In other words, the groups *with Practice* learnt more. The insignificant interaction effect between time and group factor in the repeated measurement design shows that the *Practice* effect is stable over both measuring points as there is no interaction between time and the affiliation to a particular group. Table 13 shows the means and standard deviation at the immediate and delayed post-tests.

Table 13. Means and Standard Deviations (in Parentheses) of Procedural Knowledge

	Experimental condition				
Dependent variable	**Control group without practice**	**No pacing, no label, practice**	**Pacing, practice**	**Label, practice**	**Pacing & label, practice**
Procedural knowledge	2.41	2.59	2.62	2.94	2.65
Post-test	(.52)	(.44)	(.51)	(.46)	(.51)
Procedural knowledge	2.74	2.85	2.86	3.15	2.80
Delayed post-test	(.46)	(.46)	(.51)	(.40)	(.55)

Thus, it can be concluded that *Practice* indeed has an additional, favourable effect on the acquisition of procedural knowledge and can even increase the learning effect while learning with well-designed instructional videos.

5.6.2 The Effect of Practice on Near and Far Transfer

2. Do Instructionally Designed On-Screen Videos in Combination *With Practice* Foster Near and Far Transfer?

In order to prove if near and far transfer can be fostered by *Practice*; a variance analysis with repeated measurements was conducted. The planned contrast comparing the *without Practice* control group with the four *with Practice* conditions revealed that learning *with Practice* in the case of *near transfer* shows no additional benefit in the learning outcomes. This is visible in Figure 12, where it can be seen that the control group is comparable to the worst performing experimental groups.

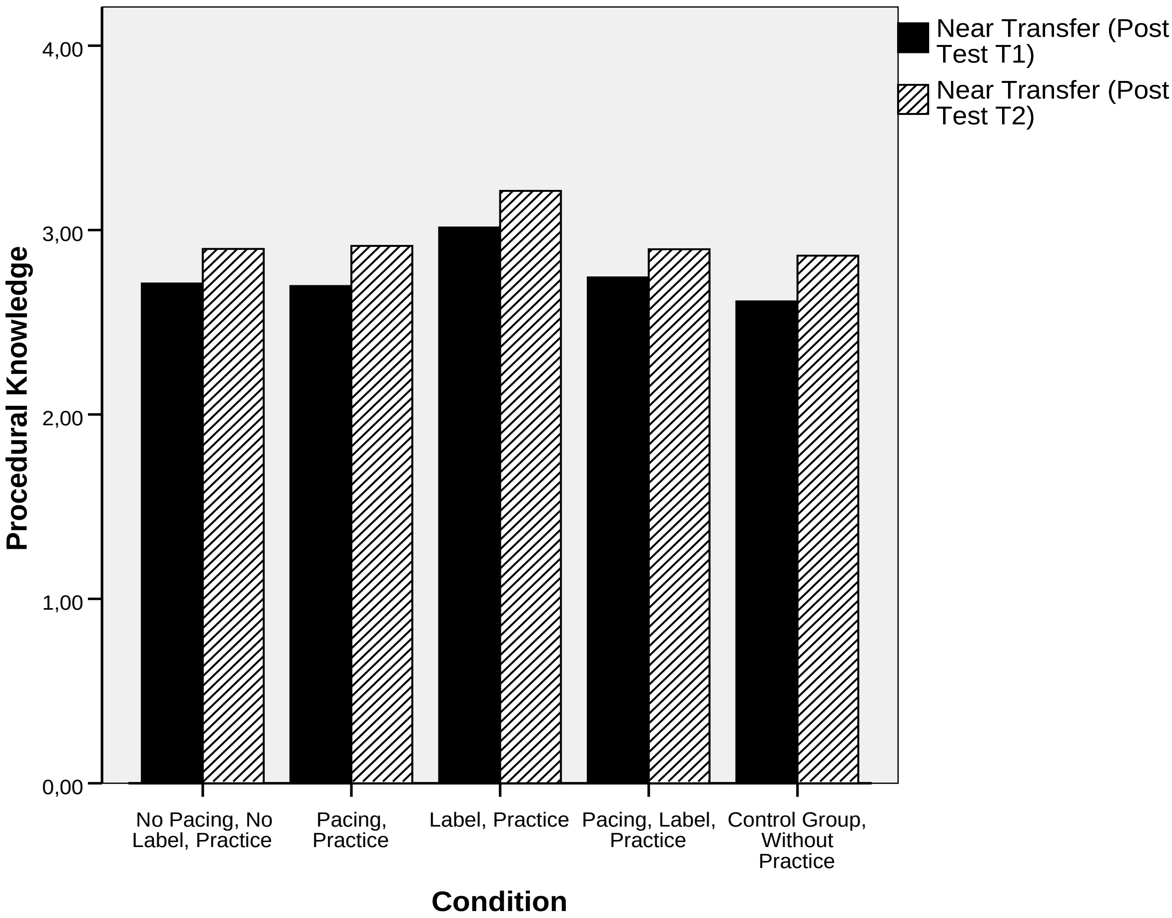

Figure 12. Near transfer within the five learning conditions at both measurement points.

In the case of *far transfer*, there was a significant difference between the *with Practice* groups and the *without Practice* group in favour of the Practice groups, $F(1, 98) = 4.73$, $p < .05$, $\eta^2 = .04$ (small effect). The interaction between the time and the group factors was not significant, which implicates that the effect of *Practice* on far procedural knowledge tasks was stable over the two measurement points (see Figure 13 for visualisation).

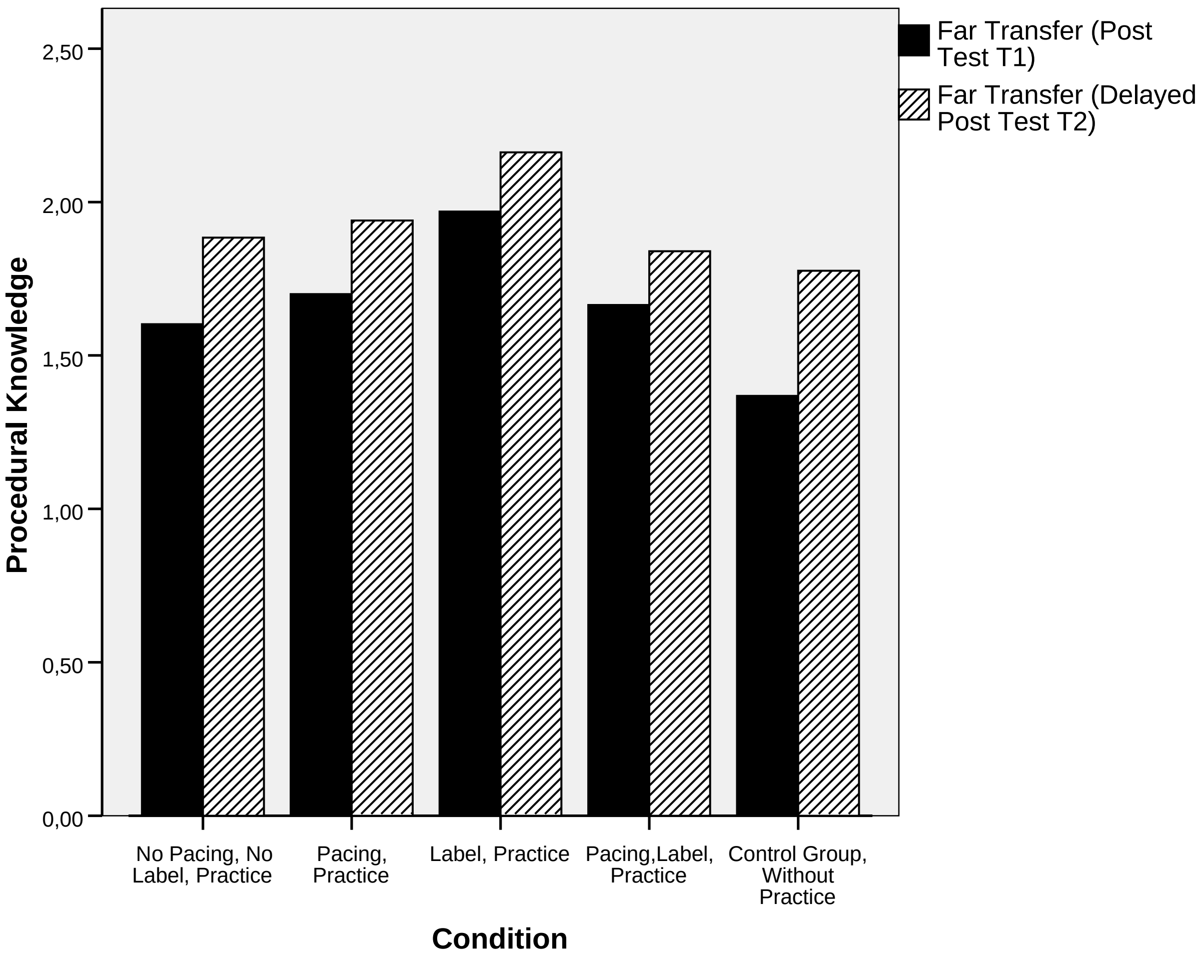

Figure 13. Far transfer within the five learning conditions at both measurement points.

