Individual Differences in the Benefits of Feedback for Learning
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What is This?
Individual Differences in the Benefits of Feedback for Learning

Christopher M. Kelley and Anne Collins McLaughlin, North Carolina State University, Raleigh, North Carolina

Objective: Research on learning from feedback has produced ambiguous guidelines for feedback design—some have advocated minimal feedback, whereas others have recommended more extensive feedback that highly supported performance. The objective of the current study was to investigate how individual differences in cognitive resources may predict feedback requirements and resolve previous conflicted findings.

Method: Cognitive resources were controlled for by comparing samples from populations with known differences, older and younger adults. To control for task demands, a simple rule-based learning task was created in which participants learned to identify fake Windows pop-ups. Pop-ups were divided into two categories—those that required fluid ability to identify and those that could be identified using crystallized intelligence.

Results: In general, results showed participants given higher feedback learned more. However, when analyzed by type of task demand, younger adults performed comparably with both levels of feedback for both cues whereas older adults benefited from increased feedback for fluid ability cues but from decreased feedback for crystallized ability cues.

Conclusion: One explanation for the current findings is feedback requirements are connected to the cognitive abilities of the learner—those with higher abilities for the type of demands imposed by the task are likely to benefit from reduced feedback.

Application: We suggest the following considerations for feedback design: Incorporate learner characteristics and task demands when designing learning support via feedback.

Keywords: individual differences, aging, fluid ability, feedback, crystallized intelligence, learning

INTRODUCTION

Learning requires the use of cognitive resources such as fluid ability, working memory capacity, and crystallized intelligence (Baddeley, 1986; Horn & Cattell, 1967; Morris, Bransford, & Franks, 1977). Previous research has shown these resources are limited and thus subject to demands beyond capacity (Baddeley, 1986; Sweller, 1988). Given that previous research has also shown individual differences in these cognitive resources (Engle, Kane, & Tuholski, 2004), the current study investigated the interactions between individual differences in cognitive resources and task support during the process of learning via feedback.

The amount of cognitive resources that learners possess positively relates to learning; those with higher fluid abilities (working memory capacity), crystallized intelligence (verbal ability), or other abilities related to the task learn faster than those lower in those abilities (Craik & Salthouse, 2000; Engle & Kane, 2004). The advantage for learners with higher resources can be explained through cognitive load theory: Learning occurs when these finite cognitive resources are not overwhelmed during the acquisition period (Sweller, 1988). That is, a learner must have the cognitive resources necessary to meet the demands imposed by the task. One strategy to help learners meet these demands is to provide support that reduces the initial need for cognitive resources when learning a new task. This may be done through instruction (Sweller, 1988), by changing the task (van Gog, Paas, & van Merriënboer, 2004; Wightman & Lintern, 1985), or by providing feedback—the focus of the current investigation.

ACCOMMODATING INDIVIDUAL DIFFERENCES IN COGNITIVE RESOURCES

We define support as information provided to a learner that reduces the demands placed on his
or her cognitive resources by a task. One method of providing support is to offer feedback—information from an external source about performance (Kluger & Denisi, 1996). It is generally acknowledged that feedback assists learning, but there are no definitive conclusions regarding the optimal amount to provide. In addition, there are counterintuitive circumstances where feedback harms learning (Schmidt & Bjork, 1992). Those who advocate the supportive role of feedback in learning emphasize that providing extensive, frequent, immediate feedback during the acquisition stage frees the cognitive resources required for learning (Sweller, 1988). However, providing little feedback may force the learner to engage in the cognitive processes that will be necessary when the feedback is no longer available, such as on a retention test (e.g., Schmidt & Bjork, 1992). We propose that these opposing theories both are correct and can be explained through the study of individual differences: optimal feedback depends on learner ability levels for the demands of the task being learned.

For learners with lower cognitive resources, feedback may reduce the need for self-assessment during learning by providing the standard of correctness rather than requiring the learner to subjectively evaluate his or her own performance. Such support reduces cognitive load during acquisition and results in freed cognitive resources. Providing more feedback also reduces complex reasoning activities that increase cognitive load by communicating task specific information to a learner (Sweller, van Merriënboer, & Paas, 1998). Given that low ability learners have the most limited cognitive resources, more feedback during learning may be especially beneficial because the feedback could free resources the learner needs to dedicate to the learning of the task.

