Summary Knowledge of Results for Skill Acquisition: Support for the Guidance Hypothesis

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Summary knowledge of results (KR) involves the presentation KR for each of a set of trials (e.g., 10) only after the last trial in the set has been completed. Earlier, Lavery (1962) showed that, relative to providing KR after each trial, a 20-trial summary KR was detrimental to performance in a practice phase with KR present but was beneficial for a no-KR retention test. Using a relatively simple ballistic-timing task, we examined summary lengths of 1 (essentially KR after every trial), 5, 10, and 15 trials, searching for an inverted-U relationship between summary length and retention performance as predicated by a guidance hypothesis for KR. During acquisition when KR was present and being manipulated, all groups showed improvements in performance across practice, while increased summary lengths generally depressed performance. However, in a delayed no-KR retention test, there was an inverse relation between the summary length in acquisition and absolute constant error on the retention test. A guidance hypothesis is favored to explain how, relative to immediate KR, long KR summaries can provide detrimental effects in acquisition while enhancing retention performance.

For the acquisition of movement skills, it is widely recognized that feedback information describing the performer's success in meeting the experimenter-imposed environmental goal is a critically important factor in performance and learning (e.g., I. M. Bilodeau, 1966; Salmoni, Schmidt, & Walter, 1984). These issues have been studied chiefly via knowledge of results (KR), usually defined as augmented, verbal(izable), postresponse information about some aspect of goal achievement. KR has been the subject of an enormous research effort in the past few decades (for reviews, see Adams, 1971, 1987; Newell, 1977; Salmoni et al., 1984), where numerous variations in the nature and scheduling of KR on motor and verbal acquisition have been considered.

In one interesting experimental variation, investigated over 2 decades ago by Lavery (1962), the errors on each of a set of trials (e.g., 20) are placed on a graph (not visible to the subject) and are shown to the learner only after the last trial in the set has been completed. In this method (termed summary KR), various numbers of trials intervene between a given trial and the KR that the subject receives about it via the graph (except for the last trial in the set, of course). This method shares various features with the so-called trials-delay procedure studied by Lorge and Thorndike (1935; I. M. Bilodeau, 1956; Lavery & Suddon, 1962), in which KR about each trial is presented after a fixed number of other trials. In both methods, KR seems to be very difficult to use; there is not only a temporal separation of a given trial from its KR but also the potential for confusion about the particular performance characteristics to which a given KR refers. Indeed, as compared with conditions where KR is provided after each trial, summary-KR and trials-delay procedures have been shown to be strongly detrimental for performance during acquisition when KR is present, both slowing the rate of improvement and degrading the performance asymptote after considerable practice (I. M. Bilodeau, 1956; Lavery, 1962; Lavery & Suddon, 1962; Lorge & Thorndike, 1935). Earlier interpretations of this degraded performance during acquisition (e.g., Adams, 1971; I. M. Bilodeau, 1966; Newell, 1977; Schmidt, 1975) were invariably that such variables were detrimental for motor learning.

However, Salmoni et al. (1984) pointed out that in keeping with the long-established distinction between variables that affect learning versus performance (e.g., Griffith, 1931; Hull, 1943; Lashley, 1929; Tolman, 1932), summary KR's detrimental effects in acquisition may reflect only a temporary performance factor and do not necessarily represent a decrement in the relatively permanent capability for responding that results from learning. Several factors associated with KR may exert their influence only temporarily. One is the well-1

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1 A different class of feedback information informs the learner about errors in the pattern of action that was produced, which is usually termed knowledge of performance.
known motivating (or energizing) effects of KR (Arps, 1920; Crawley, 1926; Elwell & Grindley, 1938), where subjects exert more effort and report more positive feelings toward the task. Another factor—which we emphasize in the present article—is the informational property of KR (Newell, 1977; Salmoni et al., 1984), in which KR informs about the magnitude and direction of error and thus directs or guides the subject in terms of how to correct the error on the next trial; in this way, the subject gradually converges (or is guided) toward the goal with practice. The conclusions about the effects of various KR manipulations in much of the earlier research have been based on the analysis of the effects on performance in an acquisition phase when KR is being manipulated, thus confounding the relatively permanent and transient effects of KR variations. According to Salmoni et al. (1984), various transfer or retention tests are needed to separate these effects.