In sum, *Practice* not only has an additional positive effect on procedural knowledge in general but also on far procedural knowledge tasks.

5.6.3 The Effect of Practice on Mid-term Retention

3. Do Instructionally Designed On-Screen Videos in Combination *With Practice* Lead to Mid-term Retention in Procedural and Declarative Knowledge?

A positive time effect was found both with procedural knowledge in general and as it relates to near and far transfer (procedural knowledge: $F(1, 98) = 75.12$, $p < .01$, $\eta^2 = .43$ (very strong effect); near transfer: $F(1, 98) = 51.72$, $p < .01$, $\eta^2 = .34$ (very strong effect); far transfer: $F(1, 98) = 56.06$, $p < .01$, $\eta^2 = .36$ (very strong effect). As shown in Figure 12 and Figure 13, procedural knowledge improved between measuring point T1 to T2 meaning that learners perform even better at the delayed post test T2. In the case of declarative knowledge, the completely opposite picture was found (see Figure 14). Over the course of time, performance in declarative knowledge deteriorated. This is true for declarative knowledge in general and in the multiple choice questions, but not in the open-ended questions (declarative knowledge: $F(1, 98) = 9.59$, $p < .05$, $\eta^2 = .08$ (medium effect); multiple choice questions: $F(1, 98) = 10.66$, $p < .05$, $\eta^2 = .09$ (medium effect); open questions: $F(1, 98) = 1.06$, $p = .30$). This is a surprising effect as recognition tasks (multiple choice questions) are typically considered easier than recall tasks (open-ended questions).

Figure 14 shows declarative knowledge in general at both measurement points.

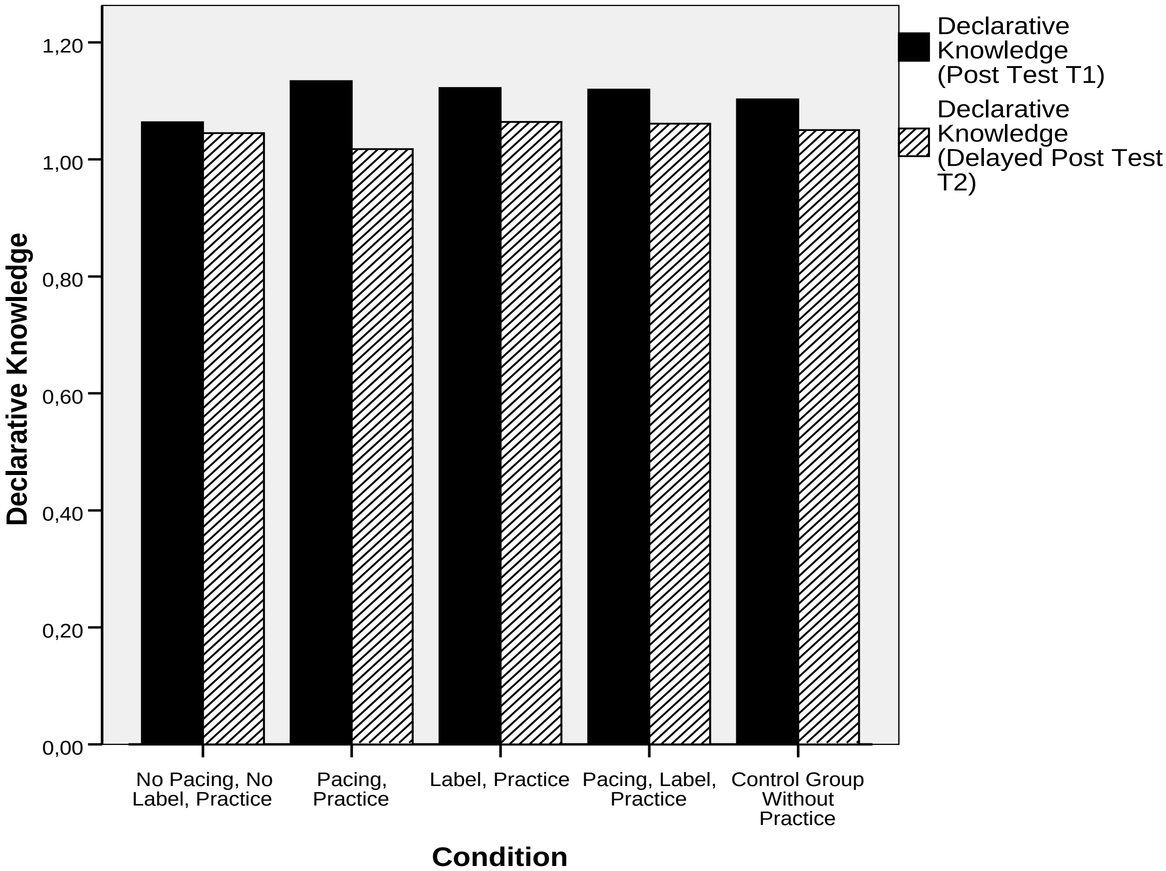

Figure 14. Declarative knowledge within the five groups at both measurement points.

In abbreviation, a positive time effect was found in the case of procedural knowledge, indicating a consolidation of knowledge among learners despite the lack of training between sessions. The opposite was found in terms of declarative knowledge, where, except in the case of open-ended questions, a decrease in knowledge from the immediate post-test to the delayed post-test was apparent.

5.6.4 The Effect of Practice in Combination with the Instructional Design Variants

4. What are the Effects of the Instructional Design Variants Labels and Pacing in Combination *With Practice* on Procedural and Declarative Knowledge?

The first experiment showed *Labelling* as being particularly good at fostering declarative knowledge, whereas *Pacing* enhanced procedural knowledge acquisition. It was then asked if this result is influenced by *Practice*. It was expected that *Labelling* in combination with *Practice* would have a positive effect on learning results. Furthermore, it was assumed that *Practice* would diminish the effect of *Pacing*, so that no substantial effect for *Pacing* would be anticipated. For this analysis only the groups *with Practice* were used: Namely no *Label*, no *Pacing*, *Practice – Pacing*, *Practice – Label*, *Practice – Pacing*, *Label*, *Practice*. Regarding procedural knowledge in general, a significant contrast comparing the *Labelling* group with the other three groups was found, $F(1, 79) = 6.76$, $p < .05$, $\eta^2 = .08$ (medium effect). This means that the *Labelling* condition *with Practice* is the best performing condition across measuring points (see Figure 15). The same contrast is found when regarding near transfer, $F(1, 79) = 7.25$, $p < .05$, $\eta^2 = .08$ (medium effect), and far transfer, $F(1, 79) = 5.52$, $p < .05$, $\eta^2 = .07$ (medium effect). However, as expected in Experiment 2 *with Practice*, *Pacing* no longer had an especially advantageous effect.

