COMPUTER-BASED INSTRUCTION IN TRAFFIC THEORY

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ABSTRACT

The current curriculum for traffic theory at the driving school of the Royal Netherlands Army requires relatively much instructor time and it does not prepare student drivers very well to participation in every-day traffic. In order to increase the practical relevance and efficiency of instruction in traffic theory, the staff of the driving school has decided to develop a computer based instruction (CBI) program utilizing multimedia facilities to create a functionally valid and interactive learning environment. This paper reports the results of the psychological and instructional analyses underlying the CBI program.

Analyses of the driver's mission and associated tasks have been carried out to identify the relevant task knowledge for theoretical instruction. The perspective taken on the learning mechanisms underlying the acquisition of knowledge and skills indicate that information is to be presented in functional and realistic task settings. These principles have been elaborated into an instructional design by utilizing theories of instruction eclectically. A number of fundamental design issues are discussed in this paper. It is concluded that the combined technology of computer based instruction and multimedia facilities offer the means to accomplish the principles presented in this paper and should enable students to become better drivers with fewer practical lessons.

INTRODUCTION

The curriculum for learning to drive a passenger car at the driving school of the Royal Netherlands Army consists of 26 hours of practical lessons and 12 hours instruction in traffic theory. Education in traffic theory is fairly traditional: an instructor explains the text book by using slides and schematic pictures. Classes consist of approximately 10-15 students. In order to make theoretical instruction more effective and efficient by means of individualization and differentiation, the staff of the driving school has decided to develop a computer based instruction (CBI) program. The program should utilize multimedia facilities to create a functionally valid and interactive learning environment. This paper reports the results of the psychological and instructional analyses underlying the CBI program rather than discussing technical system specifications.

ADVANCED LEARNING AIDS IN THE ROYAL NETHERLANDS ARMY

In the past decade, the Royal Netherlands Army has been confronted regularly with substantial budget cuts, leading to personnel reductions. The new circumstances compel the army training centres to develop more effective and efficient training courses that require a minimum of instructor time. An important strategy in the army's policy for achieving that goal is to develop advanced learning aids, such as computer based instruction and simulators.

One of the advantages of CBI is that it is more flexible than traditional classroom instruction. Students can work with the program at self selected moments and individual differentiation in difficulty level and speed is possible. Because students can more easily be made active, this type of instruction is often effective and highly motivating.

New sophisticated technology has expanded the potential of CBI programs to create realistic interactive learning environments. Until recently, static pictures were about the technological limit.

Now it is possible to combine a variety of media, like printed text, spoken comment, sound, static and moving pictures (digital video), animations, in one multimedia application. If the student has, to some extent, control over the (instruction) program (e.g. starting a video clip, requesting spoken feedback, zooming in on a detail of a picture, etcetera), this is called an interactive multimedia program. An important question is whether this new technology not only looks better, but also improves instructional effectiveness. Earlier research has yielded ample evidence that the efficacy of training courses can indeed be increased by advanced learning aids, provided that the application of the technology is grounded in a consistent theory of learning and a sound framework of instruction (Baggett, 1988; Fletcher, 1989; Smith, 1987).

The implementation of the army's policy is already started. As yet, the standard platform selected for developing multimedia programs is the IBM Ultimedia M77. This configuration will be installed soon on all training centres.

THE ARMY'S EXPERIENCE WITH CBI IN TRAFFIC THEORY

In 1988, in the context of an explorative study into the potential of CBI for the army, a commercial software company developed and implemented a CBI program in traffic theory utilizing interactive video. The objective of that program was to prepare student drivers more adequately on the driving task in actual practice(lessons). The implication of that goal is that the instructional material should not be confined to statutory traffic rules alone because safe and alert driving is to a large extent determined by implicit and informal rules. Knowledge of these rules, and understanding as to why the application of such rules increases a smooth and safe traffic flow is therefore considered to be part of student drivers' education. The trial program consisted of two, separated parts. One part addresses a number of chapters of the traditional textbook method. The other addresses the more implicit rules.

The program did not satisfy the staff's expectations on all points. As a result of its cursory structure and the emphasis on explicit knowledge of formal rules, the program does not harmonize sufficiently with actual task performance. The choice to divide formal and informal task knowledge in separate modules does not seem to be a very good approach because prerequisite knowledge for task behaviour is not being addressed integratively, but at different moments in the curriculum. Another criticism is that the interaction between student and program is limited to navigational aspects (clicking the "proceed" button) rather than with respect to content. The video facilities were insufficiently exploited to offer students the opportunity to actively apply the acquired theoretical knowledge in presented traffic situations. The developers of the program deserve credit, however, for the technical competence with which they implemented the learning aids in the program. This convinced the staff of the driving school that multimedia computer based instruction programs are potentially effective for delivering instruction in traffic theory.