Not everyone ignored this distinction, however. Lavery (1962, 1964) employed delayed no-KR retention tests that allowed the evaluation of the relatively permanent effects of summary-KR conditions presented in acquisition. Three very simple tasks were used, in each of which a single kinematic dimension had to be controlled (e.g., the force with which a ball was struck by a small hammer). He studied three conditions across 6 days of acquisition: (a) summary KR presented after a set of 20 trials, (b) immediate KR presented after each trial, and (c) both, where the summary was given in addition to immediate KR. In the acquisition phase, summary KR showed more errors than either the immediate or both conditions. But in the no-KR retention tests on Days 7 through 10, the summary group retained performance essentially perfectly, whereas the immediate and both conditions suffered considerable retention losses, to the point that the summary group was more effective than the immediate and both groups in the retention tests. That is, relative to the immediate and both conditions, summary KR caused decrements in performance during the acquisition phase, but it increased performance on the delayed no-KR retention tests. To the extent that performance on this delayed no-KR retention test can be considered as at least one way to evaluate the relative amount learned in the acquisition phase, Salmoni et al. argued that summary KR (as compared with immediate KR) produced less effective performance during practice when KR was present, but it increased learning. This interpretation runs counter to most theoretical accounts dealing with KR's operation (e.g., Adams, 1971; I. M. Bilodeau, 1966; Newell, 1977; Schmidt, 1975), which generally argue that KR variations that increase performance in acquisition should also increase learning as measured on a retention test.

These findings, as well as findings from several other paradigms (e.g., relative frequency of KR), figured strongly in the formulation of the guidance hypothesis for KR. This notion was suggested in general terms by Annett (1969) and Holding (1965), and was outlined more formally by Salmoni et al. (1984). This view begins with the informational account of KR, assuming that KR provides information about how to solve the movement problem. Thus, in this sense, immediate KR provides a strong guiding function for performance when KR is present, making performance very effective in acquisition. This property of KR is essential for initial stages of learning, when the subject must be directed toward an effective movement pattern. However, the guidance hypothesis goes beyond this informational view by postulating that after the subject has achieved roughly the correct movement pattern, because KR after each trial is so effective for maintaining performance, the learner seems to build a kind of reliance on it. This dependence is assumed to prevent the learner from processing various other aspects of task-related information (e.g., environmental or task cues, response-produced feedback) that either lead to more effective task learning or that block the development of other capabilities for responding, such as more consistent movement patterning or more sensitive capabilities for the subjects to detect errors intrinsically. This may result in degraded performance later, particularly under conditions where KR is withdrawn, and the guiding properties are no longer present for the subject to use. Summary KR, which lacks this strong guiding property, is much less effective for performance in acquisition than is immediate KR. But it forces the subject to engage in this extra (or at least different) processing during acquisition, with the benefits over immediate KR being evidenced when the temporary guiding properties of KR are removed in the retention tests.

Lavery's findings raise several important issues for theory in the area of movement learning and, in particular, for understanding how KR operates. Long-standing theoretical views of feedback operation in learning (e.g., Thorndike, 1927), more recent conceptions of it (e.g., Adams, 1971; Schmidt, 1975), as well as some reviews of the KR research (e.g., Adams, 1971; I. M. Bilodeau, 1966; Newell, 1977), have come to the generalization that any variation of KR that provides more information more precisely, more accurately, or more often is predicted to have a positive effect on movement learning. Against this backdrop of thinking about the role of KR through the 1970s, we have Lavery's (1962) findings that variations in summary KR that degrade performance in acquisition (relative to immediate KR, of course) actually enhance performance on no-KR retention tests, which is one measure of learning. The finding that some variation in KR could depress performance in practice, yet result in greater performance in retention, is contradictory to all of the theoretical ideas about how KR functions and thus provides a strong challenge to the earlier viewpoints about feedback and movement learning.

Motivated by Lavery's important discoveries, we wanted to investigate further this role of summary KR for learning. According to the guidance hypothesis, KR after each trial—or short summary KRs (i.e., describing very few trials)—is detrimental to performance in retention tests because it provides too much guidance during acquisition and fosters too little processing of movement information. On the other hand, long summary KRs encourage processing of movement information but do not provide sufficient guidance during acquisition so that the performer can acquire the proper movement pattern. If so, then the guidance hypothesis predicts an optimum summary-KR length, where the beneficial aspects of guidance and the detrimental effects of an overreliance on KR would be balanced. Therefore, we manipulated the summary-KR lengths in acquisition across a wide range, hopefully to reveal some optimal summary length for learning.
Method

We used a slightly more complicated variation of a ballistic-timing task (Schmidt & White, 1972). Different conditions experienced summary lengths of 1, 5, 10, and 15 trials in an acquisition phase. A no-KR retention test was provided after 10 min and after 2 days as a measure of the relative amount learned during the different acquisition conditions.

