FROM GUIDED TO SELF-REGULATED PERFORMANCE OF DOMAIN-GENERAL SKILLS: THE ROLE OF PEER MONITORING DURING THE FADING OF INSTRUCTIONAL SCRIPTS

doi:{ 10.1016/j.learninstruc.2011.05.001 }

Please refer this manuscript as:

Wecker, C. & Fischer, F. (2011). From guided to self-regulated performance of domain-general skills: The role of peer monitoring during the fading of instructional scripts. *Learning and Instruction*, *21* (6), 746-756.

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From guided to self-regulated performance of domain-general skills: The role of peer monitoring during the fading of instructional scripts

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Abstract

The fading of instructional scripts can be regarded as necessary for allowing learners to take over control of their cognitive activities during the acquisition of skills such as argumentation. There is, however, the danger that learners might relapse into novice strategies after script prompts are faded. One possible solution could be monitoring by a peer with respect to the performance of the strategy to be learned. We conducted a 2×2-factorial experiment with 126 participants with fading and peer monitoring as between-subjects factors to test the assumptions that (1) the combination of a faded script and peer monitoring has a positive effect on strategy knowledge compared to only one or none of the two types of support; and (2) this effect is due to a greater amount of self-regulated performance of the strategy after the fading of the script when peer monitoring takes place. The findings support these assumptions.

Keywords:

collaboration scripts, skill acquisition, argumentation, fading, peer monitoring

1. The Problem: Take-over of control in guided learning settings

During learning through guided performance, a learner in some way performs the activities to be learned. However, typically the control of these activities is taken over by a more capable person (Wood, Bruner, & Ross, 1976, p. 98; Wood & Wood, 1996, p. 391-392) who thereby creates a "zone of proximal development". In computer-supported collaborative learning, such a zone of proximal development may be created by means of the entire learning environment, including learning partners as well as technology-based instructional support. In order to acquire domain-general skills, such as argumentation, learners need to take over control of their activities. For this purpose, support may be gradually reduced or *faded* (e.g., Pea, 2004). In the following we will argue, however, that fading alone may be insufficient for taking over control, and learners may need further support of a different kind during fading.

2. Theoretical background

2.1 Components of cognitive skills and their acquisition

The literature on cognitive skill acquisition typically regards a skill as a system of knowledge components (e.g., Anderson & Lebiere, 1998). Each single knowledge component can fulfil at least one of two functions: (1) it can be used to regulate the execution of the skill by setting subgoals, or (2) it can directly contribute to performance by helping accomplish these subgoals (see Anderson, 1987, p. 198). The first kind of knowledge is critical for any skill because it embodies the overall strategy for tasks within the scope of the skill, such as the strategy for solving subtraction problems. In contrast, the second kind of knowledge is necessary to solve specific tasks and therefore varies among tasks, for example, the "number facts" required for solving a specific subtraction problem (see VanLehn, 1990, p. 14). Accordingly, a skill can later be extended by acquiring more knowledge of the second type, once sufficient knowledge of the first type concerning a strategy has been acquired. Therefore, we focus on the first kind of knowledge and refer to it by using the term "strategy knowledge". One crucial prerequisite of acquiring a unit of knowledge of both types is repeated application of that knowledge (Anderson & Lebiere, 1998). In the case of strategy knowledge, application means using that knowledge for setting subgoals during the execution of a skill by the learner.

For the purposes of this study, we selected the ability to generate a counterargument against the relevance of someone else's argument for a claim as a representative of domain-general skills. Based on the distinction of "tenability" and "relevance" as quality criteria for argumentation (Naess, 1966, p. 108-109; see also Voss & Means, 1991, p. 339) and a taxonomy of argument schemata (e.g., Walton, Reed, & Macagno, 2008), a strategy underlying this skill can be characterized by the following series of subgoals:

(1) identification of a claim in someone else's utterance (for example, "Lisa should receive attributional retraining to learn to attribute failure to external causes ...");

(2) identification of an argument put forward to support the claim (for example, "... because her actual attribution of failure to internal stable causes is detrimental for her subsequent achievement motivation.");

(3) identification of the type of the claim (in this example: recommendation of an intervention);

(4) identification of the type of the argument (in this example: negative prediction in case of the omission of the intervention);

(5) check of the fulfilment of the conditions for the argument to be relevant to the claim; these conditions depend on the types of the claim and the argument; hereafter, they are called "conditions of relevance" (in this example: the possibility of a positive prediction in the case of the execution of the intervention – which is not fulfilled); and

(6) formulation of a counterargument on the basis of the results of the analysis conducted in steps 1 to 5.

Strategy knowledge is constituted by the knowledge of this sequence of subgoals. As described above, theories of cognitive skill acquisition assume that this knowledge is acquired if learners repeatedly use it to set subgoals during the *performance of the strategy*.

2.2 Instructional scripts as a means to foster strategy knowledge

To guide learners to apply a new strategy, in computer-supported collaborative learning settings there is the opportunity to support learners by means of an instructional script (e.g., De Wever, Van Keer, Schellens, & Valcke, 2007; Kollar, Fischer, & Slotta, 2007; Rummel & Spada, 2005; Rummel, Spada, & Hauser, 2009; Stegmann, Weinberger, & Fischer, 2007). A script is a kind of instructional support that provides learners with guidance about how to interact (Kollar, Fischer, & Hesse, 2006, p. 162 ff.). If learners are supposed to also internalize the strategy suggested by the script to acquire the corresponding skill, the way learners process these scripts needs to be considered. From the perspective of cognitive skill acquisition, script prompts are processed by means of general, so-called “interpretive” procedures (cf. Taatgen, Lebiere, & Anderson, 2006, p. 46). For example, after a claim and an argument in a learning partner’s contribution have been identified, the learner may not know how to move on. Therefore he or she may consult a prompt offered by a script and use it to set the subgoal to identify the type of the claim. It is important to note that the control of a learner’s activities is exerted by the script and not by the learner in such situations.

The internalization of a strategy suggested by a script can be explained by means of compilation (Taatgen et al., 2006, S. 47): By replacing the general reference in the interpretive procedures to instructions in the environment by the activities specified in these instructions, skill-specific procedures can be built. From situations such as the example above, learners may acquire a rule to set the subgoal to identify the type of the claim when they have identified claim and argument. This piece of strategy knowledge is strengthened if learners repeatedly apply it autonomously to set this subgoal in similar situations without relying on the script (Anderson & Lebiere, 1998). This may be unlikely, however, if the script is permanently available. Accordingly, for the internalization of the strategy, it might be necessary to gradually withdraw the script (*fading*, see, e.g., Pea, 2004; Rummel et al., 2009).