OBJECTIVE OF THE PRESENT CBI PROGRAM

Analyses of the driving task often distinguish between vehicle control (e.g. gear shifting, smooth driving along curves etc) and traffic participation (e.g. reacting to other drivers and applying traffic regulations) (Van den Bosch, Korteling and Padmos, 1994). Vehicle control tasks can best be instructed and trained in the actual vehicle or in a simulator. The goal of the present program is to teach the relevant theoretical knowledge and skills required to participate correctly in actual traffic. Transfer from theory to practice is therefore considered essential. In short, the objective of the program is formulated as follows:

> "Teaching prerequisite theoretical knowledge and skills for safe, alert and environment-minded participation to traffic. Furthermore, the program should prepare the student driver to handling certain traffic situations that, for practical or safety reasons, can not be addressed in the practical lessons. Emphasis should be given to cues for recognizing and identifying potential risk and to teaching adequate manoeuvres to prevent or reduce such risk."

LIMITATIONS OF CURRENT DRIVER EDUCATION

The staff of the driving school is convinced that the relation between the current form of instruction and actual practice is too obscure. Two arguments will be presented as to why this may be so. One concerns its philosophy of instruction and selection of instructional material, and the other argument pertains to the instructional settings. These arguments will be clarified in the following sections, and alternative approaches will be presented.

Philosophy of Instruction

The contents of traditional instruction in traffic theory has been derived directly from statutory traffic rules. Instruction therefore focuses on learning definitions, rules, and the meaning of signs. It is up to the student to acknowledge the implications of the information for driving behaviour in actual task situations. Thus, the relation between theory and practice is formal and indirect. For example, students learn to identify the sign indicating a motor-way, learn that a car belongs to the category of motor-vehicles, and learn that the speed-limit for motor-vehicles on motor-ways is 55 miles/hour. Because this information is of a formal nature and presented in a context that has no correspondence at all with the setting in which it has to be used, it is doubtful whether this knowledge will be triggered and applied at the right moment.

The value of theoretical instruction for actual task behaviour can improve significantly if the material to be learned is presented in the context of traffic situations that are functionally similar to the ones students are likely to encounter in real life. Students should therefore be taught how to identify a certain road as belonging to the category of motorways (both on its formal characteristics such as the sign, and on informal characteristics, like the presence of a dual carriageway and a hard shoulder) and how to link this knowledge directly to desired driving behaviour. Such an approach, rather than teaching general rules and principles, will more likely bring about transfer from theory to practice.

Instructional Settings

An other criticism concerns the fact that the situations selected for instruction and testing often provide contexts that do not fit in with most problems encountered in reality (e.g. "Should the white car (driving on an unpaved road) give right of way to the horse and cart (riding on a paved road)?"). A related objection that specifically applies to the testing procedure concerns the phrasing of questions. Questions often explicitly refer to the nature of the problem (e.g. "should the car give right of way to the bike?"). In other words, the student is 'cued' by the way the question in phrased. This is very unlike real-life situations, in which drivers have to recognize the kind of traffic situation, identify the problem, and retrieve the required associated knowledge to solve the problem. It would be better if questions are formulated in a more open and non-directive form, like "should you stop or continue?" or even better: "what should you do next?".

Perspective on learning and implications for instructional design

The design of ffective instruction should be grounded in a consistent theory of learning and a sound framework of instruction (Patrick, 1992). Theories of instruction address the question how the environment should be arranged so that student learn the intended knowledge and skills effectively and efficiently. This question can not be solved unless there is a basic understanding of the psychological principles underlying the acquisition of knowledge and skills involved: the domain of learning theories.

Cognitive psychology has long been dominated by the view that behaviour is the result of strategies executed on internal knowledge representations. Accordingly, studies on how knowledge is represented mentally and how such representations are acquired should provide the key to understanding learning and behaviour. A major criticism against this view is that it discards the influence of the environment (the external representations) in which the knowledge is acquired or applied (e.g. Zhang and Norman, 1994). This criticism has emanated in a new movement in cognitive psychology: situated action theory (e.g. Lave, 1988; Suchman, 1987). Situated action theorists emphasize that task performance is to a large extent regulated by cues of the specific context in which the behaviour takes place. Consequently, understanding task performance and task acquisition processes should involve the important role of the environment in the acquisition, representation, and application of prerequisite task knowledge.

The views outlined above have different implications for instructional design. The traditional view emphasizes the importance of acquiring generic abstract mental representations of task knowledge, whereas situated action theories stress the functional significance and physical validity of the external learning environment.