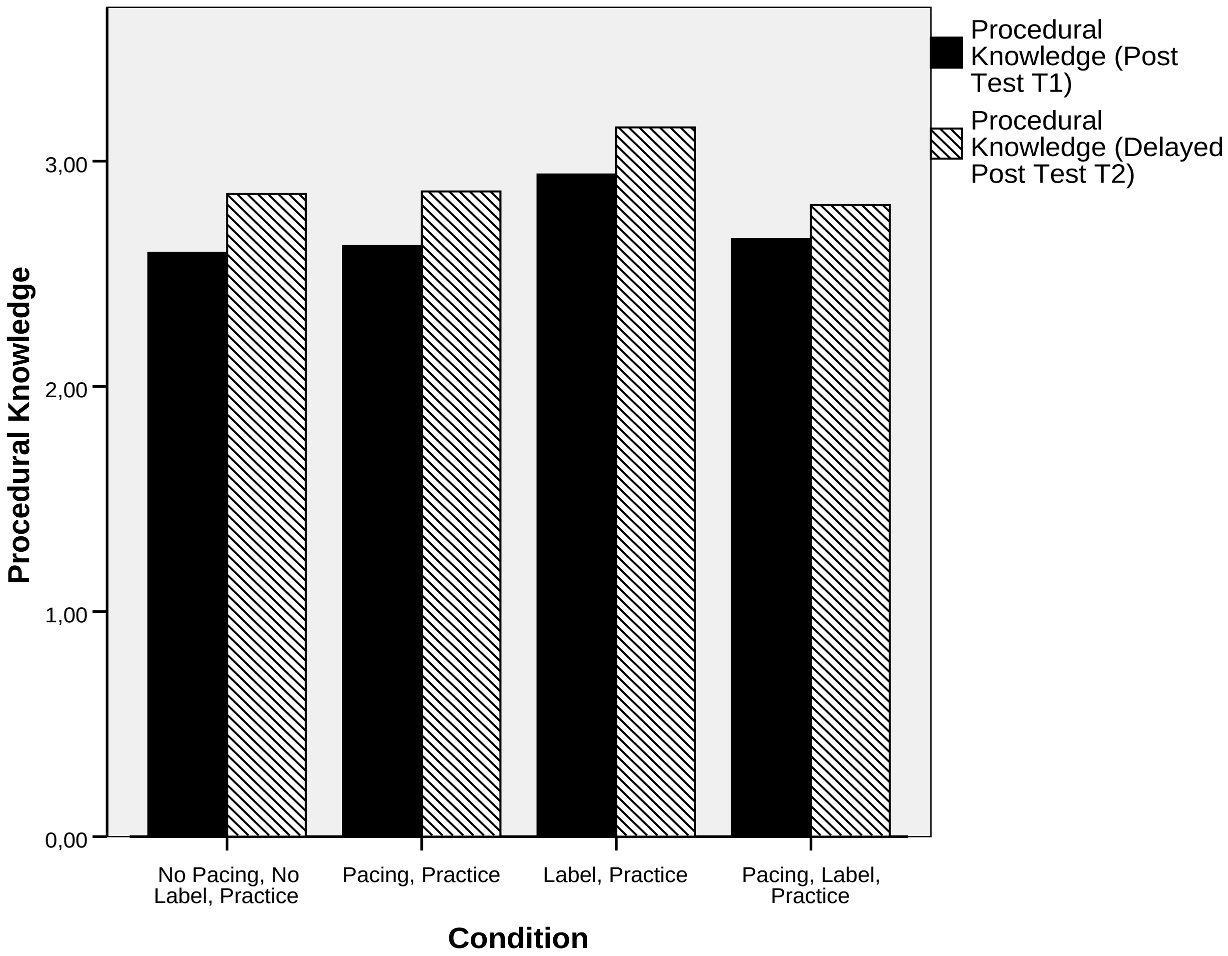

Figure 15. Procedural knowledge of the *with Practice* groups at both measurement points.

In terms of declarative knowledge, no significant results were found for *Labelling* or *Pacing*.

5.6.5 Motivation and Acceptance

5. Do the Experimental Conditions Differ With Respect to Motivation and Acceptance?

As in Experiment 1, motivation and acceptance were assessed by a questionnaire measuring different scales, such as interest, challenge, flow, effort and perceived competence. It was measured once in session 1 and again in the final questionnaire. All scales were substantially inter-correlated; therefore, overall scores were determined. The number of questions per scale (e.g., interest or challenge) varied. A question could be rated between 1 (not true at all) and 7 (absolutely true). Therefore, the number of rated points in ratio to the number of possible rating points was calculated. Consequentially, a maximum of one point per scale could be achieved. For motivation, a maximum of five points could be reached if every item was rated with a 7. For acceptance, the maximum was two points. The findings of Experiment 1 showed that there was no difference in motivation and acceptance between the experimental conditions. Between the groups *with Practice* and the overall group *without Practice* no difference was found concerning motivation, $F(4, 98) = 1.11$, $p > .05$, or acceptance, $F(4, 98) = 1.17$, $p > .05$. For a more detailed overview of how the different motivation and acceptance scales look in relation to the independent variables *Pacing* and *Label* and *with Practice* and *without Practice,* see Table 14. The table shows the overall scores in the upper parts of the rows and the five motivation scales that comprise the overall motivation score.

Table 14. Means and Standard Deviations (in Parentheses) of Motivation and Acceptance

Dependent variable	No pacing, no label	Pacing	Label	Pacing & label	Practice
Motivation (max. 5)	3.23 (.42)	2.99 (.56)	2.96 (.46)	2.90 (.72)	With
	3.40 (.21)	2.76 (.79)	2.70 (.41)	3.06 (.15)	Without
Acceptance (max. 2)	1.41 (.19)	1.22 (.34)	1.26 (.26)	1.28 (.34)	With
	1.53 (.14)	1.15 (.25)	.95 (.36)	1.49 (.23)	Without
Motivation (interest)	.66 (.10)	.58 (.18)	.59 (.15)	.59 (.19)	With
	.74 (.16)	.42 (.14)	.40 (.12)	.69 (.11)	Without
Motivation (challenge)	.62 (.15)	.53 (.14)	.54 (.10)	.55 (.15)	With
	.58 (.07)	.59 (.14)	.52 (.13)	.64 (.12)	Without
Motivation (flow)	.60 (.14)	.54 (.15)	.47 (.15)	.50 (.17)	With
	.65(.09)	.46 (.21)	.41 (.11)	.51 (.11)	Without
Motivation (effort)	.85 (.09)	.81 (.12)	.79 (.11)	.79 (.15)	With
	.90 (.18)	.81 (.16)	.86 (.05)	.85 (.08)	Without
Motivation (perceived competence)	.50 (.13)	.53 (.16)	.57 (.17)	.47 (.20)	With
	.53 (.09)	.48 (.23)	.51 (.26)	.37 (.12)	Without

As Table 14 shows, the conditions without any instructional design, such as *Labels* or *Pacing* but *with Practice*, lead to the highest scores in motivation and acceptance from a descriptive point of view. However, there is no significant difference in motivation and acceptance between the four *with Practice* conditions.

There is a significant correlation between the declarative knowledge score at session one and motivation (r = .227, p < .05). A continuous correlation between all procedural knowledge scores with motivation was found, but not with acceptance. Compare the correlations between motivation and the procedural knowledge parameters in Table 15.

Table 15. Correlations Between Motivation and Procedural Knowledge Parameters

Procedural Knowledge	Correlation
Procedural knowledge session 1	r = .224, p < .05
Procedural knowledge session 2	r = .321, p < .05
Procedural knowledge session 1 – near transfer	r = .207, p < .05
Procedural knowledge session 2– near transfer	r = .276, p < .05
Procedural knowledge session 1 – far transfer	r = .230, p < .05
Procedural knowledge session 2– far transfer	r = .332, p < .05

An attempt to find different clusters of learners, such as those encountered in the first experiment, was made.

5.6.6 Cluster Analysis for Different Learning Types

A cluster analysis was conducted and the learners were grouped according to their similarities in performance variables (declarative and procedural knowledge and motivation and acceptance values). In order to avoid the possibility that certain variables would influence the cluster solution more than other variables (due to larger variances) all variables were transformed to z-standardised variables and the Ward procedure with squared Euclidian distances was used. The dendrogram favoured a four cluster solution, as other solutions with less clusters would have dramatically increased the intracluster variance.