2.3 Problems associated with the fading of instructional scripts

Diverse kinds of instructional support can be faded, ranging from stimuli and prompts (Riley, 1995) to steps in worked examples (Renkl & Atkinson, 2003). In most of these cases, fading has proved effective for learning (e.g., Schunk & Rice, 1993; Renkl, Atkinson, & Große, 2004). The findings about the fading of steps in worked examples in particular, however, have limited pertinence for fading scripts because examples are studied *before* performance. In contrast, scripts are employed *during* performance and control of the performance.

Actually, instructional scripts can be regarded as a kind of socio-cognitive scaffolding (Carmien, Fischer, Fischer, & Kollar, 2007). Fading has always been regarded as an integral part of scaffolding (Wood et al., 1976; Wood & Wood, 1996, p. 395-396; Pea, 2004); hence it seems natural to fade scripts as well. So far, only a couple of studies on the effects of the fading of scaffolds have been conducted, with mixed and partly disappointing results. Leutner (2000) conducted two experiments on the effects of fading on the acquisition of software skills. One provided evidence for the beneficial effects of fading, and the other indicated decreased performance during fading. McNeill, Lizotte, Krajcik, and Marx (2006) found that learners acquired more knowledge about the principles of scientific explanations with fading than without. However, this difference failed to reach significance (McNeill et al., 2006, p. 175).

From the perspective of cognitive skill acquisition, these results do not come as a surprise. As long as there is unfaded support, learners do not practice the application of strategy knowledge to self-regulate their performance. As soon as support is faded, however, they are immediately required to jump in and exert self-regulation of their performance, which they had no opportunity to practice before. This indicates that whereas fading may be necessary to provide the opportunity to practice the performance of a strategy and thereby acquire strategy knowledge, it may not be sufficient.

2.4 The role of peer monitoring

When support previously available from a script is gradually withdrawn, successful performance requires control on the part of the learners. The full cycle of control involves planning, monitoring, and adapting one's steps during the performance of a strategy. This task may overwhelm learners if they are supposed to take responsibility for all of its parts at once (see Scott & Schwartz, 2007). In such a situation, the idea of distributed metacognition (King, 1998) may be useful: Specific components of control may be distributed among collaborating learners. For example, a learner can be freed from the task of monitoring the application of a strategy during the composition of a message, and instead receive feedback from a peer. As soon as the learner wanders off track, this feedback can be used in subsequent cycles to plan the steps of the activity according to the strategy to be learned. Because the acquisition of strategy knowledge requires its self-directed (i.e., unguided) application, fading may play out its full potential to foster strategy knowledge only when combined with such additional support.

Beyond this potential function of peer monitoring, of course, peer monitoring that flows into detailed feedback can also remind learners of the strategy suggested by the script. In contrast to the function of keeping learners on track, however, this aspect of peer monitoring should foster strategy knowledge no matter whether the script is faded or not. Accordingly, a different pattern of effects should be found if this second mechanism prevailed.

3. Research questions and hypotheses

In an empirical study of the effects of fading and peer monitoring on learning activities and outcomes, we focused on three research questions:

(1) What are the combined effects of fading and peer monitoring on the acquisition of strategy knowledge? Our hypothesis was that learners supported by a faded instructional script and peer monitoring acquire more strategy knowledge than those learning with only one or none of these kinds of support.

(2) What are the combined effects of fading and peer monitoring on the performance of the strategy suggested by the script during a collaborative learning phase? We expected that fading may lead to a decrease in the performance and its single steps of the strategy and that peer monitoring would prevent such a decrease.

(3) What is the relation between the performance of the strategy during the fading of the instructional script and the acquisition of strategy knowledge? We hypothesized that the acquisition of strategy knowledge is more closely associated with the performance of the single steps of the strategy *after* the fading of components of the script (i.e., self-regulated performance of the strategy) than with the performance of the strategy script *before* fading (i.e., performance of the strategy controlled by the script).

4. Method

4.1 Sample

The sample of this study consisted of 126 students from educational science and preservice teacher education programs. Participation was a prerequisite for receiving course credit. The participants were randomly grouped into 63 pairs. The units of analysis were single students. To preclude dependencies within the sample, one student from each pair was selected for the analysis based on the role he or she was assigned during the learning phase.

On average, the participants in the sample included in the analysis were 23.4 years old (SD = 3.4). Among them, there were 70% female and 24% male students; 6% did not provide gender information.

4.2 Design

We implemented a 2×2-factorial design with *fading* and *peer monitoring* as between-subjects factors (see Table 1). The students were randomly assigned to conditions and to sessions in which all students received the same experimental treatment. In each condition, the number of groups equals the number of individual students selected for analysis because only one member of each group was selected for analysis.

4.3 Instructional setting, material, and task

Up to ten participants were seated in one room at individual tables separated by partitions and supervised by one experimenter. Each participant worked on a laptop computer with network connection and a headset. This equipment was used during the learning phase and the tests.

Each learner went through an individual phase, a collaborative phase, and another individual phase. In the first individual learning phase, the learners studied two printed texts to equip them with information necessary for their task in the collaborative learning phase. The first one covered the attribution theory of achievement motivation, which was not part of the participants' curriculum before this experiment. It explained basic concepts from attribution theory by means of definitions and examples, the principles connecting attribution styles to future motivation to learn, and possible interventions to influence learners' attributions. The second text covered basic elements of argumentation (such as "argument" or "conditions of relevance"). Furthermore, it described four types of arguments appropriate for two types of claims along with their elements (such as "diagnosis" or "negative prognosis") and their associated conditions of relevance. Finally, possible starting points for counterarguments and the six steps of the strategy for generating counterarguments were covered. The students could annotate these texts and keep them until the end of the collaborative learning phase. Between reading the two texts, the students wrote a case analysis similar to the ones they discussed online later on, to gain initial experience in the application of attribution theory.

