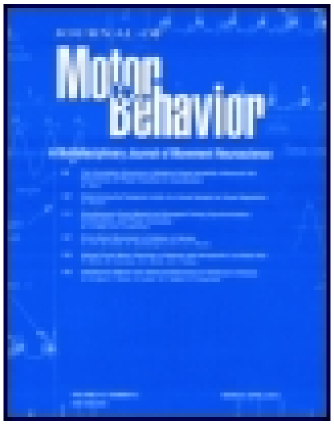

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Scheduling Scaffolding: The Extent and Arrangement of Assistance During Training Impacts Test Performance

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RESEARCH ARTICLE

Scheduling Scaffolding: The Extent and Arrangement of Assistance During Training Impacts Test Performance

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ABSTRACT. Various kinds of assistance, including prompts, worked examples, direct instruction, and modeling, are widely provided to learners across educational and training programs. Yet, the effectiveness of assistance during training on long-term learning is widely debated. The authors examined how the extent and schedule of assistance during training on a novel mouse movement task impacted unassisted test performance. Learners received different schedules of assistance during training, including constant assistance, no assistance, probabilistic assistance, alternating assistance, and faded assistance. Constant assistance led to better performance during training than no assistance. However, constant assistance during training resulted in the worst unassisted test performance. Faded assistance during training resulted in the best test performance. This suggests that fading may allow learners to create an internal model of the assistance without depending on the assistance in a manner that impedes successful transfer to unassisted circumstances.

Keywords: scaffolding, assistance dilemma, training, guidance

Instructors face countless choices when designing learning environments to effectively support student learning. A fundamental unanswered question in education design is how much and what kind of assistance learners should receive during training to promote eventual unassisted performance. With multiple cognitive theories predicting when assistance will be beneficial, and conflicting empirical results about the effects of assistance, debate continues about how, when, and if support should be given to learners during training. In the current experiment, we explored how the presence and schedule of assistance during training in a novel mouse movement task affected later unaided performance on the task.

Various kinds of assistance are frequently used across educational and training programs, including cues, prompts, partial solutions, worked examples, direct instruction, reciprocal teaching, gestures, and modeling. However, the amount, type, and schedule of assistance needed to best promote long-term learning and retention is greatly debated, with some arguing for significant assistance (Kirschner, Sweller, & Clark, 2006; Mayer, 2004), some arguing for little assistance (Jonassen, 1991; Steffe & Gale, 1995), and some arguing for moderate and adaptive assistance (Koedinger, Pavlik, MacLaren, & Aleven, 2008). Finding the appropriate balance between giving and withholding information relevant to students' learning processes has been named the assistance dilemma (Koedigner & Aleven, 2007). Koedinger et al. argued that both high and low assistance can lead to good and bad learning outcomes. When high assistance leads to good learning outcomes, the aid is labeled a scaffold but when it leads to bad learning outcomes, the aid is labeled a crutch. When low assistance leads to good learning outcomes, the instructional design is called a desirable difficulty with a high germane load (Paas, Renkl, & Sweller, 2003). When low assistance leads to bad learning outcomes, the instructional design is labeled an undesirable difficulty with a high extraneous load. However, little is known about why different types of assistance result in good or bad learning outcomes. In fact, what qualitative conditions and quantitative parameters define how assistance affects long-term learning outcomes is a fundamental open question in learning and instructional science (Koedinger & Aleven, 2007). In the next two sections, we review theories and evidence suggesting that assistance either impairs or supports robust learning. Unlike prior research, we specifically study assistance that can be provided simultaneously with a learner's unrestricted actions and examine how that assistance should be designed.

The Costs of Assistance

Several theories suggest that assistance during early training may become a crutch and impair learning and skill acquisition. The guidance hypothesis in motor learning suggests that assistance often has strong performance-enhancing effects during practice. Yet, when assistance is withdrawn in retention or transfer tests, learners who practiced without it often outperform those who practiced with it (Salmoni, Schmidt, & Walter, 1984). Learners can overly depend on an aid during practice and neglect to process the intrinsic task cues that they will have to use when the aid is no longer available (Wulf & Shea, 2002). Many, therefore, recommend that assistance be used sparingly in order to avoid the detrimental effects on learning that are associated with too much guidance (Schmidt, 1991; Schmidt & Wrisberg, 2000).

The theory of desirable difficulties suggests that manipulations that maximize performance during training can be detrimental in the long term because they promote quick

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forgetting of new information and skills (Schmidt & Bjork, 1992). According to this theory, withholding assistance can provoke more effortful learning, which fosters greater long-term learning and transfer. Similarly, providing less assistance may encourage learners to process the task more actively than if they receive high assistance throughout training (Paas, 1992; van Merrienboer, 1990).