The identified clusters were relatively unequal in size (Cluster D1: N = 9, Cluster D2: N = 23, Cluster D3: N = 36, Cluster D4: N = 35). See Table 16 for an overview of experimental condition distribution over the different clusters.

Table 16. Cross Table: Person per Cluster in Dependence of the Group

	D1	D2	D3	D4	Total
No pacing, no label, practice	1	7	5	8	21
Pacing, practice	3	4	9	6	22
Label, practice	1	3	9	7	20
Pacing, label, practice	0	4	8	8	20
Without practice	4	5	5	6	20
Total	9	23	36	35	103

A chi-square test showed no significant difference in distribution ($\chi^2(12, N = 103) = 10.82, p = .54$). Figure 16 shows the different clusters.

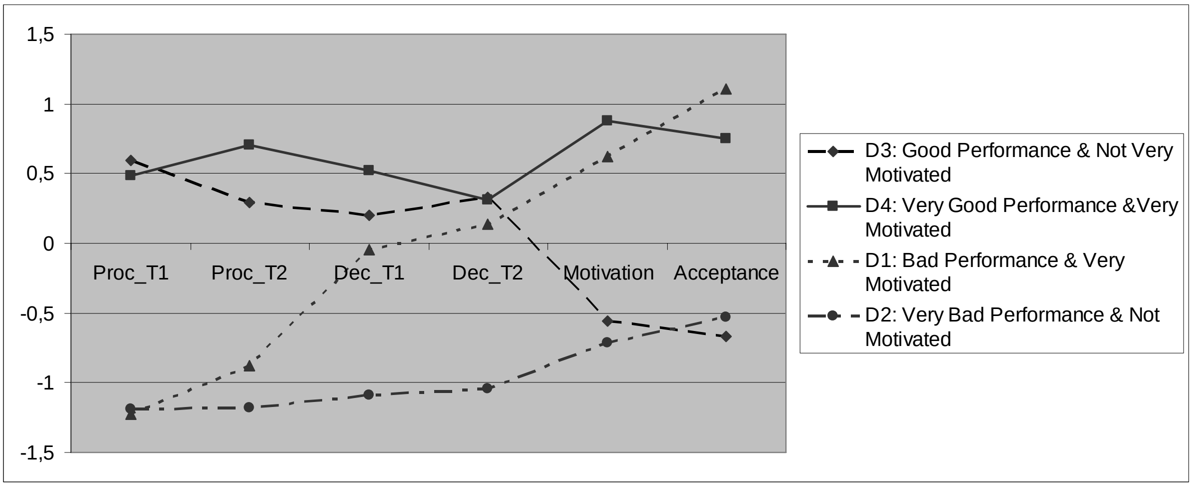

Figure 16. Cluster analysis.

Cluster D4 is the second largest group and can be described as very successful and very motivated. Cluster D3 is the largest cluster with learners who showed good performance values but who were not very motivated. 26 out of 36 persons in this cluster descend from the experimental groups with *Practice* and additional instructional design. Learners in cluster D2 showed the worst performance and were not very motivated. The last cluster D1 can be characterised by very high scores in motivation and acceptance, but by rather poor performance.

In Experiment 1, where the effects of the instructional design features *Pacing* and *Label* but *without Practice* were examined, it was found that the best performing learners were unmotivated and the worst performing learners were motivated. In contrast, in Experiment 2 the best performers were also the most motivated and the worst performers were the least motivated (see Figure 17). In Figure 17 the four cluster performance values (procedural knowledge T1, procedural knowledge T2, declarative knowledge T1, and procedural knowledge T2) were combined in an overall performance score called 'Performance'. The same was done with the cluster values in motivation and acceptance resulting in a score called 'Motivation'.

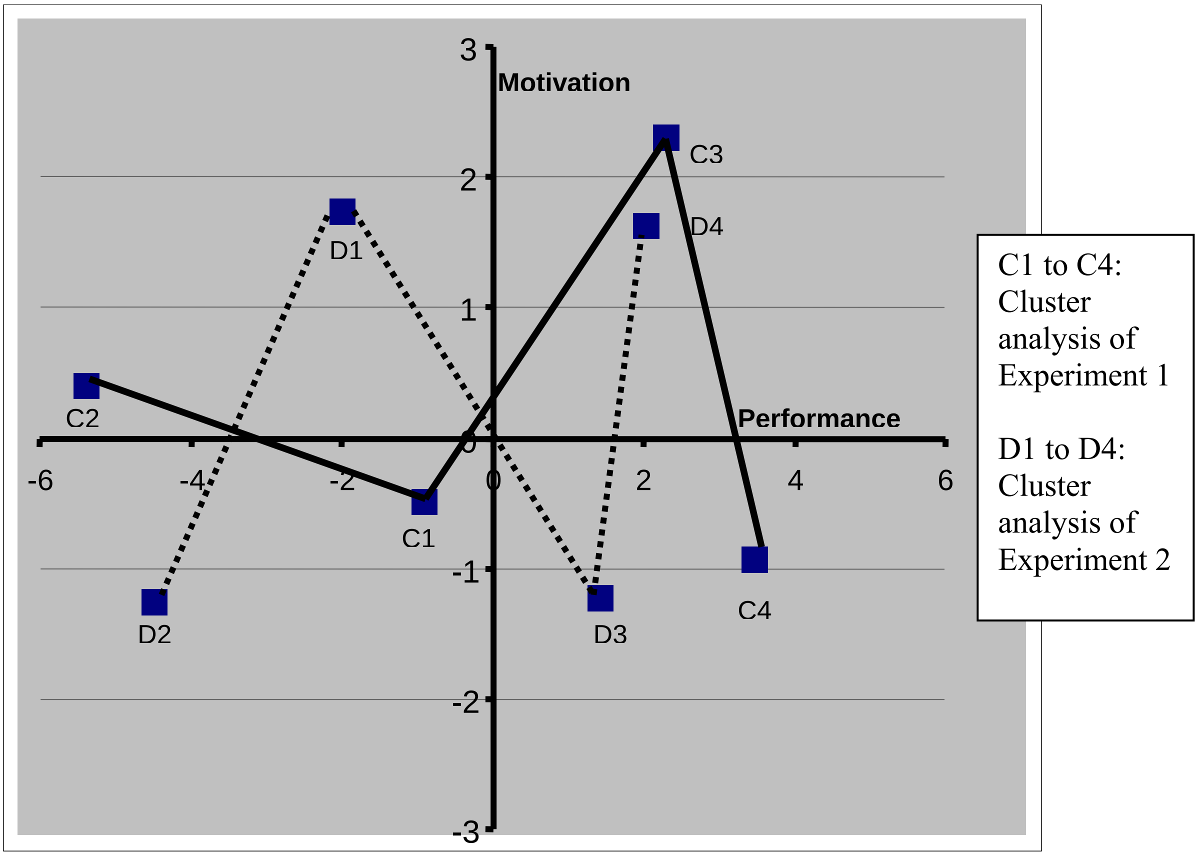

Figure 17. Both cluster analyses from Experiment 1 and Experiment 2.