In the collaborative learning phase, the students in each dyad collaborated via their own text-based discussion board, which contained the description of a case from educational practice. This case description contained a report by a pupil about his problems in mathematics and the views of his teacher and his parents. The participants were told that they would be discussing analyses of this case in groups of four and that two of the learners had the task of writing these analyses. The actual learners were asked to write critical replies to each of these analyses and could discuss any questions occurring during this task. This "task distribution" was introduced in order to narrow the learners' tasks to one specific aspect of argumentation skills that could be learned in a single experimental session. In fact, six case analyses with at least two questionable claims each were posted under the names of two simulated group members at fixed points in time.

In all four conditions, the learners were supported in the process of writing critical replies to these case analyses by means of an instructional script. This script provided instructions on how to analyze the argumentation in the case analyses and how to discover problematic assumptions. It contained three kinds of information: sequence information, argument schemata, and application support.

Sequence information describes the strategy presented in section 2.1 for analyzing the argumentation in a case analysis and the formulation of a critical reply. The steps of the strategy to arrive at a counterargument were implemented in the interface in two ways (see Figure 1): Interface elements pertaining to the actual step were surrounded by dark highlighting. Besides, text prompts were provided that changed according to the state of the composition of the critical reply and specified the next step.

Argument schemata contain information of two kinds: First, they specify what types of argument are appropriate to support the identified type of claim. Second, they indicate what conditions of relevance need to be fulfilled for an identified pair of argument and claim. These schemata were crucial for the assessment of the details of the argumentation in the case analyses. For example, a *piece of case information* is an appropriate argument for a claim that states a *diagnosis*. The corresponding condition of relevance is a *definition* that links criteria applicable to the case information to a concept used in the diagnosis. These argument schemata were implemented by means of selection fields and by a prompt (see Figure 1). The available options for the argument type and the prompt for the assessment of the condition of relevance were adapted based on the previous selections of the learner.

Application support comprises explanations and examples for the terms used in the prompts and selection fields (in accordance with the text about argumentation). They were displayed next to the respective control elements in light boxes in order to help learners understand the instructions.

To introduce the use of the script, learners were shown a five-minute video demonstrating the composition of a critical reply using these interface elements accompanied by a narrated explanation. After the video, they could explore these functions in an empty test instance of the discussion board.

In the second individual learning phase following collaboration, each learner individually wrote an analysis of another case.

4.4 Procedure

Data were collected in three-hour sessions (see Table 2). After a short introduction to the purpose and procedure of the study by the experimenter, the participants filled in an online questionnaire for demographic and other control variables. This was followed by the first individual learning phase and an introduction to the discussion board. After a short break, the collaborative as well as the second individual learning phase took place. After this learning phase, online posttests for strategy knowledge as well as further variables not pertinent to the hypotheses of this study were administered to the learners. Finally, they were given the opportunity to comment on the experiment in a debriefing.

4.5 Independent variables

4.5.1 Fading

Fading was manipulated by keeping constant versus gradually changing the components of the interface for the composition of critical replies from one message to another. The learners were informed about this in advance.

In the conditions *with faded script,* the interface for the composition of critical replies of the learners included in the analysis changed over time. These changes occurred as a function of the number of messages posted by each individual learner. The fading of the script was implemented in the following way for the three kinds of information it contained.

(1) After the learner had posted two critical replies, a pair of *sequence information* prompts was randomly selected and replaced by the request: "Please perform this step on your own." Two further randomly selected pairs of sequence information prompts were replaced after the third and the fourth critical replies, respectively. Therefore, after the fifth critical reply, only the unspecific requests were shown before each step.

(2) The *argument schemata* were faded as follows: During the composition of the third critical reply, the specific question concerning the *fulfilment of the condition of relevance* (step 5) was replaced by an unspecific one. From the composition of the fourth critical reply on, the selection field for the *type of the argument* (step 4) no longer contained any options. Instead, the learners had to fill in the type of the argument themselves. From the fifth critical reply on, the selection field for the *type of the claim* (step 3) no longer contained any options. As in the case of the type of the argument, the learners had to fill in the type of the claim themselves instead.

(3) *Application support* disappeared completely after the second critical reply had been posted.

During the last 10 minutes of the collaborative learning phase, the learners only had a simple text box for the composition of their messages, as is common in discussion boards.

In the conditions *with unfaded script*, the interface for the composition of critical replies remained unchanged throughout the learning phase.

4.5.2 Peer monitoring

In the conditions *with peer monitoring*, one of the learners was required to provide the other learner with an evaluation of the performance of the strategy suggested by the script. This task was an addition to their regular task of writing critical replies. The other learners were asked to revise their initial critical replies based on these hints. Both learners were informed about this task distribution. The participants who had provided peer monitoring to their peers were excluded from the analysis. These learners were supported by the interface during the formulation of their comments to their peers: By simply clicking on check boxes for each of the components of the script, they could indicate whether the corresponding steps had been performed appropriately by their partners. Based on this input, an evaluation message was generated automatically. In addition, they could add free text remarks. In analogy to the condition with unfaded script and peer monitoring, peer monitoring was continued during fading in the condition with faded script and peer monitoring.

In the conditions *without peer monitoring*, the learners were not asked to provide, nor supported in providing, an evaluation of their learning partners' performance of the strategy.

4.6 Dependent variables

4.6.1 Strategy knowledge

Strategy knowledge was measured by means of a task with an open answering format. The learners were asked to describe their strategy for checking the relevance of an argument for a claim and formulating a counterargument against it. The learners' unsegmented answers were coded for the occurrence of each of the six steps of the strategy listed in section 2.1. One further coding variable captured the correctness of the sequence of steps. Each of two coders analyzed equal proportions of the data from both experimental conditions individually and blind to condition. Their agreement was determined on the basis of 30% of the material analyzed by both of them. It ranged from 76% to 90%; Cohen's κ ranged from .46 to .70. Accordingly, the objectivity of the coding can be regarded as sufficient (see Orwin, 1994, p. 152). The seven coding variables were then added up to create a scale for strategy knowledge, with a possible range from 0 to 7. The reliability of this scale was excellent (Cronbach's α = .93).

4.6.2 *Performance of the strategy and of specific steps of the strategy*

The performance of the strategy during the collaborative learning phase was measured based on five dichotomous variables for each critical reply. These five variables corresponded to five of the six steps of the strategy (identification of a claim in the case analysis, identification of an argument put forward to support the claim, identification of the type of the claim, identification of the type of the argument, check of the conditions of relevance of the argument with respect to the claim) and indicated whether each step had been performed in the particular critical reply. The last strategy step (formulation of a counterargument) was omitted because it coincides with composing the message, which is performed in any reply irrespective of the strategy applied. For the first four steps, the corresponding performance variables were extracted directly from logfile data indicating whether the learners had used the interface components corresponding to the single steps. The performance variable for the fifth step of the strategy was analyzed based on the texts entered in the textbox for the fifth step. Two coders individually analyzed equal proportions of the data across the experimental conditions. Their agreement was determined based on a sample of 10% analyzed by both of them and was very high (agreement: 99%; Cohen's $\kappa = .98$).