Other theories posit that novice learners may not have enough prior knowledge to discern and understand the unique affordances of domain-specific assistance given during beginning instruction (Garner, 1974; Schwartz & Martin, 2004). Assistance provided early during training, then, may actually interfere with learning a new domain's rules (Kanfer & Ackerman, 1989) and schemata (Sweller, 1989). Instead of providing assistance to learners during their initial training, learners need time to generate conceptions, representations, and understandings (even if they are incorrect) before assistance can support their learning. Consistent with this idea, delaying corrective feedback often improves learning, in part because the delay encourages learners to generate their own predictions for what the feedback will be (Hattie & Timperley, 2007).

Finally, assistance may impair performance on unassisted trials because transfer from assisted to unassisted trials may be difficult. According to Thorndike's (1906) transfer by identical elements theory, transfer occurs to the extent to which original learning and transfer conditions share identical physical or psychological elements. Therefore, learners should perform best on a test that is identical to their training conditions. If learners have assistance during training, but none during the final test, transfer to this new situation will be impaired according to identical elements theory, and test performance may suffer.

Empirical evidence shows that assistance during training often impairs final test performance. Many studies examining motor learning reveal that providing too much guidance or feedback during training impairs later unassisted test performance. For instance, in experiments where participants must move a lever a set distance, restricting participants' movements to that exact length during training leads to worse unrestricted test performance than allowing participants more freedom during training (Hagman, 1983; Winstein, Pohl, & Lewthwaite, 1994). Similarly, forcing learners' hand movements to mimic those made by experts results in good training performance, but leads to worse retention than unrestricted training (Baker, 1968; Feijen, Hodges, & Beek, 2010). Feedback about participants' performance is thought to be a similar kind of assistance during training, and often shows analogous results. A large number of studies show that reducing the frequency of feedback about learners' training performance degrades initial performance but enhances later test performance, as compared to conditions with more frequent knowledge of results (Schmidt, Young, Swinnen, & Shapiro, 1989; Weeks & Kordus, 1998; Winstein & Schmidt, 1990; Wulf & Schmidt, 1989).

As suggested by the theory of desirable difficulties, arranging initial learning to maximize training performance often results in poor test performance. When various training schedules are blocked rather than spaced, acquisition is improved, but final test performance declines (Baddeley & Longman, 1978). Similarly, acquisition performance improves when variability during training is minimized, but transfer performance declines (Kerr & Booth, 1978). Delaying explicit instruction about the structure of the task can also enhance learning, presumably because early explicit instruction interferes with the development of learners' own exploration of the situation (Green & Flowers, 1991; Slamecka & Graf, 1978). Finally, assistance during training can impair test performance because learners have great difficulty transferring from the training to the test when training is even slightly different than the test (e.g., Gick & Holyoak, 1980; Weisberg, DiCamillo, & Phillips, 1985).

The Benefits of Assistance

While some theories suggest that assistance during training is likely to impair test performance, theories of the zone of proximal development (Vygotsky, 1978) and reminding (Ross, 1987) suggest that assistance during training should result in the most robust learning outcomes. According to the theory of the zone of proximal development, learning mostly occurs in the region between a student's present level of understanding and their higher level of potential development (Vygotsky, 1978). Assistance during training, labeled a scaffold, extends the zone of proximal development and fosters greater student progress by making complex tasks more accessible, manageable, and tractable (Rogoff, 1990). Scaffolds can reduce the cognitive load placed on the learner by decomposing tasks into simpler steps and reducing search and execution costs (Ward & Sweller, 1990). Reducing the search and execution costs of problem solving through a scaffold frees cognitive resources, which can be used to learn more about the specific solution methods, acquire schema, and improve performance (Sweller, 1990; Ward & Sweller, 1990). These arguments are echoed by proponents of errorless learning (Terrace, 1963a, 1963b).

According to reminding theory, assistance during training promotes robust learning because it reduces errors and floundering during initial learning (Benjamin & Tullis, 2010; Hintzman, 2004; Ross, 1987; Tullis, Braverman, Ross, & Benjamin, 2014; Tullis, Benjamin, & Ross, 2014). The initial learning episodes are especially important because later episodes may remind learners of earlier episodes. If the initial learning episodes are incorrect, they may be brought back to mind during later problem solving, strengthened by this reminding, and ultimately inhibit the correct schemata from fully forming (Bassok & Holyoak, 1989).

Evidence suggests that providing learners with assistance during training improves learning outcomes across a variety of domains including simple motor tasks (Winstein & Schmidt, 1990), math (Carroll, 1994), physics (Ward & Sweller, 1990), fashion design (Rourke & Sweller, 2009), debate (Jonassen & Kim, 2010), and even skiing (Burton, Brown, & Fischer, 1984). For instance, providing learners with worked examples (including the problem formation, solution steps, and final answers) during initial learning improves both performance on new problems (Atkinson, Derry, Renkl, & Wortham, 2000; Paas, 1992; Renkl, 2002; Sweller & Cooper, 1985) and learning efficiency (Paas & Van Merrienboer, 1994) compared to pure problem solving. Conceptual assistance during training has also been shown to improve training and transfer performance. For example, children who were given an elementary explanation of the theory of refraction hit targets under water more accurately both during training and when the depths of the targets were changed than those without the theoretical instruction (Hendrickson & Schroeder, 1941; Judd, 1908).

