A PEDAGOGICAL AGENT’S IMPACT IN AN OPEN LEARNING ENVIRONMENT.

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ABSTRACT
Research suggests that in learning environments that aim at factual knowledge acquisition pedagogical agents can act as tools to direct students’ learning processes. Whether pedagogical agents have a similar impact in more open learning environments has not yet been addressed. In order to fill this gap, this contribution discusses a study in which two experimental conditions are compared to a control condition. In the first experimental condition the pedagogical agent’s interventions are adapted to students’ activities (APA-group). In the second experimental group the agent interferes on fixed time intervals (NPA-group). Results show that the NPA-group outperforms the APA group, while the latter does not differ from the control group.

KEYWORDS
complex problem solving, open learning environments, pedagogical agents, advice.

1. INTRODUCTION
Pedagogical agents (PA) are commonly defined as animated characters designed to operate in an educational setting (Shaw, Johnson, & Ganeshan, 1999). Current research on PAs has mainly used pedagogical agent in learning environments aiming at the acquisition of more factual knowledge that focus on providing content or problem-solving support as the PA’s function (see Clarebout et al., 2002). If used in open learning environments PAs may have to fulfill different functions. Open learning environments (OLEs) are characterized by (a) a complex problem that has to be approached from different perspectives, (b) ample learner control and (c) the availability of a diverse set of support tools (Hannafin, Land, & Oliver, 1999). OLEs are argued to be especially functional for the acquisition of complex problem-solving skills (Jacobson & Spiro, 1995). In OLEs students decide themselves whether and how to use the support tools provided. Ample learner control is installed based on the assumption that learners have the necessary metacognitive skills to monitor and regulate their learning process. In more precise terms, students are expected to be capable of judging when the use of a specific tool is beneficial for their learning. This assumption might be problematic as research on tool use generally reveals limited and/or inadequate tool use by students (see Clarebout & Elen, in press). It seems that students lack the necessary self-regulating skills. Hence, the effectiveness of an OLE can be enhanced when the lack of metacognitive skills is compensated for.

Lee and Lehman (1993) found some initial indications that advice helps students to benefit more from tools and as such might contribute to better performance. While in general advice is indicated, research has also demonstrated that an excess of support can be detrimental (Clark, 1990). Put differently, optimal advice is argued to be adaptive.

Given the nature of OLEs, it seems indicated that PA’s in open versus in closed learning environments have different functions. Whereas in closed learning environments the PA’s main function is to deliver content or support cognitive processing, in OLEs the PA may be mainly directed towards supporting the metacognitive aspects. The cognitive and content support might be part of the tools themselves. In OLEs the main task of an agent can be said to be the encouragement of students’ adequate tool use.
This contribution presents a study that investigates the effect of a PA in an OLE. The research question addressed is whether a PA’s advice positively affects performance and whether this effect is different when the agent’s advice is delivered regularly at fixed intervals or irregularly but linked to students’ actions. Based on the literature it is hypothesized that the conditions with advice will outperform the control group, and that of the three groups the group with adapted advice will show the most increase in performance.

2. METHOD

2.1 Participants

One hundred eighty-five students participated in the study. All students were first year Educational Sciences university students. For participation in this research students earned two credit points for a course on ‘Learning and instruction’. Sixty participants served in the adapted advice condition (APA), sixty-seven in the non-adapted advice condition (NPA) and sixty-one in the control condition (C).

2.2 Materials

Open learning environment. A computer-based program, called STUWAWA, was developed using Marcomedia Director. STUWAWA confronts students with an ill-structured problem: They have to decide what type of drinking cup is the most environmentally-friendly for a music festival, while considering ecological, financial and safety aspects. The complex problem is introduced on video by a member of the neighborhood committee requesting help to solve the problem. STUWAWA contains different types of tools, namely information resources (e.g., information list, videos), performance support tools (e.g., calculator) and knowledge modeling tools (e.g. problem solving script). In other words, tools provide access to information and support cognitive processing (for a more detailed description of STUWAWA see Clarebout and Elen, 2004).

The agent was designed and developed using Microsoft Agent®. The advice of the agent had the following structure. First the students’ attention was drawn, e.g., ‘Hi, here I am again!’; next something was said about what the student was doing, e.g., ‘You’ve been busy for a while, but haven’t taken any notes.’ In a last step, the students were directed towards a tool for which the functionality was explained, e.g. ‘If you continue like this you may forget some important ideas. I advise you to take notes so that you propose a balanced solution’. In the NPA-condition the PA appeared every seven minutes, selecting at random a tool to give advice on. The PA’s advice had a similar structure for all tools. First the attention of the student was drawn by saying ‘Hello!’ or ‘May I have your attention please?’ Next the agent names the tool that will be discussed and explains its function, for instance ‘On top of the screen you can see the problem solving checklist’. This list gives an overview of all steps that you optimally take when solving a problem. This tool helps you to address the problem in a systematic way.’

Pre- and post-test. Immediately after the introduction of the problem students were asked to propose a solution to the problem. At that moment students no longer had access to any information. After working in STUWAWA, they were asked once more to present their solution. The answers prior to and after working in the environment served as the pre and post-test. The number of arguments and considered perspectives within students’ answers were looked at.

Transfer test. After the post-test, students received a new problem. The owner of a copy-center asked them to help him decide on the selection of different types of paper for copying course books.