5.7 Discussion

The purpose of the second study was twofold: To test the effect of *Practice* in general and to test its effect specifically on near and far transfer. This idea departed from the finding in the first experiment that far transfer was fostered only by working practically with the learning contents. To examine if far-transfer could be achieved by observation, the same videos that were tested and used in Experiment 1 were re-applied in the second study. All videos realised the principles of learning by observation (Bandura, 1977b), showed modelled worked-out examples (Renkl, 2005; Renkl & Atkinson, in press) and considered the multimedia principles for designing multimedia learning environments (Mayer, 2005). Additionally, short hands-on *Practices* in the form of so-called guided exploration cards were implemented (Carroll, 1990b). This was done to realise principles like task orientation, goal setting, guided explorative behaviour and, of course, *Practice*. The results showed that the implementation of *Practice* indeed led to a general improvement in procedural knowledge. According to Anderson (1983), practice has a positive effect on the compilation phase, where a sequence of single steps are integrated into larger units after having performed the sequence several times and on the autonomous stage, in which performing a skill becomes more fluent and automatic because the encoding in memory is strengthened. In other words, far transfer can be fostered with *Practice*. This is an especially pleasant result because far transfer was not only operationalised through the use of different content structures (as in various other studies), but there were also situations in which a new procedure had to be interfered. This effect and the finding that *Practice* maintained and improved procedural knowledge over one week, despite not working with the videos or the program during this time, confirms the theoretical assumption that practical, active learning stimulates deep processing and thereby transfer (Anderson, 1995a; Salomon & Perkins, 1989). However, this was not true for declarative knowledge because the learning results could not be maintained and were worse at the second measuring point. However, from our transfer definition, which is to a great extent ‘procedural-to-procedural’ transfer, *Practice* was not expected to have an effect on declarative knowledge. Surprisingly in this context is the fact that declarative knowledge in general and in the multiple-choice questions was worse after one week, yet declarative knowledge in the open-ended questions had improved. Normally, one would expect that it would be easier to recognise something than to recall it. This effect was determined to be a confirmation of the benefits of the design variant *Label*. *Labels* not only help to distinguish the important features from the unimportant ones (Decker & Nathan, 1985), but they also give names to the sub-goals (Catrambone, 1996). Hence, concepts were learnt in a manner in which they could be readily reproduced. The fact that the accuracy of knowledge is lost after one week follows the normal curve of forgetting. The *Label* condition led to the best performance for procedural knowledge in general, and with near transfer and far transfer. On a theoretical basis, this result falls in line with our expectations that learning with labelled sub-goals foster transfer to new problems (Atkinson, Catrambone & Merrill, 2003). No significant effect was found for *Label* or *Pacing* in terms of declarative knowledge. As in the first study, there was no found difference in motivation and acceptance between the groups. This is a rather surprising effect in the context of learning a new computer application because many studies show that users are motivated by actively working in the learning environment (Wiedenbeck, Zavala, & Nawyn, 2000). However, in this study integrating *Practice* in the form of guided exploration cards could not re-confirm this finding. However, adding *Practice* did lead to higher motivation levels amongst the strongest performers. In Experiment 1 the reverse pattern was found. However, the question remains if and how motivation changed during an experiment. Motivation and acceptance were assessed once at the end of the first session. It could be very interesting to assess it twice, before and after the intervention, in order to measure any changes in motivation during the experiment and across experimental conditions.

To sum up, future research needs to prove the potential of the present approach in a real-life scenario and to replicate these findings in order to assure the design framework for on-screen videos. Due to the experimental setting, the maintenance of knowledge was tested over two intervals in between which no training took place. In real-life learning situations like school, for example, learning happens continuously over multiple learning sessions. It can be expected, but needs to be proved, that more learning sessions would further enhance the learning results possible with on-screen videos. Furthermore, a number of other factors are anticipated to have an influence; in particular self-efficacy, which is related to the quantity of effort and the willingness to persist in a task (Bandura, 1997; Linnenbrink & Pintrich, 2003). Another possible factor is the amount of previous experience with a medium, which influences performance by increasing the motivation to learn (Smith-Jentsch, Jentsch, Payne, & Salas, 1996). All these factors might be seen as a further enlargement of the described design framework. However, after conducting two studies with on-screen videos it can be stated that an instructionally designed transient medium leads to stable and promising results. As such, it might be time to recognise dynamic visualisations for the valuable learning medium they are.

6 General Discussion

This final chapter gives an overall summary of both studies and the results are discussed in synopsis with a theoretical perspective. Following this, limitations of this research and fruitful lines of future research are pointed out and are discussed together with practical implications. Finally, a conclusion is drawn.

6.1 Summary and Discussion of Results in Synopsis With the Theoretical Perspective

This thesis centred around the following two main questions: (a) what possibilities do dynamic visualisations, especially on-screen videos provide (e.g., the possibility of learning-by-observation and of learning from worked-out examples)?; and (b) how should instructional design be constructed so that on-screen videos are successful? Both questions might be influenced by the prerequisites of the learners (e.g., knowledge in the learning domain and, albeit indirectly, cognitive abilities or skills such as ‘visual literacy’, see section 6.2.3). After having conducted two experiments, four main conclusions can be drawn: (1) on-screen videos are an effective learning tool for learning-by-observation; (2) an appropriate instructional design is necessary to assure that learners deeply process the modelled worked-out examples and that learning outcomes and retention are enhanced; (3) *Practice* is necessary to fostering transfer; and (4) on-screen videos (in combination with *Practice*) possess good motivational potential but do not stand out in this regard in comparison to other learning methods (e.g., learning-by-doing). These four findings help to dispel three persistent myths: Namely, that the association of videos with television hinders deeper processing, thereby dimming the possibility of reasonable learning results (Palmiter et al., 1991; Schmidt & Bjork, 1992) (Conclusion 1 and 2), and, thirdly, that videos are a particularly motivating learning tool (Conclusion 4). This was found in both experiments. The finding of Experiment 2 that that *Practice* fosters knowledge compilation (Conclusion 3) (Anderson, 1983) is in line with numerous existing research results.

6.1.1 On-Screen Videos are an Effective Learning Tool for Learning-by-Observation

On-screen videos lead to good learning achievements in declarative and procedural knowledge. Even in comparison to other learning methods such as, for example, learning-by-doing, they proved to be better (Experiment 1). From a theoretical point of view, it can be stated that learning-by-observation based on social learning theory (Bandura, 1977b) is indeed very successful. In contrast to the classic learning-by-observation approach, in this research the solution of a worked-out example was modelled, putting emphasis on the solution or solution steps and not on criteria of the model (e.g., normally the model is presented by a person). If a person is the model, criteria like similarities and emotional connections between the model and the observer, consequences of the shown behaviour, vicarious rewarding, and social status or social power of the model impact the nature and effectiveness of the observation. These features no longer have any influence when a worked-out example is modelled.

Another difference was that the modelling was not performed “live” (e.g., the Cognitive Apprenticeship, Collins et al., 1987), but recorded and displayed with on-screen videos. Videos are the ideal medium for displaying modelled behaviour because important parts can be specifically highlighted. However, there is often confusion concerning the outcomes while learning with videos: Those involving attitudes and those involving skills. Attitudes can be learnt unintentionally (Bandura, 1986), this is one reason why violence in movies and video games might be of concern. In this research the experiments were introduced as a study about skill acquisition. Therefore, more than mere observation, intentional effort and practice were necessary (Schwartz & Hartman, in press). The relevant learning contents had to be recognised as important from the onset. Subsequently the learning contents had to be deeply processed. This involved the building of a mental model of the learning situation (Gioia & Manz, 1985) and breaking down complex skills into sub-skills. All this was supported by the integration of the instructional design variants *Labelling* and *Pacing*, which will be discussed in the next section (see section 6.1.2).

A necessary pre-requisite for successful learning-by-observation through videos is good design. Therefore, videos in this research were designed according to the following principles: (1) adhere as closely as possible to the multi-media principles (Mayer, 2005), which will be discussed later in this section; and (2) implement the instructional design variants for the purpose of reducing extraneous cognitive load (e.g., caused by the split-attention effect) and enhancing germane cognitive load (e.g., deep processing) (see section 6.1.2). Crucial in this respect is the determination of a learning goal and solid infrastructure in the learning environment.