Indicators for the performance of the strategy were formed as follows: First, for each of the five steps, the proportion of all messages in which the step had been performed was determined. For this purpose, the values of the variable indicating whether the specific step had been performed during the composition of a particular critical reply (see previous paragraph) were averaged across all critical replies. This yielded five indicators for the *performance of specific steps of the strategy* (one indicator for each step of the strategy). These indicators were also calculated separately for all critical replies *before* and *after* the fading of the component of the script corresponding to the respective step. These separate indicators for the performance of specific steps of the strategy before and after fading were used for specific analyses within the conditions with the faded collaboration script, Finally, the indicator for overall *performance of the strategy* was computed by adding the five indicators for performance of the single steps of the strategy. Accordingly, it could range from 0 to 5. In addition, in the conditions with the faded script, separate indicators were calculated for the overall performance of the strategy *before* and *after* the fading of support. The reliability of the indicator for the performance of the strategy determined across all critical replies was good (Cronbach's $\alpha = .72$).

4.7 Statistical analysis

As already indicated, data were analyzed with individual students as the units of analysis. The member selected from each of the 63 dyads was always (the) one who had not provided peer monitoring, which had been determined at random when grouping the participants. The significance level was set to 5% for all analyses.

5. Results

5.1 Combined effects of fading and peer monitoring on the acquisition of strategy knowledge

The descriptive findings for the acquisition of strategy knowledge in the four conditions are displayed in Figure 2. The data were analyzed by means of an analysis of variance with strategy knowledge as the dependent variable and fading and peer monitoring as between-subjects factors. This analysis revealed a medium-size interaction effect of the two independent variables, $F(1; 59) = 5.78$; $p = .02$; partial $\eta^2 = .09$. In Figure 2, the superiority of the condition with the faded script along with peer monitoring can be observed. A contrast analysis revealed that students learning with a faded script and peer monitoring ($M = 4.24$; $SD = 2.88$) significantly outperformed the students in the three other conditions ($M = 1.35$; $SD = 2.17$) in the strategy knowledge test, $t(59) = 4.18$; $p < .001$ (one-sided). Therefore, the two significant main effects of fading, $F(1; 59) = 4.47$; $p = .04$; partial $\eta^2 = .07$, and peer monitoring, $F(1; 59) = 6.27$; $p = .02$; partial $\eta^2 = .10$, cannot be regarded as general.

5.2 Combined effects of fading and peer monitoring on the performance of the strategy

Figure 3 displays the average performance of the strategy implemented in the script as a function of the temporal position of the message for the four experimental conditions. Of the students in each condition, 65% wrote at least seven messages. This proportion drops below 50% for later messages. Therefore, only the values for the first seven messages are displayed. To analyze the temporal development of the performance of the strategy in all four conditions, we conducted a hierarchical-linear analysis. The equations of the level-1 growth model described each individual's performance of the strategy during the formulation of a specific message as a function of the number of the message (i.e., its temporal position). Base levels (intercepts, $\chi^2(62) = 229.73$; $p < .001$; $\rho = .34$) and growth rates (slopes, $\chi^2(62) = 120.79$; $p < .001$; $\rho = .02$) varied substantially among the students. As can be seen from the insignificant slope for the number of messages (see Table 3), however, on average, the performance of the strategy neither increased nor decreased over time.

The explanatory level-2 model used the experimentally manipulated variables *fading* and *peer monitoring* to predict both the base level (intercepts) and the growth rates (slopes) of the individuals' performance of the strategy. As can be seen from Table 3, the individual base levels did not vary significantly as a function of either fading or peer monitoring. The average individual growth rate in the condition with the unfaded script without peer monitoring ($\beta_{10} = -0.08$), however, was significantly below zero, indicating decreasing performance of the strategy in this condition. Although fading did not significantly affect this growth rate, peer monitoring significantly raised this negative growth rate ($\beta_{12} = 0.11$), yielding an approximately constant level of performance of the strategy in these conditions (π_{1i} = -0.08 + 0.11 > 0). The proportion of variance in slopes accounted for by the explanatory model was 6%, with the remaining unexplained variance still being significant, $\chi^2(62) = 117.59$; $p < .001$. This indicates that there may be further factors that substantially contribute to the variation.

The role of peer monitoring for the performance of the strategy was analyzed separately within the conditions with the faded script. An analysis of variance for repeated measures with *performance of the strategy* as the dependent variable and *peer monitoring* as a between-subjects factor was conducted. In this analysis, *fading state* was used as a within-subjects factor distinguishing between the measures of the dependent variable *before* and *after* the fading of the components of the script corresponding to the single steps of the strategy (see Figure 4, top part). This interaction was significant and corresponded to a large effect $F(1; 33) = 7.66$; $p = .01$; partial $\eta^2 = .19$. In the condition without peer monitoring, the performance of the strategy decreased from the phase *before* the fading of support to the phase *after* fading ($M = 4.44$; $SD = 0.91$). The corresponding t-test for dependent samples with the performance of the strategy before and after the fading of support as the two linked dependent variables was significant, $t(17) = 2.93$; $p < .01$ (one-sided). No such decrease could be detected by a corresponding t-test in the condition with peer monitoring, $t(16) = -.65$; $p = .74$ (one-sided).

Analogous analyses were performed on the level of individual steps of the strategy. They showed that this interaction effect on the level of the overall strategy is produced mainly by the learners' performance of the last two steps of the strategy (see Figure 4, middle and bottom part): For the *check of the fulfilment of the conditions of relevance*, the interaction effect between peer monitoring and the within-subjects factor of fading state was significant, $F(1; 33) = 4.61$; $p = .04$; partial $\eta^2 = .12$. This indicates that the performance of this particular step of the strategy suggested by the script remains on a higher level in the presence of peer monitoring. The corresponding interaction effect for *identification of the type of the argument* just failed to reach significance $F(1; 33) = 3.88$; $p = .06$; partial $\eta^2 = .11$. The corresponding effects for the performance of the other three steps were all insignificant (*identification of the type of the claim*: $F(1; 33) = 1.26$; $p = .27$; partial $\eta^2 = .04$, *identification of an argument put forward to support the claim*: $F(1; 33) = 1.06$; $p = .31$; partial $\eta^2 = .03$, *identification of a claim in the case analysis*: $F(1; 33) = 2.23$; $p = .15$; partial $\eta^2 = .06$).