For learners with higher cognitive abilities, highly supportive feedback may not be desirable when learning a task. Previous research has shown that feedback conditions that make a task more difficult actually contribute to learning (Schmidt & Bjork, 1992). One potential explanation is that providing less feedback facilitates more elaborate processing by forcing the learner to understand the task rather than mimic a correct standard (Anderson & Reder, 1979; Craik & Lockhart, 1972). This challenge, or “desirable difficulty,” also requires the learner to engage in the processes that will be needed when feedback is no longer available (Bjork, 1994; Guadagnoli, Dornier, & Tandy, 1996). This results in the learner practicing the retrieval of information during acquisition and can lead to increased learning (Bransford & Schwartz, 1999; Schmidt & Bjork, 1992). Thus, learners with high cognitive resources should be less susceptible to cognitive overload, and less support via feedback could create learning conditions that closely resemble those of retention tests.

In summary, the demands imposed on a learner can be altered via the amount of support; feedback may function as a scaffold during acquisition of a new task. However, since most studies of feedback looked at the learning of fairly homogeneous populations, typically college students (e.g., Butki & Hoffman, 2003; Schooler & Anderson, 1990), it has been difficult to isolate the specific role of feedback on learning without controlling for the ability level of the learner. Individual differences in cognitive resources may explain the benefits and detriments of highly supportive feedback on learning.

**OVERVIEW OF THE STUDY**

The goal of the current study was to assess the role of cognitive resources and support on learning. It was examined whether levels of support could accommodate differences in cognitive resources while learning a rule-based cue-identification task. It was expected learning would be a function of cognitive resources and the level of support.

Support was provided through varying levels of feedback. Participants were given either a lower or higher level of feedback at the conclusion of each trial. It was expected that providing higher levels of support to learners with lower abilities for the task would result in more learning as demonstrated on a retention test but that learners with high ability levels would learn more given less feedback support.

Two age groups were recruited for the study because of their documented differences in fluid ability and crystallized intelligence. Cognitive aging research has generally shown that fluid abilities tend to decline with age, whereas crystallized intelligence increases (Craik & Salthouse, 2000; Horn & Cattell, 1967; Salthouse, 1990,
Thus, older participants should have higher ability for verbal intelligence tasks compared to fluid ability tasks, whereas younger adults should have the opposite. The tasks were designed to require the use of participants’ fluid abilities or crystallized intelligence to learn cue-based identification rules. It was expected those with higher abilities related to the task would learn best when given less feedback support. Specifically, older adults should benefit from higher support on tasks that require fluid abilities but from lower support on tasks that require crystallized intelligence. Conversely, it was expected younger adults would benefit from less support in tasks that require fluid abilities but more support would be needed for crystallized intelligence tasks.

**METHOD**

**Participants**

Older and younger adult participants were recruited from the community via classifieds, job boards, and craigslist.com. Younger adults ranged in age from 18 to 28 years ($M = 21.33, SD = 2.71$) and were paid $35.00 for their participation. Older adults ranged in age from 65 to 77 years ($M = 69.32, SD = 3.14$) and were paid $40.00 for their participation because of the longer time required for them to complete the study. In all, 99 participants initially enrolled in the study, and 76 were included in the final analysis. Because of incomplete, missing, or corrupted data, 10 participants were excluded, and 15 younger adults and 1 older adult failed to attend the retention session. If attrition rates were the result of the difficulty of the task alone, we would have expected the rates for older adults to be higher than for younger adults; however, the younger adult group saw the highest attrition. We conducted a one-way multivariate analysis of variance (MANOVA) to investigate if there were differences between younger adults who returned for the retention session and those who did not. Abilities examined included perceptual speed (Wechsler, 1997), primary memory span (Wechsler, 1997), and verbal ability (Shipley, 1986). Scores did not differ, $F(5, 37) = 0.83, p = .54, \eta^2_p = .10$. Therefore, given these results and the lower attrition rate for older adults, we concluded the attrition rate for younger adults was related not to the experimental task but to some other circumstance such as scheduling and returning for a retention session.