The learning goals: The selection of learning contents is closely associated with the selection of a learning goal and thus directly with the instructional design variants. A good example, that was already used to illustrate the importance of this decision, is if someone wants to learn a new sport. Four totally different learning goals are imaginable: (1) playing; (2) explaining; (3) evaluating good play; or (4) learning more (Schwartz & Hartman, in press). In each case the learning contents would be different. In this research there were two main objectives: (a) learners should acquire declarative knowledge about the computer application and (b) should be able to actually use the program afterwards to solve both familiar and new tasks (procedural knowledge: near and far transfer). In the sport metaphor, these objectives would be the acts of explaining and playing. In the context of learning a new computer application, providing a concrete learning goal like solving tasks can easily induce task orientation. Task orientation is especially crucial in this learning domain because the user cannot otherwise build a mental model of the system (Gong & Elkerton, 1990). Having a coherent understanding is utterly necessary as research on training, tutoring, and lecturing suggests that skills are more successfully developed and maintained when they become part of coherent understanding of the domain (Aleven & Koedinger, 2002). Furthermore, task orientation is closely related to authenticity; an important design principle that was realised in the two experiments conducted. Authenticity is hereby defined as the degree to which videos actually teach a particular computer application. Furthermore, it refers to the adherence of test tasks to the learning process (Shaffer & Resnick, 1999). Finally, authenticity is important for the ecological validity of a study and consequentially for the generalisability of the learning results. In order to achieve the learning goal 'declarative knowledge', the content-related design variant *Label* was implemented. For the realisation of the goal 'procedural knowledge', *Pacing* was introduced in Experiment 1 to encourage flow and short practices were implemented to foster transfer in Experiment 2 (see section 6.1.3).

Level of structure: In contrast to unguided learning, this research showed that learning with worked-out examples with set learning goals enables learners to use their cognitive capacity to concentrate on crucial learning processes. The results of Experiment 1 confirmed these findings because the videos containing a modelled worked-out example led to better learning outcomes in both declarative and procedural knowledge than the explorative approach. Several studies have shown that if the learning goal is set on a rather general level it might overburden the learner as he has to set or formulate the goal or task on his own. This problem is frequently encountered in learning a new computer application. Explorative learning approaches have shown limited success in this context (Charney et al., 1990). This finding was also confirmed in the first experiment (see chapter 4). What is more, the lack of a specific learning goal is not only a problem while learning with computer applications, but holds true in many domains; unless learners have sufficient prior knowledge that provides internal guidance (Kirschner, Sweller, & Clark, 2006). Minimal guidance might not only be ineffective but also harmful (Clark, 1989) as nothing, very little or "wrong" concepts might be learnt.

The multi-media principles: The basis for the design of the on-screen videos on a general level was the idea that the instructional design variants have to be integrated if they are to produce the desired effect. Therefore, all fourteen multimedia principles (Mayer, 2005; Mayer & Moreno, 2003) were realised (see chapter 4.4). With the exception of the segmenting principle and the worked-out examples principle, none of these principles were explicitly tested. This is discussed further in the next section as success of all principles has been confirmed in various experiments. In any case, to ensure good quality videos it is recommended that all principles be realised.

6.1.2 The Importance of Instructional Design Variants

In Experiment 1 *Labels* improved learning achievements with respect to declarative knowledge in comparison to a learning-by-doing standard introduction. Furthermore, retention improved when tested three days later. Especially against the background that other studies on learning with videos showed unstable retention, (Palmiter & Elkerton, 1993; Palmiter et al., 1991) this is a very positive finding. It can be concluded that *Labels* indeed serve as cues for creating sub-goals (Catrambone, 1996). In Experiment 2, in which *Practice* was included, it was demonstrated that the awareness of meaningful building blocks is important for the development of procedural knowledge in general and for near and far transfer. In the second experiment, the *Label* group fostered procedural knowledge building at the immediate post-test and at the delayed post-test one week later. In fact, results were even better at the second test (see chapter 4.6 and 5.7 for a detailed discussion). The same is true in terms of near and far procedural knowledge. These findings are in line with the contention that knowledge acquisition proceeds from a declarative to a procedural compiled form (Anderson, 1993, 1995b). Acquiring knowledge about individual steps and their function (i.e., the sub-goals to be achieved) facilitates the construction of procedural knowledge, especially in combination with *Practice* (see Experiment 2). As this process generally takes some time, immediate testing can often be a poor indicator of long-term retention (Bjork, 1994; Linn & Eylon, in press). Thus it may not be surprising that results were better at the delayed post-test.

The effects of *Pacing* – the second instructional support variant – also built on the segmentation of the overall solution into small meaningful building blocks. It fully corresponded to the expectations that *Pacing* would be particularly effective when the learners learnt merely by observation (Experiment 1). If *Practice* is not available, *Pacing* is necessary to fostering procedural knowledge acquisition at the immediate post-test. *Pacing* involves the learner in a 'procedural way' during the learning phase. In this study, if the learner was not attentive and did not click at the crucial point of a meaningful building block, the video ceased playing. Indeed the learner could avoid an interruption if he was actively engaged in the learning and "anticipated" the important steps by clicking before the video stopped. That said, recent studies have demonstrated that it makes no difference if *Pacing* is induced by the learner or the system. The important point is that the learning flow be paced in some way (Moreno & Valdez, 2005). By integrating *Pacing*, extraneous cognitive load can be reduced (Bodemer et al., 2004). Cognitive load was not assessed explicitly in this research but the results show that *Pacing* produced better procedural results in comparison to the video control group without any instructional design (Experiment 1). This might be explained by the fact that the temporal split attention effect was avoided by the *Pacing* and thereby greater cognitive capacity could be dedicated to deep processing. In Experiment 2, with *Practice*, *Pacing* no longer had such a large influence as any benefits were considered the result of the *Practice* element.

Both instructional learning variants had very positive effects: In Experiment 1 the video groups not only performed better than the learning-by-doing group, but the three instructionally designed video groups also performed better as the video-control group when procedural knowledge was regarded as an overall value for both post-tests. Thus, it can be concluded that videos serving as worked-out examples are a new, but effective variant of the worked-out example principle. It was demonstrated that the modelled worked-out example led to better understanding as the learners learnt not only quantitatively more than the learning-by-doing group, but they also mastered qualitatively more demanding concepts. However, even after having established a good overall quality of on-screen videos, it was clear that learning-by-observation from modelled worked-out examples does not happen automatically as videos are a transient medium that places heavy demands on working memory. Therefore, a special focus was put on avoiding overload, reducing extraneous cognitive load and stimulating deep cognitive processing (Sweller & Chandler, 1994). The finding that a learning tool enjoyed by learners does not necessarily lead to the best results can be contradicted (Schmidt & Bjork, 1992). Additionally, it is assumed that dynamic visualisations impose heavy demands and hinder deep processing of the learning contents (Atlas et al., 1997). By introducing worked-out examples, cognitive load is reduced. This could be confirmed in Experiment 1 by the video versus standard introduction comparison. However, extracting the message of a dynamic visualisation is still challenging and requires instructional support. Therefore, the design of the worked-out examples was based on the meaningful building blocks guideline (Renkl, 2005) that draws on the sub-goal approach introduced by Catrambone and Holyoak (1990). Using Mayer’s (2005) terminology, this is called a segmenting principle. By segmenting the overall solution, emphasis is placed on making the sub-goals salient by assigning them a *Label* or visually isolating them. The provision of a *Label* makes the learner aware of what is going to be learnt. Furthermore, realizing the meaningful building block guideline counteracts the tendency of learners to represent the problem solving procedures of training problems or worked-out examples as a set of linear steps (Atkinson & Catrambone, 2000), which are then mimicked and not deeply processed. The results of the two experiments show the success of implementing this guideline.

6.1.3 Practice is Necessary to Fostering Transfer

As the goal of fostering far transfer was not achieved in Experiment 1, the question arose if fostering far transfer is possible without *Practice*. Consequentially, *Practice* was integrated in Experiment 2 as a new independent variable. It was already mentioned in the last paragraph that transfer can be seen as gradual compilation from declarative to procedural knowledge and occurs as a consequence of *Practice* (Anderson, 1983). By integrating *Practice*, emphasis was placed on the second and the third stages of Anderson’s model. The second associative stage is an in-between stage, as part of the knowledge is declarative and part of it is compiled. In the third autonomous stage, procedural knowledge is compiled, fast and error-free accessible. Whether the third stage was actually reached here requires further investigation. However, the *with Practice* conditions worked faster and with fewer errors; thereby achieving significantly better results in procedural knowledge in general and in far transfer.