5.3 Relation between the performance of the strategy and the acquisition of strategy knowledge

A significant small- to medium-size correlation between the performance of the strategy and the acquisition of strategy knowledge was found, $r = .25$; $p = .01$ (one-sided). However, it has to be kept in mind that the four experimental conditions did not differ with respect to the performance of the strategy averaged over all messages. Therefore, this correlation does not explain the differences in the acquisition of strategy knowledge between the experimental conditions.

As argued above, the performance of a strategy while being guided through its steps rather than performing them in a self-directed way is unlikely to contribute much to strategy knowledge acquisition. What may play a role, however, is the performance of the strategy after support has already been withdrawn and learners have the opportunity to practice the self-regulation of these steps (i.e., after the fading of the single steps of the script). A higher degree of performance of the strategy in such phases was found in learners who received peer monitoring, as described in the previous section.

Accordingly, for five single steps of the strategy, we compared the performance of the step in the learning phase between students who demonstrated knowledge of the step in the posttest and those who did not. This was done separately for the performance of the respective single steps *before* the fading of the corresponding support, and the performance of the respective single steps *after* the fading of the corresponding support. For three of the five steps (*identification of a claim*, *identification of an argument* and *identification of the type of the claim*) there were no differences between the students who did and those who did not demonstrate knowledge of the corresponding step in the posttest for strategy knowledge – both *before and after* the fading of the corresponding support, all *t*s(33) < 1; *n. s.* (one-sided). Learners who demonstrated knowledge about the *identification of the type of the argument* had performed this step more often *after* the corresponding support had been faded than those learners who did not demonstrate this knowledge, $t(21.61) = 2.33$; $p = .01$ (one-sided). However, they had not performed this step more often *before* the corresponding support had been faded than those learners who did not demonstrate this knowledge, $t(14.29) = -0.76$; $p = .77$ (one-sided). Likewise, learners who demonstrated knowledge about the *check of the fulfilment of the conditions of relevance* had performed this step more often *after* the corresponding support had been faded than those learners who did not demonstrate this knowledge, $t(23.29) = 2.69$; $p = .01$ (one-sided). However, they had not performed this step more often *before* the corresponding support had been faded than those learners who did not demonstrate this knowledge, $t(33) = 0.74$; $p = .23$ (one-sided). These findings provide some evidence that it is not the performance of the strategy *with* support by the script that is associated with the acquisition of strategy knowledge. Instead, the self-directed performance of the strategy *without* support by the script seems to play a role for the acquisition of strategy knowledge.

6. Discussion

The findings of this study show: Although the performance of the strategy suggested by a script may decline over time, it can be kept on a high level by means of peer support. One kind of such peer support is peer monitoring. Although the decline without peer monitoring appears rather slight, the explanatory multilevel model explains 6% of the variance in the performance of the strategy, which corresponds to a medium-size effect. In practical settings it may be of some importance whether, for instance, the performance of a strategy drops by about one-third in the course of about fifteen messages. This would correspond approximately to the rate observed in the present study.

Note that this decline occurs whether or not the script is faded. This indicates that factors other than not knowing what steps to perform may lead to degrading performance, including motivational aspects, such as lack of perceived autonomy due to the script. Furthermore, as mentioned above, a great amount of variation between individual learners in the degree to which performance declines remains unexplained. The same motivational factors may be responsible for this finding because they may vary between learners.

On a finer level of analysis, in spite of similar descriptive patterns of results, an interaction effect between peer monitoring and the within-subjects factor fading state could not be detected for all steps of the strategy in the conditions with fading. On the one hand, this may be due to a lack of statistical power, given that these analyses had to be performed based on about one-half of the sample. On the other hand, the last two steps, the performance of which was kept up by peer monitoring, are most dependent on the results of the previous steps. So performance of the last two steps may decline in a more pronounced way whenever learners are not completely sure that they are on the right track. Thereby a more pronounced pattern of results that reaches significance more easily could be produced.

The performance of the last two steps of the strategy was related to the acquisition of strategy knowledge, particularly in phases in which components of the script have been faded. These are the phases in which learners have the opportunity to practice self-regulation of the strategy. In contrast to the last two steps, the first three appear to be easier to perform and to acquire, both a priori and in light of the data. Therefore, the variation in these variables may have been too small to detect such associations.

The relation of the performance of two steps to strategy knowledge provides a partial explanation for the beneficial effect of combining a faded script with peer monitoring on strategy knowledge. This combined effect also helps decide whether the main function of peer feedback is to keep learners on track or to remind learners of the steps of the strategy. If the latter were the case (i.e., if the repetition of the information contained in the script fostered strategy knowledge), no interaction between fading and peer feedback with respect to strategy knowledge should occur. The same pattern of results should be found if the opportunity to revise one's critical replies based on the feedback constituted a surplus in terms of practice of the strategy. The fact that an interaction between fading and peer feedback was found, however, points in a different direction: It lends evidence to the assumption that peer feedback primarily secures a high level of self-regulated performance during the fading of a script.

An important limitation of the present study is that argumentation skill was measured only by means of a declarative test of strategy knowledge, and not in a separate posttest based on performance in argumentative situations. Some evidence for the actual skill acquisition can be found, however, in the increasingly unsupported performance of the strategy during the learning phase in the fading conditions. In these conditions, the continuously high performance of the strategy in the presence of peer monitoring indicates that these learners are able to apply the skill even after the support has gone. Future research should address these issues by means of performance-based posttests.

Due to time constraints, the study did not include a pretest of strategy knowledge. Besides eliminating potential alternative explanations of effects, controlling for pretest differences can also increase statistical power. Furthermore, the study captured only rather short-term effects of learning with a faded script and peer monitoring. Because the study was conducted under laboratory conditions, the claims put forward in this paper are still in need of validation for more natural learning environments. Further research should also test the theoretical claims put forward in this study with other domain-general learning outcomes, such as online search competence (see Wecker, Kollar, Fischer, & Prechtl, 2010). Finally, ways to adapt a script automatically to a learner's current competence level are very promising directions to explore (for a review, see Diziol, Walker, Rummel, & Koedinger (2010)).