**Materials**

**Ability tests.** Participants provided demographic information and completed tests of perceptual speed (Digit Symbol Substitution; Wechsler, 1997), memory span (Reverse Digit Span; Wechsler, 1997), verbal ability (Shipley Institute of Living Scale; Shipley, 1986), and working memory capacity (Automated Operation Span; Unsworth, Heitz, Schrock, & Engle, 2005; Table 1). To check for systematic differences between the randomly assigned groups, these measures were analyzed using a MANOVA. Expected age differences were found where younger adults scored higher on tests of fluid ability and older adults scored higher on verbal ability (Rogers, Hertzog, & Fisk, 2000). However, scores did not differ between feedback groups at either age level (Table 1). Near vision was assessed using a Snellen chart. All participants had 20/40 or better corrected vision.

**Questionnaires.** Participants also completed a questionnaire designed to assess previous experience with technology and computers (Table 1; Czaja, Sharit, Charness, Fisk, & Rogers, 2001). Questionnaire items were analyzed using a MANOVA to investigate the differences between age groups and feedback conditions. As shown in Table 1, younger adults reported having used computers a longer total time and more frequently over the previous 3 months. When compared to their own age group, participants’ computer use did not differ between feedback conditions.

**Equipment.** The experimental task was performed on IBM-compatible computers (1.80 GHz Pentium Dual Core, 1.96 GB RAM). Screen size was 19 in., with a resolution of 1280 x 1024 pixels and a refresh rate of 60 Hz.

**Experimental Task**

The task required participants to decide whether a given pop-up was legitimate (e.g., generated by Windows) or fake (e.g., created by a virus). The correct answer was based on cues learned in the study through feedback on answers.
# Table 1: Participant Characteristics Divided by Feedback Condition and Age

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## Frequencies

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| Education\(^a\)    | 3.20  | 1.24   | 3.81  | 1.28   | 5.16  | 1.83   | 5.05  | 1.65   | 3.51* |
| Health compared to others\(^b\) | 3.05  | 0.69   | 3.00  | 0.52   | 3.37  | 0.60   | 3.63  | 0.60   | 11.21* |

## Technology Experience Questionnaire

| Indicate the total length of time you have used computers\(^c\) | 5.00  | 0.00   | 4.92  | 0.29   | 4.78  | 0.55   | 4.61  | 0.78   | 4.28* |
| Max computer usage over three months\(^d\) | 4.65  | 0.67   | 4.50  | 0.67   | 3.39  | 1.04   | 3.78  | 1.17   | 6.93* |

## Ability Tests

| Perceptual speed\(^e\) | 68.90 | 9.97   | 64.62 | 11.63  | 51.43 | 12.77  | 49.00 | 5.36   | 42.24* |
| Memory span\(^f\) | 4.45  | 1.32   | 4.13  | 0.89   | 3.71  | 0.77   | 3.33  | 0.62   | 10.65* |
| Intellectual ability\(^g\) | 31.85 | 3.42   | 31.38 | 3.86   | 36.00 | 2.18   | 34.47 | 3.46   | 20.50* |
| Working memory capacity\(^h\) | 46.90 | 17.16  | 43.75 | 14.66  | 35.47 | 20.43  | 33.20 | 9.89   | 3.25*  |

\(^a\)Choices were 1 = did not graduate high school, 2 = high school graduate or GED, 3 = some college, 4 = associate’s degree, 5 = bachelor’s degree, 6 = some graduate school, 7 = master’s degree, 8 = MD, PhD, or other advanced degree.

\(^b\)Choices were 1 = poor, 2 = fair, 3 = good, 4 = very good.

\(^c\)Choices were 1 = less than 6 months, 2 = 6 months but less than 1 year, 3 = 1 year but less than 3 years, 4 = 3 years but less than 5 years, 5 = at least 5 years.

\(^d\)Choices were 1 = once every few months, 2 = every month, 3 = once per week, 4 = several days per week, 5 = daily, but infrequently during the day, 6 = daily, frequently during the day, 7 = daily, most of the day.

\(^e\)Digit Symbol Substitution (Wechsler, 1997).

\(^f\)Reverse Digit Span (Wechsler, 1997).

\(^g\)Shipley Institute of Living Scale (Shipley, 1986)

\(^h\)Automated Operation Span (Unsworth, Heitz, Schrock, & Engle, 2005).