It was shown in Experiment 2 that the *Practice* groups not only achieved better results in general but also, and especially gratifyingly, in far transfer. Additionally beneficial was the instructional design variant *Labelling*. This counteracted the tendency of learners to represent the problem solving procedures of training problems or worked-out examples as a set of linear steps (Atkinson & Catrambone, 2000). Therefore, these steps could be successfully applied to solve novel problems (Singley & Anderson, 1989). Far transfer, in this case, was not limited to procedural-to-procedural transfer but also required inferences to be drawn (see section 5.2.2). If inert knowledge (Renkl et al., 1996) is to be avoided, transfer must be deep-level oriented from the onset of instruction. This means that the focus has to be on conceptual and connected understanding and it must be orientated toward learning for transfer (Prawat, 1989; Renkl, 1996). Thereby, prior knowledge and the authenticity of the learning context play a crucial role. Both factors influence the strength of knowledge encoding in memory; which is a, if not *the* critical factor for the accessibility of declarative knowledge and the performance of procedural knowledge. Another influential factor is the elaborateness of the learning material. This depends on the depth of processing and the amount and type of practice (Anderson, 1995b). Consequently, forgetting is less likely, as can be seen in Experiment 2 where the retention of procedural knowledge actually improved at the delayed post-test. The rate of forgetting over a period of time is dependent on the number of steps required to perform the tasks. If the steps are not cued, they are even more likely of being forgotten (Druckman & Bjork, 1991). This was demonstrated in Experiment 2: *Labels* indeed served as a cue and thereby supported the maintenance of the learning achievements. *Practice* is not only central to ACT-R theory, but also within the two phases of observational learning theory: Especially, (1) in the retention process phase in which the modelled behaviour is symbolically represented in memory and behaviourally rehearsed; and (2) in the motor reproduction phase in which the learnt skill is used in various procedures to enhance transfer (Bandura, 1977a; Manz & Sims Jr., 1981). When *Practice* is available and the learner is independently active during learning, the effect of the instructional design variant *Pacing* diminishes. To sum up, whether to include *Practice* in the learning environment depends on the learning goal. If far transfer is the goal, it is strongly recommended. If procedural knowledge in general is enough, one can use the *Pacing* variant instead.

Another idea for future research would be to change the point at which *Practice* is integrated into the learning environment. When *Practice* is integrated prior to watching a movie, it can have a significant effect on mid-term retention (Baggett, 1987). By practicing, the learner is able to develop a mental model that is reinforced by viewing the film. A recommendation for future research might, therefore, be to think about the ideal placement of *Practice* in the learning process.

6.1.4 The Motivational Potential of On-Screen Videos

In both studies, motivation and satisfaction values were settled in the upper part of the rating scales, but in Experiment 1 there was no difference between the video conditions and the learning-by-doing group. The same was true in Experiment 2 between the *with Practice* conditions and the *without Practice* conditions. A rather low correlation between the learning results and the motivational values indicated that there was no close relation between them. Consequentially, only between 4% and 11% of the variance can be explained. Nonetheless, the kind of pattern found between learning achievements and motivational values was of interest. In Experiment 1 (*without Practice*), the best learners were not very motivated, whereas the worst performers were quite motivated. The reverse pattern was found in the *Practice* groups: The best learners were the most motivated and the lowest achievers were the least motivated. Nevertheless, motivation is considered to be a crucial factor for transfer. This will be discussed later in this section 6.2.3.

These results contradict the finding that dynamic visualisations are more motivating than other learning methods (Waterson & O`Malley, 1992) and can be used as an extrinsic motivator. Motivation and acceptance were assessed in both experiments as their existence makes it more likely that learners stay interested and maintain their concentration for a longer period of time (Rieber, 1991). For the same reason motivation is a highly important feature of the CTLM (cognitive-affective theory of learning with media, see section 3.1.3) (Moreno, 2005). A possible danger is the inverse relation between interest (as one construct of motivation) and achievement: New learning tools like videos provoke interest.

Unfortunately, this interest is occasionally triggered by the expectation that learning might be much easier with these tools. As a result, less effort is put into learning, which can lead to lower learning achievements. However, this was not true for the two experiments in this research as the ‘effort’ scale had the highest scores in each case.

6.2 Limitations of Results, Practical Implications and Directions for Future Research

An important question deals with the generalisability of the findings of this research. Possible restrictions are discussed with respect to generalisability. Based on this, fruitful lines of future research are proffered.

6.2.1 The Learning Media

The variants of videos and their possibilities of usage are plentiful. In this study, the design concept was tested exemplarily with a special variant of videos, namely on-screen videos. Unique for on-screen videos is that they show what is happening on the screen. Thus, the two main possibilities of use are showing: (1) how to use or get started with, for example, a learning environment; and (2) how to learn a new computer application. However, as declarative and procedural knowledge have to be acquired in the latter case, they have more the status of an educational video. Educational videos are used to learn historical facts (Tibus & Schwan, 2006), and certain skills like arguing (Schworm & Renkl, 2005) or being cooperative (Rummel & Spada, 2005). They can be used both in individual and collaborative settings. The use of the herein tested design concept in collaborative learning settings has yet to be proven. From a practical point of view, it can be assumed that the design concept can be, at least partially, generalised to other learning settings using videos where the learning goal is also knowledge acquisition.

The instructional design variant *Labelling* is particularly expected to be successful. Integrating *Labels* can easily support the goal of most educational videos; that is, to learn facts. Furthermore, it is imaginable to integrate *Labels* in other dynamic visualisations, such as animations. If procedures have to be learnt, it is recommended to integrate *Practice* in order to stimulate far transfer. The application of the instructional design variant *Pacing* is seen rather limited only for the above described variants of on-screen videos, particularly when interactivity is important when it is learned how to use a learning environment or a new computer application.

The finding that the processes while learning-by-observation resemble the ones while learning-by-doing and that even (motor) skills can be learnt was confirmed (Blandin et al., 1999). The verbal description of the modelling is thought to have increased this effect (Decker & Nathan, 1985). The confirmation of these latter two findings has yet to be proved. To sum up, it is assumed that the findings concerning on-screen videos can also be generalised to other variants of videos. However, a confirmation of this conjecture is necessary and constitutes a starting point for future research.

6.2.2 The Learning Domain

Using the ‘learning a new computer application’ learning domain provides the rare case that the experimental testing situation matches the most common application situation of the medium itself. Consequently, an experiment could be conducted without heavy losses in ecological validity. The only differences to a real life setting were the restrictions of time while working with the videos and the tasks. In both experiments the computer application Ragtime® was used due to the fact that it was unknown to the users. However, it is expected that the design concept can be fruitfully used for any other computer application or for any kind of introduction into a new learning environment as well.

6.2.3 The Learners

***Prior knowledge*:** In this study, it was taken into account that nowadays most learners already possess experience and knowledge about computer applications. This was confirmed by the pre-test on existing knowledge. As there is evidence that observational learning is particularly recommended for learners with intermediate knowledge (Jentsch et al., 2001), only learners at this level were eligible to take part in the study. Only learners with too little knowledge had to be excluded as there were no situations where knowledge exceeded the intermediate level. Nonetheless, there was still a range of knowledge among learners. The positive learning results clearly provide evidence for the adequacy of the intermediate knowledge criterion. However, whether the findings can be generalised, and if and how the effectiveness of the instructional design variants might change with another level of expertise (cf. expertise reversal effect, Kalyuga et al., 2003) remain unclear. The videos may have been too quick for learners with little prior computer knowledge. A possible and easy solution in this case is to provide them a VCR controller so that they can rewind and review sections at will. However the use of this controller has to be prompted. Another approach would be to integrate *Practice* at an earlier point of time.

Like in the *Label* conditions, providing an overview slide with all the upcoming steps would enable learners with high prior knowledge to omit the steps they already know and concentrate on those they do not. Furthermore, experts might not need to perform the included practices. Interestingly, initial results indicate the possibility of a totally different solution: Learners with high prior knowledge might profit more from working on *Practice* problems than modelled worked-out solutions (Reisslein, Atkinson, Seeling, & Reisslein, 2006). The prerequisite for the realisation of the described steps and for a generalisation of the results is a more active learner beyond a restricted experimental setting. These practical implications are at the same time a starting point for future research. In any case, if the learning environment is to be successful, prior knowledge is a variable that must be considered. The instructional design variants have proven to be adequate for an intermediate level of knowledge. The successful re-formulation of the design for lower or higher knowledge levels has yet to be demonstrated.