The current study extends our understanding of instruction by identifying an important boundary condition of the effectiveness of fading: additional support to secure continuous performance of a strategy, such as peer monitoring and feedback. This might also contribute to a clarification of the reasons for the varying effects of fading reported in previous studies on the fading of scaffolds (see McNeill et al., 2006; Leutner, 2000).

Based on the findings from this study, it can be recommended to fade out scripts to provide learners with the opportunity to practice the self-regulation of skilled performance (as suggested by Pea (2004) and others). However, we need to add the caveat that it is important to keep learners' performance of the strategy to be acquired at a high level in self-regulated phases. Collaboration may be employed to accomplish this goal.

Thus, fading may be a way to move from a high degree of support to self-directed learning with authentic tasks. In this process, the acquisition of competence can be considered as an internalization of control that has been exerted by peers and instructional support before.

Acknowledgments

This research was supported by the Deutsche Forschungsgemeinschaft (DFG).

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Table 1

Design of the study

Peer monitoring	**Fading**	
	Unfaded script	*Faded script*
Without peer monitoring	15 students/groups	18 students/groups
With peer monitoring	13 students/groups	17 students/groups

Table 2

Procedure of the study

Phase	*Time*
Introduction	2 min
Questionnaire	6 min
Individual learning phase 1	31 min
Introduction to the discussion board	11 min
	5 min
Pause	5 min
Collaborative learning phase	80 min
Individual learning phase 2	10 min
Posttest	30 min
Debriefing	5 min
	180 min

Table 3

Hierarchical-linear analysis of the development of the performance of the strategy suggested by the script as a function of fading and peer monitoring

Growth model: Prediction of performance of the strategy y_{ti}	π_1	t	p
Number of message	-0.03	-1.18	.24
Explanatory model:			
Prediction of the base level π_{0i} *in the growth model*	β_{0q}	t	p
Fading	0.21	1.39	.17
Peer monitoring	0.09	0.57	.57
Prediction of the growth rate π_{1i} *in the growth model*	β_{1q}	t	p
Basal growth rate (without fading and peer monitoring, *intercept* β_{10})	-0.08	-2.19	.03
Fading	0.01	0.24	.81
Peer monitoring	0.11	2.45	.02

Figure Captions

Figure 1

Implementation of the script in the interface of the online discussion board with sequence information (black box), argument schemata (selection fields and text prompt in black box) and application support (gray box)

Figure 2

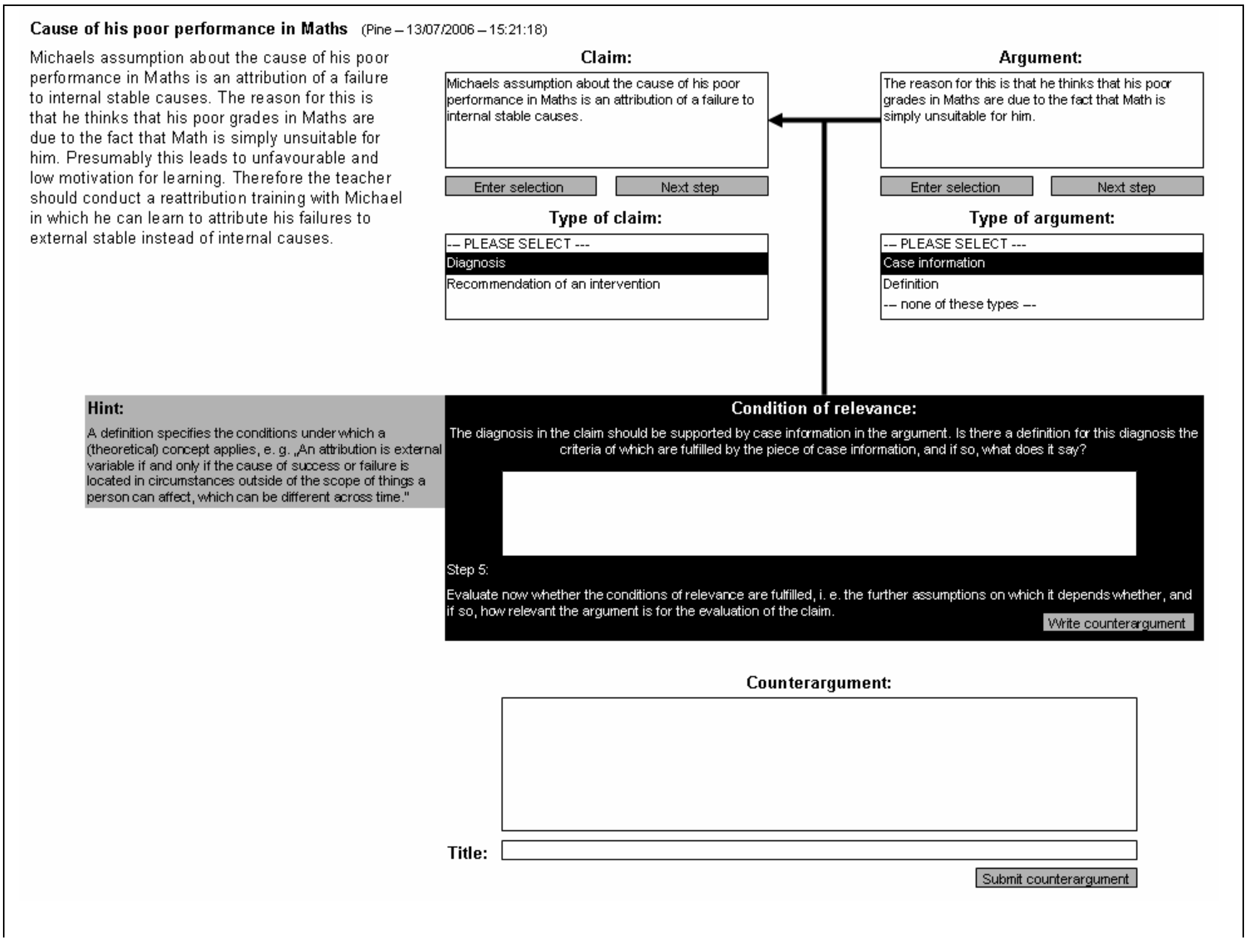
Means of strategy knowledge (posttest scores) in the four experimental conditions