\*Significant difference between age groups at \(p < .05\); there were no interactions of age group and support level and no differences between levels of support within an age group (all \(ps > .05\)).
Memory-color cue. One of the cues was associated with the color of the icon contained in the pop-up and therefore required the use of participants’ fluid abilities such as pattern recognition and memory. In the fake pop-up, the color of the icon was changed from its original color to a different color (Figure 1). Two different icons were used; each had a real and fake version, for a total of four icons. A total of 10 pop-up messages (unrelated to whether the pop-up was real or fake) were created and used in the pop-ups. Each message appeared an equal number of times, when the pop-up was real and when it was fake.

Grammar-tone cue. The second cue was associated with the language, or tone, of the message contained in the pop-up and required use of crystallized intelligence, such as knowledge of grammar (Figure 1). A total of 10 actual Windows error messages were used for the real pop-ups. A fake version of each real pop-up was created with either incorrect grammar or tone. Incorrect grammar-tone cues included use of all capital letters, multiple exclamation points, or spelling mistakes. For example, one of the fake pop-ups read, “ARE YOU SURE YOU WANT TO QUIT??”

Task complexity. The task was designed to be simple as it required one judgment (real or fake) for each trial. In addition, the cue types were presented in blocks so there was no need to switch back and forth between cue judgments. The task was a simple cognitive task in that there were no interacting elements to the pop-up identification task and only a single step was required to determine the correct answer (Sweller et al., 1998).

Support Conditions

Lower support. The lower feedback support condition provided knowledge of results, a common form of feedback in previous studies (e.g., Butki & Hoffman, 2003; Park, Shea, & Wright, 2000; Schmidt, Young, Swinnen, & Shapiro, 1989; Weinstein & Schmidt, 1990), where participants were simply told whether their answer was correct or incorrect. This condition required participants to develop a hypothesis regarding why their answer was correct or incorrect and then test this hypothesis on subsequent trials.

Higher support. In the higher feedback support condition, participants received the same information given in the low feedback support condition as well as information regarding why their answer was correct or incorrect. For example, an incorrect response to a grammar-tone
cued would generate “A real Windows pop-up does not use this grammar, ‘The applications fail to initialize because window station is shut down.’” These participants did not have to allocate any cognitive resources to identify why their answer was correct or incorrect because they were directly informed.

**Design**

The amount of support available via feedback was manipulated between participants to be low or high. Age group was a quasi-independent grouping variable. The type of cue present, requiring either fluid or crystallized ability, was manipulated within participants. Accuracy of performance and response time per trial were measured during an acquisition session with feedback present and in a retention session with feedback removed. Accuracy was defined as the average number of correct responses. Response time was also collected to measure any trade-off between accuracy and time to answer. If older adults were more accurate than younger adults and also took longer to respond, then this difference in accuracy might be explained by their response times. Participants were randomly assigned to a support condition.

**Procedure**

*Acquisition.* When participants arrived, they were randomly assigned to a feedback condition, provided informed consent, and completed the Digit Symbol Substitution and Reverse Digit Span ability tests. They were then instructed on the pop-up task and then completed the 80 acquisition trials at their own pace. When finished, they completed the vocabulary test and were scheduled to return 4 days later. The interval of 4 days was chosen based on previous studies of learning (e.g., Rogers, 1996; Schmidt et al., 1989).

*Retention.* Participants returned 4 days after acquisition and completed a 60-trial retention task with no feedback. On arrival, participants completed a vision test, followed by the experimental task. They then completed the Automated Operation Span test and an exit interview, then received compensation and debriefing.

**RESULTS**

Pop-ups were presented in blocks of 20 trials for each cue, and the presentation order of cues was counterbalanced between participants. A repeated-measures MANOVA showed no effects of or interactions with counterbalance, $F(2, 65) = 0.80, p = .46, \eta^2_p = .02$; thus, the groups were collapsed for analysis.