Finally, some theories suggest that assistance is most beneficial when it is provided during initial training, but faded away during later training. Scaffolds, according to the zone of proximal development theory, should be adaptive and temporary (Vygotsky, 1978). Assistance during training should be withdrawn in order to transfer the responsibility from the scaffold to the learner through a process of internalization (Stone, 1998). Similarly, in the cognitive apprenticeship model, support should be faded away to successively approximate mature practice and ensure that the trainee can work independently after the support has been removed (Collins, Brown, & Newman, 1987). Reminding theory also suggests that the testing trials need to be similar enough to the training that the learner can use the training during the test. Fading away external support may support long-term learning because it can reduce the cognitive redundancy effect (Kalyuga, Ayres, Chandler, & Sweller, 2003). As learners' expertise grows, they no longer need assistance provided to them; in fact, coordinating their mental representation with the redundant external support may waste cognitive resources and impair performance. Therefore, gradually fading away the external support may foster better learning by eliminating the need to coordinate the internalized mental representation with the external support (Fyfe, McNeil, Son, & Goldstone, 2014).

Recent evidence reveals the advantages of fading away external support during training. For example, fading away assistance during training in a motor learning task produces better retention and transfer performance than constant assistance (Winstein & Schmidt, 1990; Wulf & Schmidt, 1989). When given control over their levels of support during motor learning, learners choose to have high levels of assistance during initial training and slowly fade away this support (Hartman, 2007; Wulf & Toole, 1999). Importantly, the group with this faded schedule of assistance outperformed a control group, which has no control over their schedule of assistance. Fading away worked examples by removing a step from each consecutive studied example also produces greater transfer performance (Atkinson, Renkl & Merrill, 2003; Kalyuga & Sweller, 2004; Renkl, Atkinson, & Grosse, 2004) and more efficient learning (Schwonke et al., 2007) than alternating between worked examples and pure problems. Students even learn more about the principles that were faded away than those that were consistently present (Renkl et al., 2004).

Adaptive scaffolding is another means of fading assistance; as a student's expertise grows, less support is provided. Research suggests that adaptive tutoring (based on a student's performance) leads to better long-term learning on long-division math problems than either high or medium assistance conditions (Pratt & Savoy-Levine, 1998). A summary of the arguments for and against assistance during training is presented in Table 1.

The Present Experiment

In the present experiment, we examined how the amount and schedule of assistance during training on a novel mouse movement task impacted unassisted test performance. Learners manipulated a computer mouse so that the

TABLE 1. A Summary of Arguments For and Against Assistance During Training

In support of. . .	Theory	Argument
Minimal assistance	Desirable difficulties	More effortful training produces better retention
	Guidance hypothesis	Learners overly depend on assistance and neglect self-generated understanding
	Transfer by identical elements	Training should exactly match test circumstances
	Active processing	Less assistance prompts learners to be more cognitively active
Substantial assistance (faded assistance)	Reminding theory	Reducing errors during initial learning is vital
	Zone of proximal development	Scaffolding frees cognitive resources to better learn problem solutions
	Cognitive apprenticeship	Assistance should be faded to successively approximate testing
	Cognitive redundancy effect	As learners develop internal mental representations, external assistance should be faded so as not to interfere

corresponding on-screen cursor entered the goal box as quickly as possible. The cursor was rotated 90° clockwise around the center of the screen from the mouse position. Similar mouse transformation tasks have been recently used to investigate the acquisition of internal models across brain regions (Imamizu, Kuroda, Miyauchi, Yoshioka, & Kawato, 2003; Imamizu et al., 2000). The position of the mouse was displayed on some trials as assistance for the learners. Learners received different schedules of assistance, including the mouse position always being indicated, never being indicated, probabilistically indicated, indicated on every other trial, and faded away during training.

The assistance we utilized in this motor task differed from that used across the existing literature. First, in the existing motor guidance literature, assistance frequently restricts participants' movements to the correct motions so that participants cannot make errors or sample the full range of responses. In our paradigm, participants could explore the problem space as freely during scaffolded trials as during unscaffolded trials. This freedom during training allowed us to uniquely track performance over the course of both assisted and unassisted training. Second, in experiments examining knowledge of results, guidance is provided after a participant completes the motor movement; the assistance we provided occurred during the training trials themselves. This distinction is important because presenting feedback after a trial may prevent participants from assessing their own performance and developing metacognitive monitoring skills during training. Third, in the prior motor movement literature, assistance is either present or not present during each trial. One of the schedules of assistance that we test involves slowly fading it away rather than just having it be present or absent. This unique feature allowed us to easily vary the type and schedule of assistance provided to learners and to examine the impact of different schedules of support on both training and test performance, even when the total number of scaffolded trials was equivalent.