For the present project we adopt the notion of situated action theories that all knowledge is inextricably a product of the activity and situations in which it is acquired. The specific characteristics of the situation and the performance recast the knowledge in a new and more fully specified form with each new occasion of use. The implication of this perspective for instruction is that the process of knowledge acquisition should be guided by presenting information in a variety of realistic settings, so that students learn to associate and use the relevant knowledge with the implicit and explicit correlates and restrictions of the context in which the knowledge eventually needs to be applied. The aimed association between context and appropriate behaviour requires students to acquire a method for identifying certain (traffic) situations. One way to achieve this is to provide a framework for classifying traffic situations into categories. The nature of this category framework will be discussed in the section "mission analysis".

INSTRUCTIONAL ANALYSES

A system for instructional design, developed at TNO Human Factors Research Institute, was used to identify the training needs (Riemersma and van Berlo, 1993a, 1993b). This approach is related to instructional system development (see Patrick, 1992) and emphasizes the need for analyses to identify the relevant task knowledge, to designate which knowledge should be addressed in training, and to obtain cues as to how the information should be presented and what learning aids or media are most appropriate.

Mission Analysis

In order to develop a task-oriented instruction program, a mission analysis is required to determine the overall goal, or mission, of the system (driver in car) and the position of the system in its context (road system with other traffic) (Boer, 1991). The mission of the driver has been formulated as follows:

"The driver's mission is to ride from one place to another in a safe and alert fashion, thereby minimizing the load to the environment"

The implication is that the student needs to know, understand and select the appropriate manoeuvres for driving in the style specified above.

The context of the system can be classified thematically, with themes corresponding to prototypical road categories, arranged by their functionality and their setting (Janssen, 1991). Three functionalities are distinguished: roads serving local traffic, roads designed to serve large quantities of traffic with long-distance destinations, and roads designed to connect local with interlocal roads. Two settings are distinguished: within and outside the city limits. The structure is represented in Figure 1.

	Primary Function		
	residential	connecting	flow
within city limits	residential area's	give right-of-way road	right-of-way road
outside city limits		country roads	motor ways

Figure 1: Framework for classifying road scenes with examples

Task Analysis

Task analyses have been conducted for all themes. First, relevant clusters of behaviour have been identified. For example, the behavioral clusters for "motorways" are: 'turning onto the approach road and joining the traffic', 'driving and following', 'overtaking', and 'exiting'. The result of the task analysis specifies the prerequisite (internal and external) knowledge and skills for performing this behaviour, the criteria for adequate performance and a specification of possible task conditions. Correctly driving onto a motorway, for instance, requires that the driver can recognize approach roads both on their formal and informal characteristics, that he is familiar with the appropriate driving procedures, and that he is aware of potential complications and knows the proper actions when such situations arise.

Analysis of Target Population

Trainees may vary in terms of past experience, knowledge, skills, age, attitudes, motivation, intellectual capacity, etcetera, all of which can influence how new or related skills are mastered. It is important to assess the characteristics of the target population, i.e. the range of potential applicants, so that the instructional design can accommodate them. The current student group is 18 year old conscripts. However, the planned abolishment of the compulsory military service system in the Netherlands will have its effect on the composition of the target population. This makes a reliable analysis impossible. It is clear, however, that the anticipated target group of professional soldiers will be more homogenous in terms schooling. On average, the level of schooling and the motivation to follow training courses will be below that of the current group. This requires instruction to be directive, attractive and explicit.

Training Analysis

The purpose of training analysis is to specify the instructional objectives, determining both the content and design of instruction and also what the students should be able to accomplish after following the program. Objectives are specified, according to Mager (1962) in a behavioral components (e.g. "maintaining an appropriate following distance"), a conditional component (e.g. "on a clinker paved right-of-way urban road under rainy conditions"), and a criterion component (e.g. "anywhere between 20-40 meter"). Instructional objectives differ in type. They can refer to factual knowledge (e.g. the meaning of a particular road sign), conceptual knowledge (e.g. categorizing a road scene as member of a certain category), procedural knowledge (e.g. prescribed action sequence when overtaking), or understanding principles (e.g. the relation between road conditions and stopping distance). Each type of instructional objective requires its own instructional strategy and learning media for achieving them. It is beyond the scope of this paper to discuss these guidelines for instruction in detail, but a few issues are discussed in the section "selection and use of media".

INSTRUCTIONAL DESIGN ISSUES

The results of the psychological analysis provide the framework for the general approach, which should now be elaborated into global specifications for an instructional design. A number of different methodologies for instructional design have been proposed in the literature (e.g. Gagné, 1985; Merill, 1983). For this program we adopt an eclectical approach. A number of important design issues are discussed in the following sections.