**Overall Effects**

The mean accuracy between sessions divided by age group, support condition, and cue type is shown in Figure 2. A 2 (learning stage: acquisition and retention) × 2 (age group: younger and older) × 2 (support: low and high) × 2 (cue: memory-color recall or grammar-tone recognition) mixed-model MANOVA was conducted on accuracy and response time. Results showed multivariate main effects of age group, $F(2, 69) = 44.66, p < .001, \eta^2_p = .56$; support, $F(2, 69) = 3.84, p < .05, \eta^2_p = .10$; cue, $F(2, 69) = 4.46, p < .05, \eta^2_p = .11$; and session, $F(2, 69) = 13.91, p < .001, \eta^2_p = .29$, prompting consideration of the univariate analyses. Univariate tests showed younger adults were more accurate than older adults, $F(1, 70) = 73.48, p < .001, \eta^2_p = .51$, and responded more quickly on each trial, $F(1, 70) = 39.14, p < .001, \eta^2_p = .36$. Those who received high support were more accurate than those who received lower support, $F(1, 70) = 5.43, p < .05, \eta^2_p = .07$, and accuracy for the grammar-tone cue was higher than for the memory-color cue, $F(1, 70) = 7.63, p < .01, \eta^2_p = .10$. Retention accuracy was higher than acquisition accuracy, $F(1, 70) = 20.89, p < .001, \eta^2_p = .23$, and retention response times were longer than were acquisition response times, $F(1, 70) = 6.94, p < .01, \eta^2_p = .09$.

**Age Group Differences in Cue Performance**

A significant Support × Cue × Age interaction for accuracy and response time, $F(2, 69) = 6.19, p = .003, \eta^2_p = .15$, indicated that performance differed between support conditions according to age and cue (Figure 3). Tests of simple main effects using Bonferroni corrected post hoc contrasts were conducted to decompose this interaction. Results showed accuracy differences occurred between support conditions for older adults when learning the color-memory cue, $F(1, 70) = 12.26, p < .01, \eta^2_p = .16$, where those who received more support had higher accuracy than those who received less ($ps < .01$). Results also showed differences
between cues for older adults who received less support, $F(2, 69) = 15.29$, $p < .001$, $\eta^2_p = .3$. When receiving less support, older adults were faster and more accurate for the grammar-tone cue than the memory-color cue ($ps < .01$).

**Support Differences in Cue Performance**

There was a significant Support $\times$ Cue interaction, $F(2, 69) = 4.15$, $p < .05$, $\eta^2_p = .11$, where participants who received higher support were more accurate than those who received lower support, $F(1, 70) = 5.43$, $p < .05$, $\eta^2_p = .07$. Contrasts indicated that for the participants who received less support, accuracy for the grammar-tone cue was significantly higher than accuracy for the memory-color cue ($p < .001$). In addition, participants who received higher support had higher accuracy for the memory-color cue than those who received lower support ($p < .01$).

**Session Differences in Cue Performance**

The Cue $\times$ Session interaction was also significant, $F(2, 69) = 6.19$, $p < .05$, $\eta^2_p = .11$. Contrasts indicated retention accuracy was higher than acquisition for the memory-color cue ($p < .05$) and the grammar-tone cue ($p < .001$). For the memory-color cue, reaction times were slower on the retention test than in acquisition ($p < .001$). Contrasts also revealed retention accuracy was highest for the grammar-tone cue ($p < .01$), whereas reaction times were slowest for the memory-color cue ($p < .05$). In sum, retention accuracy for both cues was higher than acquisition accuracy. In addition, the grammar-tone cue had higher accuracy and faster response time for retention than did the memory-color cue.

Figure 2. Mean accuracy between sessions divided by age groups, support condition, and cue type.

Figure 3. Mean accuracy between age groups divided by support condition and cue type. Bars represent standard error.


DISCUSSION

The aim of the current study was to investigate whether feedback requirements depended on the cognitive resources of the learner, helping to explain some of the mixed findings from previous studies. It was expected that younger adults would benefit from higher support in tasks that required crystallized intelligence, whereas older adults would benefit from higher support for tasks that required fluid abilities.

The findings from the current study were similar to studies of cognitive load theory (Sweller, 1988) where learning occurs most when support reduces the load of the task. A key finding in the current work was that all participants benefited from increased feedback support; those who received higher feedback support learned more than did those who received less support. However, this main finding was tempered by interactions of age group and task demand.

These data also suggest support requirements were affected by ability levels. For the memory-color cue, the cue that required the use of fluid abilities, older participants benefited from higher support whereas younger participants performed similarly with both levels of support. These findings are consistent with others that have shown age-related differences in fluid abilities (Craik & Salthouse, 2000; Salthouse & Babcock, 1991). Younger participants’ high fluid abilities may have made it easier to learn the patterns between correct and incorrect memory-color pop-ups, whereas older participants, who tended to have lower fluid abilities, required additional support. It is possible that older participants lacked the cognitive resources required to both identify the patterns of the memory-color cue and learn the rules (Salthouse & Babcock, 1991; Sweller, 1988). In this view, increased support directed attention to relevant information in the task (Morrow & Rogers, 2008) and reduced the demands on learner resources, thus increasing the resources available for learning.