The three main questions we seek to answer are the following: (a) Does the presence of concurrent, nonrestrictive assistance during learning create a crutch that impairs unassisted test performance?; (b) Can fading support during training foster better performance than never presenting help?; and (c) Can the schedule of support, even when the number of assisted trials is equal, impact final performance?

Our rotated mouse-cursor mapping task was used as a model task for studying the role of assistance because pilot studies showed that the presence of a simple visual scaffold could dramatically improve performance. Figure 1C shows an unscaffolded trial in which, for example, as the participant moves the mouse to the right, the cursor moves downward, and downward mouse movements translate to leftward movements of the cursor. This counterintuitive and frustrating action-effect mapping was appreciably ameliorated by indicating the mouse's unrotated position with a white square and lines connected to the center, which showed the rigid, deterministic relationship between mouse and cursor positions, as shown in Figure 1A. With the white square and connecting geometric line structure present, participants could typically rapidly control the black square. Participants can explicitly see the rigid relationship between the mouse movement and the cursor movement during scaffolded trials. This may reduce the cognitive load placed on participants because they do not need to mentally calculate the mouse location. Consequently, learners can develop more efficient movement strategies during scaffolded trials than unscaffolded trials. The task thus features a scaffold that affords a powerful performance advantage, but which also can potentially be internalized and imagined by participants so that it no longer needs to be physically present. The assistance dilemma question as instantiated in this task becomes, "How can the scaffolding box and lines be presented in such a way that it helps learners acquire the counterintuitive action-effect mapping but also so that learners eventually learn to

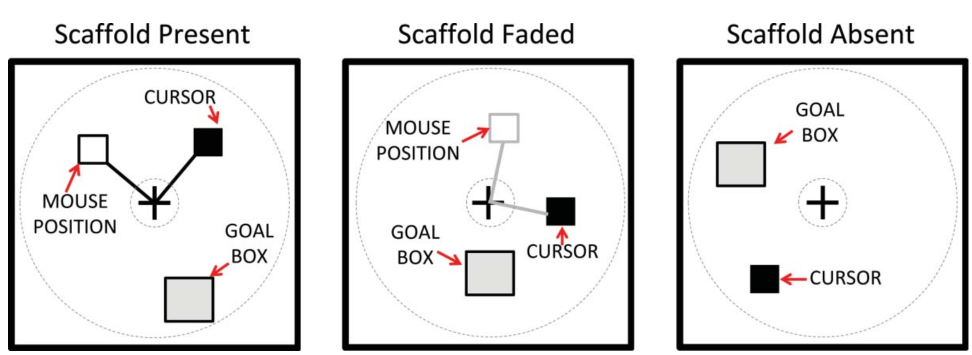

FIGURE 1. The different trials a participant experienced. The goal square appeared in a random location between the dashed rings (which were not shown to participants) on each trial.

generate the scaffold themselves rather than always relying on its physical presence?"

Method

Participants

Two hundred introductory level psychology students at Indiana University participated in exchange for partial course credit.

Procedure

The experiment was programmed in Matlab (The MathWorks, Natick, MA) using the Psychophysics Toolbox (Brainard, 1997). Participants completed the experiment across 10 different computers in individual testing booths. Participants were tasked to move the mouse so that an on-screen cursor (represented by a small black box) entered the goal square as quickly as possible. However, the movement of the cursor was a transformation of the movement of the mouse. While many transformations could have been employed, we chose a transformation for which the movement of the cursor was rotated 90° from the middle of the screen clockwise from the mouse movement. For instance, if the mouse was directly above the center of the screen and the subject moved the mouse right, the cursor would be directly right of the screen center and would move down. With the center of the screen at (0, 0), the relationship between the cursor position and the mouse position was:

$$\text{cursor}_x = \text{mouse}_y$$
$$\text{cursor}_y = -\ \text{mouse}_x$$

An interactive, web-based example of the mouse transformation is located at http://www.indiana.edu/~pcl/cursor/cursor.html (within this demonstration, press *d* to see the scaffold and *n* to hide it). Participants were not told what the relationship was between the mouse's movement and the cursor's movement.

For each trial, the cursor appeared in middle of the screen and a goal square appeared in a random location within a ring centered at the middle of the screen, as shown in Figure 1. Once the subject moved the cursor into the goal square, both the cursor and the goal square disappeared. Participants clicked the mouse to begin the next trial whenever they were ready. Then the goal square would appear in a new random location within the ring and the cursor would appear in the center of the screen. The time needed to reach the goal square was recorded. Participants completed 60 training trials and 30 test trials.