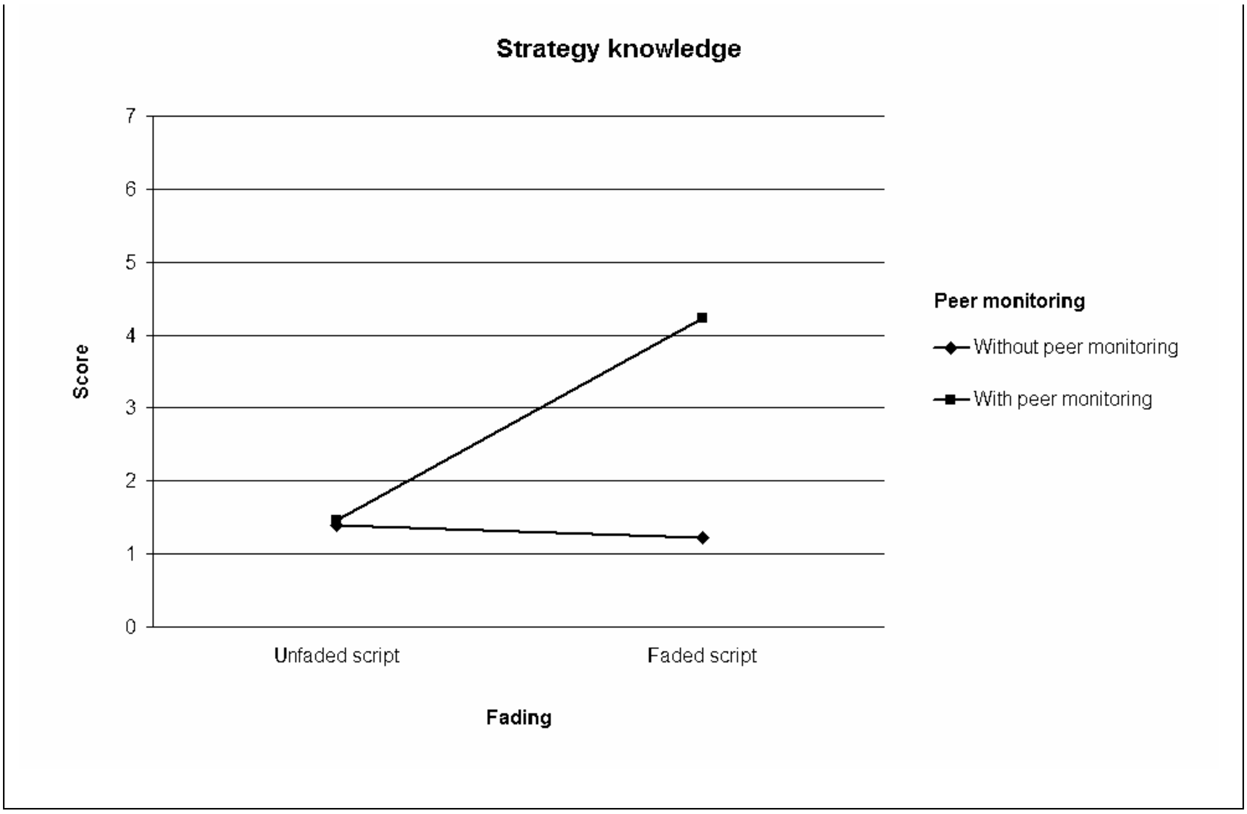
Figure 3

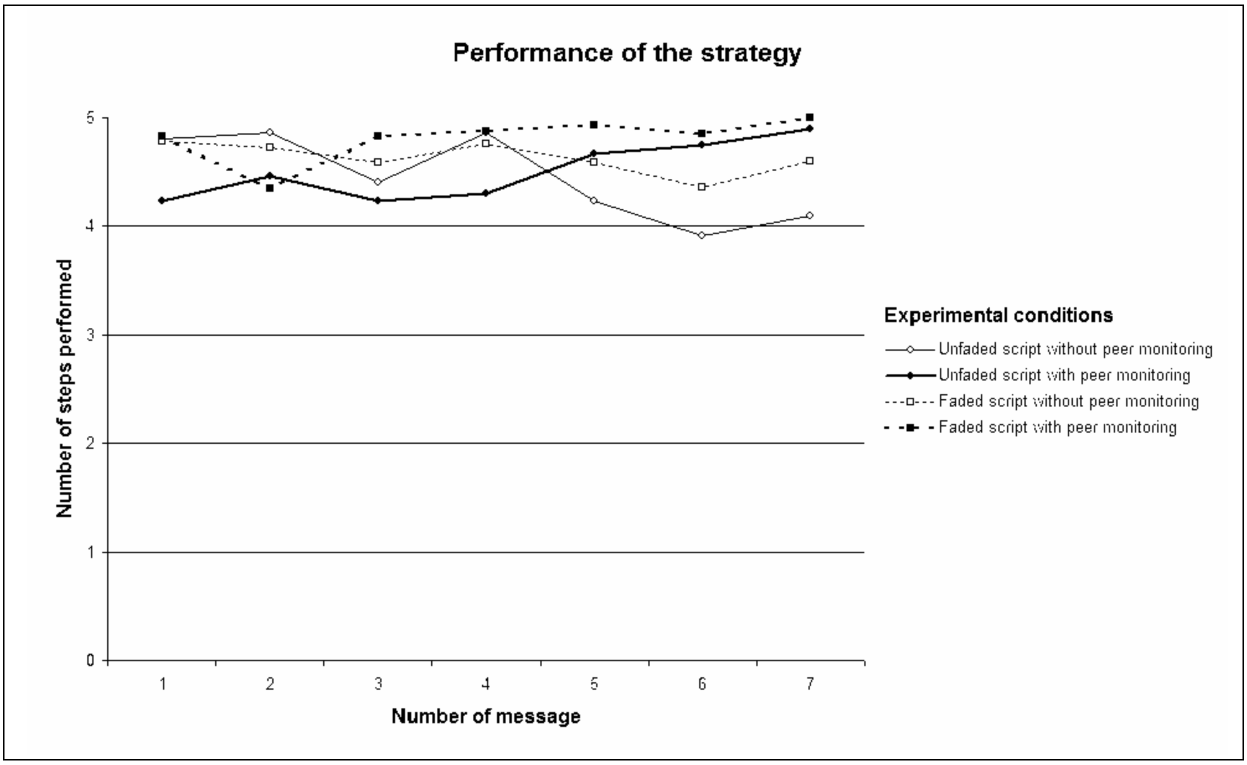
Means of the performance of the strategy (as measured by the number of steps performed) as a function of the temporal position of the message (separated for the four experimental conditions)