Learner Control

An important question in the design of a (computer based) instruction program is how much guidance should be provided. An often recommended approach is exploratory learning, in which students are completely free to delve into the material to acquire the knowledge and learn the relations between the elements (Mager, 1961). Because the instructional elements in traffic theory are interrelated and some elements are prerequisite for the mastery of others, constraints in the student's freedom are necessary (Gagné, 1985). We therefore adopted an approach with both directive and explorative characteristics. A directive approach is used for learning arbitrary information. For instance, the design of a traffic sign is often arbitrary, as is the rule to keep the right side of the road. It is rather senseless to let students 'discover' this knowledge. Explorative teaching is used for learning material in which clear relations can be distinguished. For example, the design of road types is logically related to their function, and it might be instructive to let student discover these relations.

Mastery Learning

In traditional methods of instruction, the curriculum is arranged in such a fashion that it fits the average student. For the present instruction program it was decided to embrace the concept of mastery learning (Bloom, 1971), stating that the selection and presentation of instructional material should accommodate each individual student. All students should eventually pass on all learning objectives. In order to achieve that goal, frequent testing is necessary to continually adjust the type and amount of instruction to the individual's need.

The instructional material for instruction in traffic theory is divided into modules and sub-modules, corresponding to themes (road categories) and behaviour clusters, respectively . After each (sub)module, students receive a series of questions. The sub(module) can only be concluded if the students achieves at criterion or higher. If the student fails, the program assesses problematic sections and provides remediation or additional instruction, followed by a new test.

Integration of Theory and Practice

Driver education currently consists of a theoretical and a practical part, but these parts are not very well integrated in the curriculum. The present program proposes to integrate theory and practice by distinguishing a main and a secondary phase. Relatively standard traffic situations and associated task performance are addressed in the first phase. Students follow computer-based instruction for a particular theme or themes. This prerequisite theoretical knowledge is subsequently put into practice and consolidated during practical driving lessons. The second phase addresses less regular and problematic situations that (sometimes) require specially adapted task behaviour. Again, this phase starts with computer-based instruction. Finally, if possible, this knowledge is again consolidated during practice lessons.

Selection and Use of Media

It has been argued that students can make the link between theoretical knowledge and practice more easily if the information is presented in real-life like contexts. Perhaps the most salient characteristic of real-life traffic is that it is dynamic. The technical capabilities of the system makes it possible to represent the dynamic aspect of traffic situations through digitized video. Video is suited to demonstrate the characteristics and function of a certain road design, to show (potential) problems and conflicts in traffic situations, to show the outcomes of different reactions to a certain problematic situation, and to show the antecedents that produced the problematic situation in the first place.

Running video is, however, not required for all learning objectives. More static aspects of traffic can be addressed with photo's very well. Because digitized photo's can be manipulated relatively easy, they offer more opportunities than simple slides. An example for instruction in road classification may illustrate this point: appropriate or inappropriate features of a road category can be added or deleted at will, thus allowing for effective highlighting of essential characteristics. Defining (invisible) area's in the picture permits the program to respond to requests for information (e.g. by mouse-clicking).

Special attention is required with respect to the production of visuals (photo's/video). In the current method of instruction, visuals are often very schematic. The helicopter-view is very popular, possibly because they allow orderly presentation of information. Well known are helicopter-view diagrams of three- or four-way crossings with conflicts between all kinds of road users. This format allows rules of way to be explained in a compact and orderly fashion. Experience suggests that this seems to be an effective procedure because students learn to solve such problems rather quickly. It is questionable, however, whether such knowledge transfers to the actual task because the driver's view through the windshield is from a totally different perspective. Too many (visual) transformations are required to acknowledge the correspondence between instructional and actual context. Visuals in the present program are therefore taken from the driver's viewpoint, whenever possible.

CONCLUSION

This paper is about the development of a computer based program for instruction in traffic theory. The perspective taken on the learning mechanisms underlying the acquisition of task relevant knowledge and skills impels the information to be presented in functional and realistic task settings. The combined technology of computer based instruction and multimedia facilities offer the means to accomplish the instructional principles of functional fidelity and student activity.

The development of the program is currently underway. Instructional analyses have been completed and guidelines for instructional design are specified. The driving school is working out scenario's for instruction which provide information on the required instructional material (photo's, video, text for spoken comment). A start has been made to collect these materials. In order to test the proposed method of instructional design, a prototype of the program will be developed and, subsequently, evaluated.

Developing a CBI program for traffic theory along the lines presented in this paper is a time and labour consuming job taking considerable more energy than simply transforming the old curriculum into a computerized version. The reward for these efforts is a program addressing theoretical traffic knowledge relevant to actual task behaviour. It is expected that through this program, students need fewer practical driving lessons to become better drivers.

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