During the training trials, the position of the mouse was sometimes indicated on the screen by an unfilled box connected by a line to the center point of the screen, as shown in Figure 1A. Whether the position of the mouse was displayed during training depended on the condition of the subject. Participants were alternately assigned to five between-participants training conditions: the scaffold was (a) always present, (b) never present, (c) faded away, (d) probabilistically present, or (e) alternated on and off. For the faded away condition, the mouse indicator faded from black to gray to absent across the 60 training trials. The fading of the mouse indicator followed the equation: contrast = 1/j, where j = trial number. The mouse indicator was largely invisible by the 40th trial. The quick initial fading was implemented to encourage internalization of the scaffold, because, in pilot experiments, slower linear fading resulted in an easily visible scaffold throughout the training trials. In the probabilistically present condition, the probability that the mouse position was indicated on each trial dropped off linearly from 1 to 0 across the 60 training trials. On average, then, participants in the probabilistically present condition received assistance on half of their training trials. This condition was included based on the theory that scaffolding should tend to be removed over time to avoid overreliance on it. Finally, in the alternating condition, the position of the mouse was indicated on all odd trials but not on even trials. This condition was included because many previous studies have compared pure problem solving (no assistance) with alternating between worked examples and problem solving (alternating assistance).

After completing the training trials, participants were asked to rate on a 6-point Likert-type how quickly they would be able to complete the test trials when the position of the mouse would not be present, with responses ranging from 1 (*very slowly*) to 6 (*very quickly*). This metacognitive question slightly delayed the unassisted test, which happened immediately after they entered their metacognitive judgment. Participants completed 30 test trials, which were exactly like the training trials but the scaffold was never present.

Results

Completion times by block and condition are displayed in Figure 2. A 2 (training or test block) × 5 (training condition) mixed-design analysis of variance (ANOVA) on completion times revealed a significant interaction, $F(4, 195) = 42.49$, $p < .001$, $\eta^2_{\text{partial}} = .18$. The effect of the assistance condition, therefore, depended on whether the learner was being trained or tested. We tested how conditions impacted training and test performance separately. All *t* tests presented are two-tailed.

Does Assistance Support Better Training Performance?

A one-way ANOVA on training performance revealed a significant effect of condition, $F(1, 4) = 2.47$, $p = .05$, $\eta^2 = .048$). We tested whether the presence of the mouse with connecting lines reduced the time needed to reach the goal state. During training, the always present condition reached the goal state faster than the never present

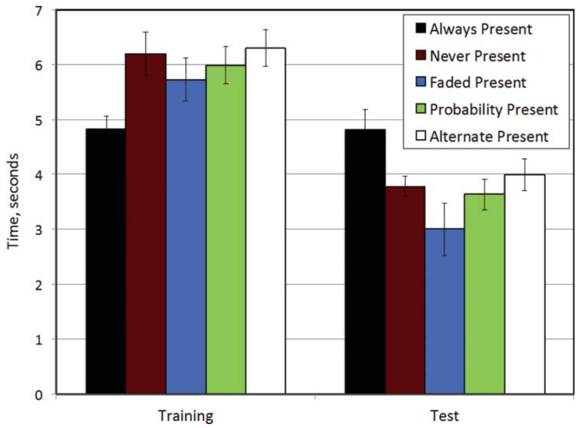

FIGURE 2. Mean times to solve each trial as a function of block (training vs. test) and assistance condition. Error bars indicate standard errors of the mean.

condition, $t(78) = 2.49$, $p = .01$, Cohen's $d = .69$, as shown in Figure 2. Further, in the alternating condition, the present trials (the odd trials) were faster ($M = 5.23$ s, $SD = 1.44$ s) than the absent trials (the even trials, $M = 7.37$ s, $SD = 3.40$ s), $t(39) = 4.43$, $p < .001$, $d = .71$, as shown in Figure 6. These results confirm the strong intuition that the mouse indicator did, in fact, facilitate performance.

How Does Training Condition Affect Unassisted Test Performance?

A one-way ANOVA on unassisted test performance revealed a significant effect of condition, $F(1, 4) = 4.95$, $p = .001$, $\eta^2 = .092$. We conducted planned, orthogonal contrasts between specific conditions' test times in order to minimize Type I error. First, we compared test performance in the always present condition with all the other conditions to assess whether assistance in the always present condition became a crutch. The always present condition performed worse during the test than the group of all of the other conditions, $t(198) = 3.67$, $p < .001$, $d = .52$.

Second, we tested whether fading away assistance resulted in better test performance than never presenting assistance during training. Fading the scaffold away during learning resulted in faster test performance than never presenting the scaffold, $t(78) = 2.50$, $p = .03$, $d = .57$, as shown in Figure 4.

Finally, we tested whether the schedule of assistance impacted final performance when the overall amount of assistance was held constant. While both the probabilistic scaffold and the alternate scaffold provided assistance on half of the training trials, the assistance was displayed during early training in the probabilistic condition and evenly spread throughout training in the alternating condition. No significant difference was found between the probabilistically present versus the alternating conditions, $t(78) = 0.88$, $p = .38$, $d = .20$.