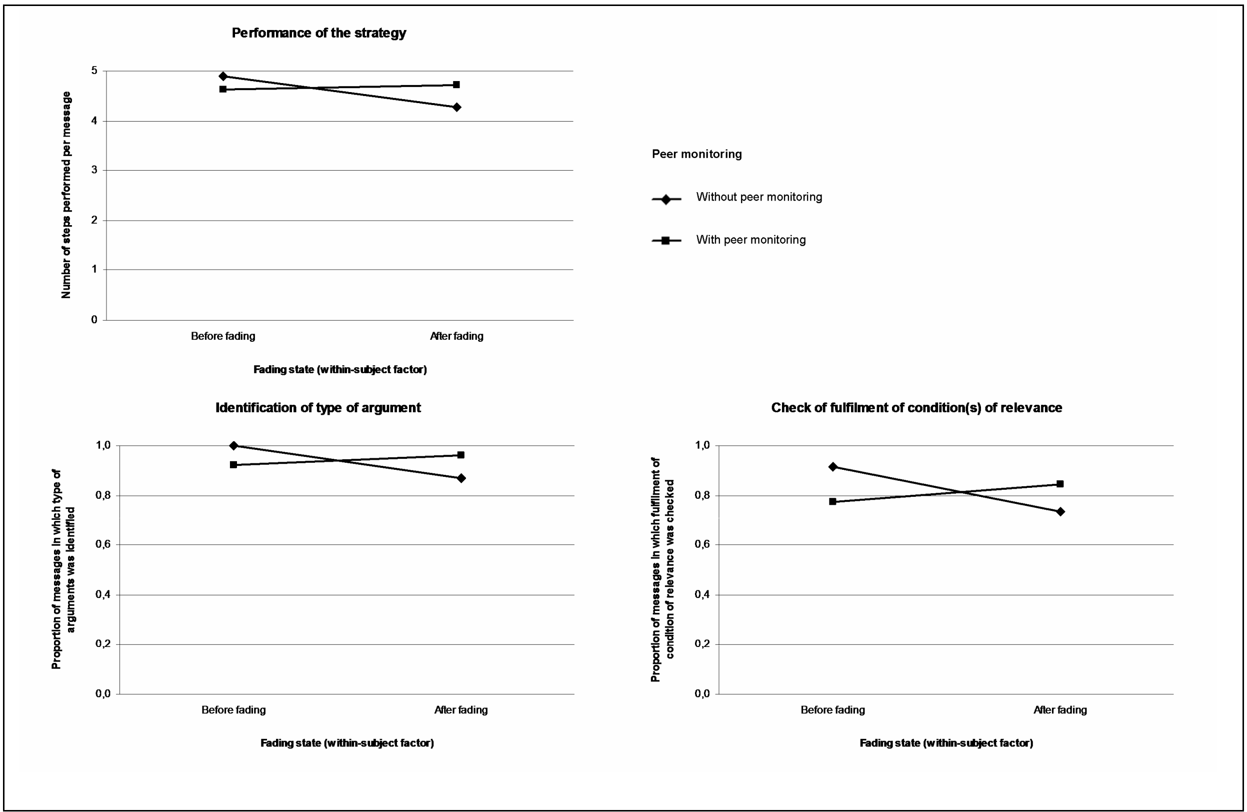
Figure 4

Average proportions of messages in which the strategy as a whole (top part) or specific steps of the strategy (left and right bottom part) were performed before and after fading (separated for the conditions with and without peer monitoring)


Cause of his poor performance in Maths (Pine – 13/07/2006 – 15:21:18)
Michaels assumption about the cause of his poor performance in Maths is an attribution of a failure to internal stable causes. The reason for this is that he thinks that his poor grades in Maths are due to the fact that Math is simply unsuitable for him. Presumably this leads to unfavourable and low motivation for learning. Therefore the teacher should conduct a reattribution training with Michael in which he can learn to attribute his failures to external stable instead of internal causes.
Claim:
Michaels assumption about the cause of his poor performance in Maths is an attribution of a failure to internal stable causes.
Enter selection
Next step
Type of claim:
--- PLEASE SELECT ---
Diagnosis
Recommendation of an intervention
Argument:
The reason for this is that he thinks that his poor grades in Maths are due to the fact that Math is simply unsuitable for him.
Enter selection
Next step
Type of argument:
--- PLEASE SELECT ---
Case information
Definition
--- none of these types ---
Hint:
A definition specifies the conditions under which a (theoretical) concept applies, e. g. „An attribution is external variable if and only if the cause of success or failure is located in circumstances outside of the scope of things a person can affect, which can be different across time."
Condition of relevance:
The diagnosis in the claim should be supported by case information in the argument. Is there a definition for this diagnosis the criteria of which are fulfilled by the piece of case information, and if so, what does it say?
Step 5:
Evaluate now whether the conditions of relevance are fulfilled, i. e. the further assumptions on which it depends whether, and if so, how relevant the argument is for the evaluation of the claim.
Write counterargument
Counterargument:
Title:
Submit counterargument


Strategy knowledge
7
6
5
4
3
2
1
0
Score
Unfaded script
Faded script
Fading
Peer monitoring
Without peer monitoring
With peer monitoring


Performance of the strategy
Number of steps performed
0
1
2
3
4
5
1
2
3
4
5
6
7
Number of message
Experimental conditions
Unfaded script without peer monitoring
Unfaded script with peer monitoring
Faded script without peer monitoring
Faded script with peer monitoring


Performance of the strategy
Number of steps performed per message
5
4
3
2
1
0
Before fading
After fading
Fading state (within-subject factor)
Peer monitoring
Without peer monitoring
With peer monitoring
Identification of type of argument
Proportion of messages in which type of arguments was identified
1,0
0,8
0,6
0,4
0,2
0,0
Before fading
After fading
Fading state (within-subject factor)
Check of fulfilment of condition(s) of relevance
Proportion of messages in which fulfilment of condition of relevance was checked
1,0
0,8
0,6
0,4
0,2
0,0
Before fading
After fading
Fading state (within-subject factor)