Visual literacy: Another factor potentially influencing learning achievements might be the visual literacy of each particular learner. Visual literacy, a widely neglected consideration, deals with the learners' capabilities or premises to "read" all kind of visual information:

> *Visual Literacy refers to a group of vision-competencies a human being can develop by seeing and at the same time having and integrating other sensory experiences. The development of these competencies is fundamental to normal human learning. When developed, they enable a visually literate person to discriminate and interpret the visible actions, objects, symbols, natural or man-made, that he encounters in his environment. Through the creative use of these competencies, he is able to communicate with others. Through the appreciative use of these competencies, he is able to comprehend and enjoy the masterworks of visual communication (Debes, 1969).*

Besides this classical definition, there are currently vast numbers of multi-faceted definitions of visual literacy from a number of academic disciplines. The diffusiveness of this definition is also based on the fact that visual literacy is an interdisciplinary concept for all kinds of media. For example, visual literacy is researched within linguistics, art, psychology, media pedagogy and philosophy. Unfortunately, there is no research known to us which deals particularly with visual literacy in the context of dynamic visualisations from a psychological perspective. Hence, this research relies on rather general findings, namely, that visual literacy is an important pre-requisite to interpreting and learning with dynamic visualisations. As such, while visual literacy is something learners come in with, it can always be further developed (Weidenmann, 1994). Furthermore, several studies have shown that visual attention is best stimulated when the material has a medium level of difficulty (Huston & Wright, 1983). Visual attention is especially needed in the retention phase of Bandura's learning model (Bandura, 1977b). If the material is too simple, illusions of understanding are the likely result (Weidenmann, 1994). In fact, simple material evokes reduced cognitive effort (Salomon, 1984), resulting in an illusion of knowing (Glenberg et al., 1982) or an illusion of simplicity (Hansen, 2006; Nickerson, 1999). Hansen (2006) found the illusion of simplicity especially dangerous because it causes shallow processing when learners are already familiar with the learning material. Learning with videos might also possess this danger; as the results in Experiment 1 showed: The video control group, without any instructional design variants stimulating deep processing, showed significantly worse results in procedural knowledge than the instructionally designed video groups. It remains to be seen if videos that are *too* well-designed possess the inherent danger of leading to illusions of understanding and reduced visual attention.

However, as there is no scientific knowledge about the effects on individual differences in visual literacy on learning, learning situations where visual attention is guided are recommended. Therefore, green highlights were integrated. In contrast to some findings that suggested that highlights or cues offer no advantages in dynamic visualisations (Hoeffler & Leutner, 2005, August), our findings suggest that the signalling principle is absolutely necessary to guiding the learner's attention in a transient media and thereby avoiding unnecessary extraneous load. Green highlights were integrated in the two experiments in order to focus the learner's attention on the relevant material. It was expected that colour coding enhanced the visual processing of the learning contents more effectively (Folker et al., 2003). To test this hypothesis an eye-tracker has to be integrated in the experimental setting in future experiments. Hence, in the context of worked-out examples, cues highlighting the organisation of the learning material led to deeper processing (Renkl, 2005). In sum, it is important to be aware of individual differences in visual literacy. Ideally and practically, a baseline of visual literacy should be determined. Then it would be possible to assess if one’s ability to deal with dynamic visualisations is trainable.

Motivation and acceptance: Other possible variables that can place a limitation on the generalisability of these findings are motivation and acceptance. As a starting point in assessing this, several studies eluding to the motivational potential inherent in dynamic visualisations (e.g., Waterson & O’Malley, 1992) were examined. In these studies, scales such as interest, challenge, flow, effort, and perceived competence were tracked, but they fell short of examining how the motivational potential of dynamic visualisations was judged by the learners in comparison to other learning tools. In Experiment 1, this was assessed indirectly as a learning-by-doing condition was implemented into the four video conditions. Similarly in Experiment 2, the effect of *Practice* on motivation and acceptance was indirectly assessed. However, in both studies no differences were found between the different conditions. Two explanations for this finding might be that: (1) there are no differences existing between different learning methods; or that (2) motivation and acceptance were both assessed at the very end of the first session. As such they measured ‘experience’, whereas assessing them beforehand, as other studies have done, measures ‘attitude’.

Nonetheless, motivation and other related concepts are expected to be a crucial factor, in transfer. In Experiment 2, the results also show significant correlations between the transfer measures and motivation. Both, motivation and acceptance, are accompanied by extensive bodies of literature; which have not been well integrated yet (Pugh & Bergin, 2006). Transfer has been regarded primarily from a cognitive perspective and not in combination with motivation. Thereby, there is lot of evidence available that there is a close relation between interest and cognitive engagement. If interest is provoked by important features of the learning content, it leads to deeper processing and consequently to better learning results (for an overview compare Pugh & Bergin, 2006). A pending question is why some students are involved, engaged and motivated and others are not (Linnenbrink & Pintrich, 2003). A variable providing a possible answer to this query is ‘self-efficacy’, which is defined as “people’s judgments of their capabilities to organise and execute courses of action required to attain designated types of performances” (Bandura, 1986, p, 391).

Linnenbrink and Pintrich (2003) suggest an interesting framework that distinguishes between behavioural, cognitive and motivational engagement. Self-efficacy is conceptualised as an antecedent that indirectly influences learning and achievement through the three aforementioned engagement possibilities. Learning and achievement then reinforce self-efficacy. As described before, this model is not yet complete: It misses connections between the three engagement variants, for example, that motivational engagement, like interest, might influence the use of strategies (cognitive engagement) or persistence (behavioural engagement). Furthermore, transfer is not considered. To be more comprehensive, factors besides the characteristics of learners, such as self-efficacy, must be considered. For example, characteristics of the media and the task also, presumably, have a mediating effect through the engagement factors of learning and transfer (Cennamo, 1994). Therefore, more emphasis on the connection between motivational variables and transfer, as it has been done in this study, is needed in future experiments. This would contribute to the completion of this framework introduced by Linnenbrink and Pintrich (2003).

6.3 In Closing

The aim of the two experiments was to investigate the potentials, possibilities and limitations of dynamic visualisations; in particular using on-screen videos as a learning tool. The findings revealed that generally well-designed on-screen videos indeed have the potential to be an effective and efficient learning tool. The instructional design, however, is dependent on the learning goals and the level of the learner's prior knowledge. The big challenge in instructional design is to maximise the effort that learners put into elaborating content while minimising the effort they must expend to make sense of this content (Cennamo, 1994). In doing so, learners retain enough cognitive capacity to concentrate on deep processing. Modelling a worked-out example has proven to be an adequate strategy. It is recommended to integrate *Labelling* in any case. This means to assign each meaningful step of a solution procedure with a *Label*. While mere observational learning can foster declarative knowledge, adding *Practice* improves procedural knowledge in general and especially in far transfer. If *Practice* cannot be part of the learning environment, *Pacing* in form of an interactive click button set at the crucial point of a step should be integrated to ensure general procedural knowledge acquisition.

In sum, even when these findings concerning dynamic visualisation allow a rather optimistic perspective, a number of research issues concerning instructional design and the use of on-screen videos remain. For example, one must take into account the existing differences between learners and, more importantly, the growing differences between them as a result of knowledge and skill development (de Jong, 2006). As such, the development of an adaptive learning environment remains a necessary field of research. That said, it is once again stressed that the learner is to be placed at the centre of these efforts rather than the technology. The following quotation addresses this aptly:

> *The potential for computer-based aids to learning environments remains high, although the current contribution of technology to pedagogic innovation is frustratingly low. Instructional development is too often based on what computers can do rather than on a research based theory of how students learn with the technology. In particular, the visual-based power of computer technology represents a grossly underutilized source of potential educational innovation (Mayer, 1997, p. 17).*

I hope that this dissertation contributes to efforts to exploit the full potential of dynamic visualisations like on-screen videos and stimulates further research in this area.

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