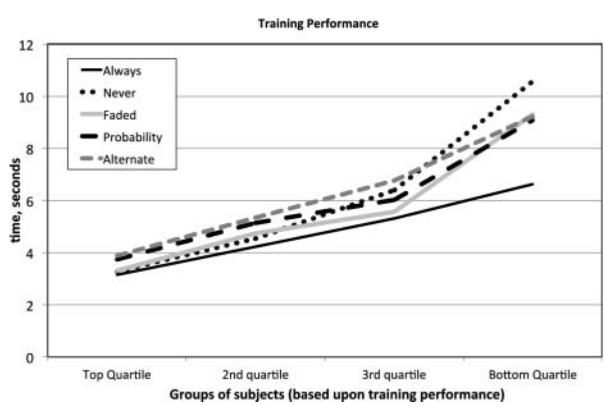

FIGURE 3. Training performance split based on the condition and performance of subjects during training.

Does Training Condition Affect Metacognitive Predictions of Test Performance?

Finally, metacognitive predictions are displayed in Figure 5. We conducted planned comparisons among participants' ratings of their anticipated speed during testing. Participants in the never present condition expected to be faster than those in the faded condition, $t(78) = 2.25$, $p = .03$, $d = .51$. Participants did not make differential predictions between the probabilistic and alternating conditions, $t(78) = 0.50$, $p = .62$, $d = .11$. Interestingly, the fastest test performance was not predicted by learners in the fastest training group (the always present condition).

Discussion

The amount and schedule of assistance provided to learners during training largely influenced test performance. Knowing the location of the mouse and connecting lines consistently improved training performance, but had a complicated relationship with unassisted test performance. Too much or too little support during training resulted in poorer test performance than fading away support during learning. Support was most beneficial for test performance when learners were given significant assistance that was slowly faded away during training.

Displaying the location of the mouse on the screen improved training performance. Learners more quickly moved the cursor to the goal when the location of the mouse was indicated during training. Evidence suggests that this assistance may be most beneficial to the poorest performing participants. The variability across participants in the never present condition was greater ($SD = 3.12$) than the variability across the participants in the always present

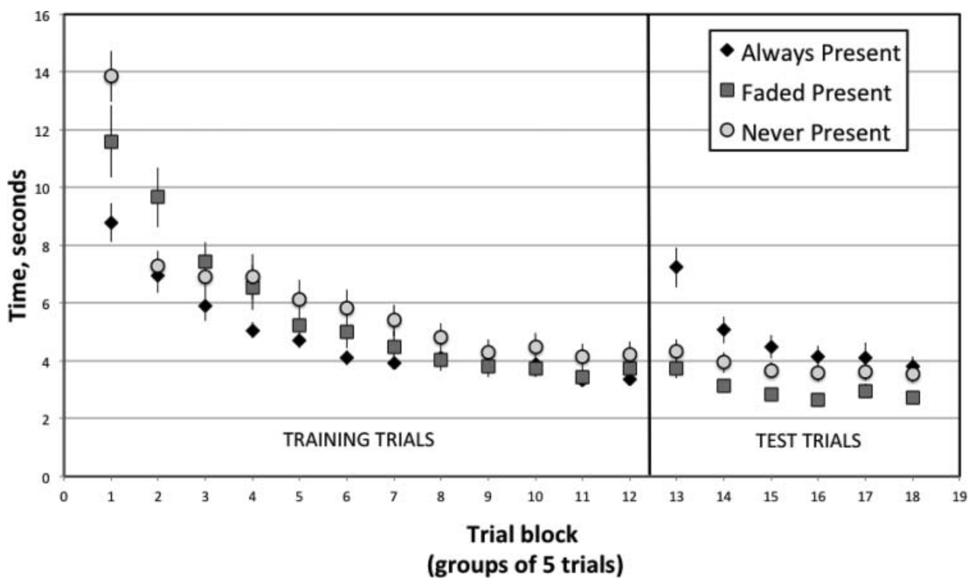

FIGURE 4. Mean times to solve each trial throughout the training trials and the immediately following test trials for the always, faded, and never present conditions. Error bars indicate standard errors of the mean.

condition ($SD = 1.40$), $F(39, 39) = 1.81$, $p = .03$. This suggests that assistance homogenized the performance of the always present participants; the worst participants likely benefited the most from assistance, which caused the variability among participants within the always present condition to drop, as displayed in Figure 3.

Even though constant assistance resulted in the best training performance, learners who enjoyed constant assistance during training performed worse than all other assistance schedules during the unassisted test. The concurrent and nonrestrictive assistance became a crutch on which learners relied; when the crutch was removed, learners' performance dropped significantly. Learners heavily relied on the constant assistance and could not accomplish the task as easily when that assistance was removed. The visual scaffold assisted performance while present but only continued to support test performance if it had been slowly faded away throughout training. Learners who had some unassisted training trials performed better during the unassisted test because they began to learn how to accomplish the task without the external assistance. Reducing assistance throughout training, therefore, may prove to be a good example of a desirable difficulty that encourages more active processing during training and ultimately enhances long-term learning and transfer (Schmidt & Bjork, 1992). The results reveal disadvantages of guidance, even when that guidance does not restrict participants' opportunities to sample a wide range of responses (cf. Annett, 1959). Further, final performance was impaired even when assistance did not prevent participants from developing their own metacognitive monitoring skills during training.