2.3 Design and Procedure

Students were randomly assigned to the three conditions. The researcher told students that they are asked to solve a complex problem on the computer, that all necessary information is available and that they have maximum one hour to reach a solution. They are then asked to put their headphones on and to start working.
The PA’s influence on performance was analyzed by a MANOVA with condition as independent variable and the difference between the pre and the post-test’s total score, between the number of arguments and between the number of perspectives as dependent variables. For the transfer test, an ANOVA was performed with condition as independent variable and the score on the transfer test as dependent variable. Both the significance level and the effect size measured through $\eta^2$ were looked at. When a significant difference for condition was retrieved a Scheffé post hoc test was performed.

3. RESULTS

The descriptive statistics reveal that overall students scored better on their post-test than on their pre-test with an average gain of 4.70 (SD = 3.08). On average students considered 1.60 perspectives more than on the pre-test (SD = 1.35) and 3.11 arguments (SD = 2.23). Students gave on average 3.41 (SD = 1.39) aspects to consider when choosing paper as an answer for the transfer test.

The MANOVA reveals a main effect of condition ($\lambda = .945$; $F(4,354) = 2.56$; $p \leq .05$; $\eta^2 = .03$). The test of between-subjects effects reveals that this effect is mainly due to a significant effect on the total test-difference score ($F(2,180) = 3.88$; $p \leq .05$; $\eta^2 = .04$) and on the difference score for number of arguments provided ($F(2,180) = 4.61$; $\leq .05$; $\eta^2 = .05$). The post-hoc test indicates that the NPA-group scores significantly higher (Mean = 5.49; SD = 3.20) than C-group (Mean = 4.00; SD = 3.27) for the total test difference score, while the APA-group takes a middle position (Mean = 4.5; SD = 2.58) and does not differ from either of the two other conditions. For the number of arguments similar results are revealed by the post-hoc test. The NPA-group (Mean = 3.75; SD = 2.33) provides significantly more arguments than the C-group (Mean = 2.64; SD = 2.30). The APA-group (Mean = 2.84; SD = 2.64) does not differ from the other two groups. The number of perspectives provided was equal for participants from different conditions.

For the transfer test no significant differences were found between the different groups for the score on the transfer test ($F(2,180) = 1.45$, $p>.05$; $\eta^2 = .02$).

4. CONCLUSION AND DISCUSSION

Results of the study confirm only some of the hypotheses. The PA-groups were hypothesized to outperform the control group. Indeed, the NPA-group outperformed the control group. This result shows that a PA can increase performance providing metacognitive support at regular times. The PA succeeded in compensating for the lack of metacognitive skills and helped learners in making adequate decisions with respect to their learning process. More precisely, it helped to increase performance. Expectations for the APA-group are not confirmed. While it was expected that the APA-group would outperform both the control and the NPA-group, this condition took a middle position. The APA-group did not differ from either the control group or from the NPA-group.

These unexpected results can be explained by referring to different aspects. First, the amount of support offered in the different groups differed for some participants. In the NPA-group all students received advice at regular intervals. Students who followed the ‘optimal path’ and used tools in line with that path only received assistance from the PA twice. Although this should have been sufficient, it might be that students like to get some additional confirmation for their interpretation of the functionalities of the available tools and that cognitively speaking the support was sufficient, but that on a more motivational level the support might have been insufficient.

Second, in line with findings of Carroll (1989) indicating that time on task is one of the important determinants of learning results, it could be suggested that the study time on the program might have influenced the results. However, it is the APA-group who spent most time on the program (Mean$_{APA}$ = 45’42’’; SD = 7’06’’; Mean$_{NPA}$ = 43’17’’, SD = 8’19’’; Mean$_{C}$ = 41’08’’; SD = 9’41’’).

A third explanation suggested by Reeves and Nass (1996) might be related to the formulation of the advice. In the APA condition the advice was more personal than in the NPA condition. The agent pointed to the students’ actual behavior, telling them in an indirect way that they were not on an ‘ideal track’. It might be that students perceive this as a ‘personal attack’. It might be that students found the agent ‘impolite’. Reeves and Nass (1996) for instance state that ‘when technology violates a politeness rule, the violation is
viewed as social incompetence and it is offensive’ (p. 29). Moreover, they also indicate that people tend to ignore criticism. This could explain the lack of effect of the APA condition, since more 81.4% received intermediate advice, indicating that they were not following the ‘optimal path’ which could be interpreted as a criticism on their actual behavior.

A fourth explanation might be related to the predictiveness of the advice. Already in 1955, Kelly argued that an individual’s ultimate aim is to predict and control events. Participants in the NPA-condition received more predictable advice than those in the APA-condition, since every 7 minutes, independently of what participants were actually doing, advice was provided. In the APA group this was not the case.

A fifth explanation relates to the ‘adaptiveness’ of the advice. It might be that the advice was not well enough adapted to students paths. It could be that, although a theoretical problem solving process was followed to design the advice, it did not correspond to students’ way of handling such a complex problem.

The results of the NPA-condition do raise the question whether adaptiveness is actually needed. It seems that pointing out at regular times the functionality of the different tools is already sufficient for better performance. This of course questions research linking PAs to artificial intelligence to make them react in an extremely adaptive way to students’ paths.

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