A similar pattern was seen with the grammar-tone cue that required crystallized intelligence. Younger participants were more accurate with increased support, whereas older participants benefited from less support. For younger participants, this result is consistent with the idea of ability levels affecting support requirements. Specifically, support compensated for a lack of crystallized intelligence, resulting in lower task demands and thus an increase in learning. Results for older participants, however, support the notion of desirable difficulties (Schmidt & Bjork, 1992). It may have been that the grammar-tone cue did not require older participants to learn per se but use previously acquired knowledge, or expertise, to draw conclusions about the legitimacy of a given pop-up. Previous research concerning the redundancy effect and expertise reversal effect (for reviews, see Kalyuga, Ayres, Chandler, & Sweller, 2003; Sweller et al., 1998) found less support was more effective for learners with higher levels of knowledge, or schemas, associated with the task. Novice learners relied on instructional support to comprehend a task, whereas experts used previously acquired knowledge. Experts may have been unable to ignore instructional support, resulting in a higher cognitive load when they attempted to integrate it with their schema. For older adults, information about the accuracy of a response may have been sufficient for learning because their schema for grammar and tone enabled task performance. Increased support may have resulted in an attempt to integrate the provided feedback with their own schema, thus increasing cognitive load and reducing learning. Therefore, higher support may be effective only for learners with lower ability levels needed in the task but not for those with higher abilities needed in the task.

This study examined the role of individual differences in cognitive resources and support during the learning process. The pattern of results suggested that the abilities needed to learn are related to support requirements. When a learner lacks the abilities needed to learn, the demands placed on cognitive resources can exceed the cognitive resources available, but feedback support may be used to decrease these demands.

APPLICATION

Feedback requirements based on the cognitive resources of the learner, specific ability levels, and prior experience can inform teachers, tutors, and system designers as they create effective instructional systems. The results of the current study suggest feedback may be a
function of learner characteristics and the demands imposed by the task. These findings led to the development of the following considerations for feedback design.

**Know the learner.** It is important to identify the needs and abilities of the learner. This could be achieved by conducting a questionnaire, a survey, or by utilizing traditional tests of ability. Support requirements for learning may be determined by accurately assessing learners’ ability levels (Sweller et al., 1998).

**Know the task.** Traditional human factors methods of task analysis could be employed to identify the components of the task that most contribute to the overall task demands. For example, a task may be highly spatial, verbal, or both. In addition, areas that would benefit from increased feedback support, such as those that are more complex or require abilities or experience the learners might not have, could also be identified during task analysis.

**Match support to learner and task.** Support should match the needs of the learner. If a learner has little experience with a task or lower levels of abilities associated with the task, then supportive, scaffolding feedback could be provided during acquisition. When a learner has experience with a task or high levels of ability associated with the task, lower levels of support may encourage the learner to engage in the processing activities such as subjective assessment needed for learning. Human tutors sometimes naturally adapt their support in this way, but training is often required (Merrill, Reiser, Merrill, & Landes, 1995).

Feedback should be matched to support components of the task that contribute most to the demands placed on cognitive resources. For example, if a particular component of a task consumes a significant amount of learner resources, increased support could reduce the cognitive load imposed on the learner, resulting in increased retention.

**CONCLUSION**

The results of this study add to the body of evidence that increased feedback leads to increased learning, but this finding is not without qualification. Results also showed feedback requirements may be affected by the cognitive resources of the learner, specifically ability levels and prior experience, demonstrating the importance of considering individual differences in instructional design.

**ACKNOWLEDGMENTS**

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**KEY POINTS**

- Research on the support required to learn has been inconclusive.
- Results from the current study suggest learner abilities may affect support requirements.
- Learner characteristics and task demands should be incorporated into the design of support for learning. Lower levels of support may be appropriate when a learner has higher levels of abilities needed for a task. Conversely, higher levels of support can reduce cognitive demands for learners with lower levels of abilities needed for a task.

**REFERENCES**


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