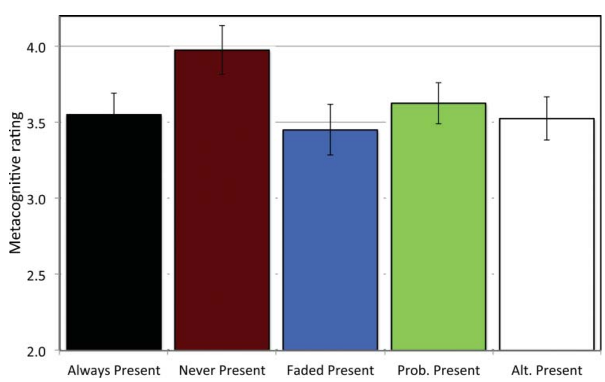

FIGURE 5. Mean metacognitive ratings of how quickly learners will finish each trial during the test by assistance condition. Higher values indicate judgments of greater speed. Error bars indicate standard errors of the mean.

Interestingly, there was a dissociation between participants' metacognition and test performance. For example, participants in the never present condition thought that they would do better during test than those in the faded condition, whereas actual test performance was better in the latter than in the former condition. Like other dissociations between performance and metacognition (e.g., Roediger & Karpicke, 2006; Simon & Bjork, 2001; Tullis, Finley, & Benjamin, 2013), this dissociation suggests caution in letting learners choose their own training regime. Even when they are trying to choose a regime to optimize future performance, learners may choose suboptimally. Further, this pattern of results suggests that learners' metacognitive predictions follow Thorndike's transfer by identical elements—participants believe they will be fastest when the training exactly matches testing.

Fading away the assistance during training led to the best test performance, as it resulted in the fastest mean performance on 24 of the 30 test trials. In fact, post hoc two-tailed *t* tests show that the fading condition had faster test performance than the alternating condition, $t(78) = 2.89$, $p = .005$, and marginally faster performance than the probabilistic condition, $t(78) = 1.86$, $p = .07$. Fading support may prove advantageous for several reasons. First, providing assistance at the beginning of training reduces errors during the initial learning. Initial learning may be very important because later trials may remind learners of earlier trials and reinforce those solutions (Ross, 1987). In errorless learning, learners do not confuse error responses with correct responses and do not experience distracting emotions associated with errors (Terrace, 1963a).

Second, fading may also help by providing insight into the structure of the task. Learners could use a perceptually available cue to aid their performance and support their understanding of the relationship between the cursor and their mouse movement. As this perceptual information is faded, learners may continue to respond on the basis of their acquired understanding of the action-effect relation (Terrace, 1963b). Quickly fading away assistance may have encouraged learners to internalize the assistance originally provided to them, and allowed them to solve the task expertly even when the assistance was completely removed (Collins et al., 1987; Stone, 1998). The importance of fading away the support is revealed by the poor test performance of the always present condition, wherein during training, learners could rely on the external support without internalizing it. The combination of reducing initial errors while gradually encouraging learner responsibility may prove to be the optimal training schedule.

Transfer by identical elements and specificity of learning theories suggest that the never present condition should perform best during the test because the never present condition had the most training with the exact task that learners faced during the test. However, the never present condition produced worse test performance than the fading away condition. Greater transfer occurred between dissimilar tasks (faded training and unassisted testing) compared to the exact same tasks (unassisted training and unassisted testing). This suggests that providing assistance to learners can improve performance on a slightly dissimilar task when the training task only gradually comes to approximate the transfer task. Performance on a transfer task, then, depends on both the similarity between training and test, the transition between training and test, and the learner's performance during the training task.

Encouraging internalization of the scaffold is difficult. Data patterns from the alternating and probabilistic conditions suggest that learners treated the assisted and unassisted trials as distinct and separate throughout training. In the alternating condition, performance jumps up and down as a function of whether support was provided, as shown in the left panel of Figure 6. Further, learning curves for the probabilistically indicated condition reveal two separate trajectories based on whether learners received assistance or not, as shown in the right panel of Figure 6. These clear patterns suggest that learners do not integrate across the two kinds of training trials. Rather, learners develop two distinct problem representations based on whether support is present or not. Only the learners in the faded condition successfully combined the two mental representations into one during training. Why nonfading subjects apparently fail to construct a persistent mental model even though the mechanical model is presented to them remains a persisting puzzle. One likely lesson from these results is that simply making a scaffolding signal available to learners does not assure that the learners will make use of the signal to improve their learning when that signal is absent. Only when the signal becomes increasingly difficult to use, as in the faded condition, will the advantages of internalizing the signal be salient enough to compel learners to engage in this process. A possible generalizable implication for education is thus: to circumvent learners' inclination to use a signal as a crutch rather than a scaffold, design the signal to be progressively more difficult to use.

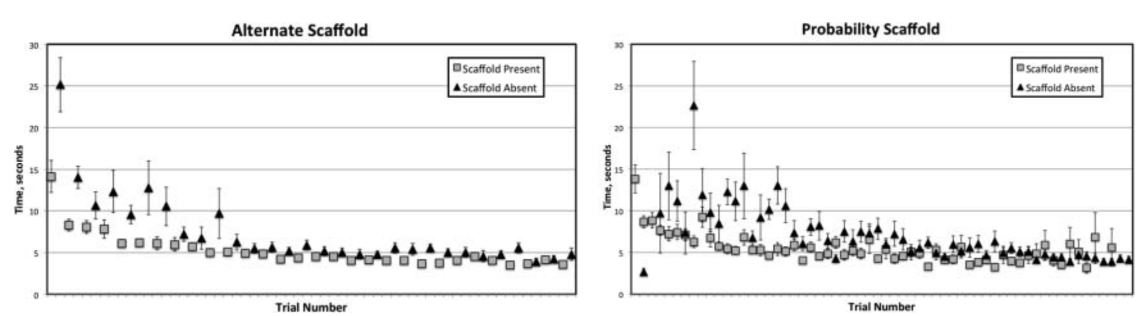

FIGURE 6. Performance across training trials when the scaffold was present and absent in the alternating condition (left panel) and probabilistic condition (right panel). Error bars represent standard errors of the mean.

One of the underlying difficulties that makes the assistance dilemma a dilemma is that one may need to provide assistance if learning is going to be at all efficient. However, given the laziness of learners, people may use the assistance as a crutch to improve momentary performance, rather than long-term learning (see Bjork & Bjork, 1992). For example, assuming that learners can acquire the relation between the scaffold and the cursor on the trails in which the scaffold was present and use that information to project the scaffold onto the screen when it was absent, learners in the alternating condition could have utilized the cue from the present trials to help them perform well on the absent trials. However, students appeared to lack either the metacognitive awareness or motivation to engage in such strategic learning. In the faded condition, as the cue become harder to see and use, learners can simultaneously intuit the benefit of internalization and still have the cue physically present from which to learn, on the very same trial.

Finally, no significant differences were found between the alternating condition and the probabilistically indicated condition—the two schedules that had the same level of support. Learners in these two conditions received support on half of the training trials, but differed according to when the assistance was provided. In the alternating condition, assisted trials were evenly spread throughout training, while in the probabilistically indicated condition, they were concentrated toward the beginning of training. The equivalence of these conditions suggests that when the unassisted training trials occur may not largely matter in this paradigm. However, in these two conditions, the schedule of support was confounded with the number of transitions between support and no support; the alternating condition maximized the transitions between supported and unsupported trials, while the probabilistically indicated condition had many fewer of these transitions.

This rotated mouse-cursor mapping task easily allows for testing various questions about assistance during learning and transfer. The mouse movement task affords a simple means of measuring performance throughout training and testing, and assistance to learners can be smoothly scheduled in various ways. This task can be used to explore other unanswered questions about the assistance dilemma, such as how various levels of support impact performance on a more dissimilar transfer task (e.g., where the cursor movement is a different transformation of the mouse movement). Further, the task can be modified to assess whether various schedules of assistance encourage learners to internalize the scaffold during training. The mouse movement task, however, is a rather simple task, and the results of this study may have limited generalizability to more complex skills and complex knowledge (Wulf & Shea, 2002). The simple instructional principles derived from these results, then, may be most applicable to such tasks as building mnemonic fluency (Koedinger, Corbett, & Perfetti, 2012).

Using a tightly controlled experiment, we have begun to characterize the qualitative conditions involving assistance that can aid instructors in making sound pedagogical decisions. The complex relationship between the amount and schedule of assistance during training and final test performance was revealed in a novel mouse movement task. Instructors must consider how much support they provide to students in order to optimize student learning. Instructors need to provide substantial assistance during training for difficult tasks, while simultaneously preparing learners for subsequent conditions in which no support is provided. Maximal levels of support during training may impair unassisted test performance because learners are not prepared for unsupported conditions. Specific schedules of reduced support (e.g., fading support during training) may foster strong test performance. Fading away assistance throughout training may reduce cognitive costs (e.g., initial errors and floundering) while providing cognitive benefits (e.g., actively engaging learners and encouraging learners to internalize the scaffold). Instructors need to make conscious choices about how much and when assistance is provided during training to support robust learning, and fading away assistance has the promise of substantially easing students' cognitive burdens while improving test performance.

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