Subjects

Undergraduate students at the University of California, Los Angeles, 36 male and 36 female right-handers, participated for extra class credit. All were unaware of the purposes of the experiment, and none had previous experience with the task.

Apparatus and Task

A horizontally mounted stainless-steel shaft (2.54-cm diameter) was fitted with a slide consisting of a ball-bearing sleeve on which was mounted a vertical handle, allowing the slide to move nearly frictionlessly through 100 cm. The apparatus was secured to the top of a standard desk. A switch at the right end (with respect to the subject) of the slide’s travel closed when the slide was moved away from it, and another switch mounted 40 cm leftward closed when the slide passed it, starting and stopping a digital millisecond timer, respectively. In addition, two 5-cm-wide target zones were positioned under the shaft, located 15 and 30 cm from the right end of the slide’s travel.

The seated subject’s task was to grasp the handle positioned against the right end of the shaft, move the slide leftward to the second zone (i.e., 30 cm), reverse direction to the first zone (15 cm), and then reverse direction again to move through the switch at the far left, with a follow-through. Further, this movement was to be produced so that the movement time was as close to a 550-ms goal as possible on each trial. Scores were in terms of movement time; no measures of accuracy at the intermediate targets were taken, although it was obvious that all subjects typically followed directions to reverse the movements over the target zones. The subject was instructed to initiate the movement shortly after the illumination of a “go” light, but reaction times were neither stressed nor measured.

Procedures

Four groups of 18 subjects (9 male and 9 female subjects in each group) were assigned to conditions that differed in terms of summary-KR length, with either 1 (essentially KR after each trial), 5, 10, or 15 trials being summarized. After each trial, the experimenter plotted the subject’s constant error (with respect to sign, e.g., -124 ms) for each of the treatment groups over blocks of 5 trials. Dependent measures were never significant, the effects of gender will not be discussed further here.

Results

Performances in acquisition were grouped into blocks of 15 trials for analysis, whereas the 25 trials in the retention tests were analyzed in blocks of 5 trials. Dependent measures for each subject computed over these blocks were absolute constant error (|CE|), the absolute value of each subject’s constant error) as a measure of directional error or bias and variable error (VE, the within-subject standard deviation of the subject’s scores about his or her own mean) as a measure of within-subject variability. Conditions × Blocks × Gender analyses of variance were run for these dependent measures; however, because interactions between gender and conditions were never significant, the effects of gender will not be discussed further here.

In keeping with the learning-performance distinction discussed earlier, and with the application of these ideas to research on feedback and learning (Salmoni et al., 1984), we consider the performances during the acquisition phase (where feedback was manipulated) as being a complex combination of relatively permanent (i.e., learning) effects and temporary phenomena. Therefore, the relative performance levels during acquisition, and any subsequent differences between these levels and performance in the retention tests, are not emphasized because they confound performance and learning effects (see also, Schmidt, 1988). The main conclusions about the relative amount learned are based only on performances in the no-KR retention tests, where the temporary effects of the feedback manipulations are assumed to be equated.2 Of course, other retention tests are possible (e.g., KR retention tests; Lange & Schmidt, 1988), and it is possible that the effects may interact with the nature of the retention test used.

Acquisition Phase

Absolute constant error. The averaged absolute constant errors (|CE|) for each of the treatment groups over blocks of

2 However, this focus on absolute performance on the retention tests (without regard for the performance in acquisition) as a measure of relative amount learned in acquisition raises another concern. Performance on a retention test confounds (a) the relative memory strength produced through the end of the acquisition phase and (b) any differential loss in memory strength (i.e., forgetting) that occurred since the end of acquisition. However, theories of feedback and skill learning have not made this distinction, and all predict implicitly that factors that increase memory strength will produce improved performance at any retention interval; that is, conditions in acquisition should not interact with retention-interval length in determining retention performance.
15 trials in acquisition are shown in Figure 1. Errors decreased across practice for all groups, F(5, 320) = 62.1, p < .05. Even though the functions for the 10- and 15-trial conditions occasionally crossed (e.g., Blocks 2 and 6), increasing the summary-KR length from 1 to 15 trials generally produced systematically larger errors in acquisition across all the trial blocks, evidenced mainly as a slowing in the rate of improvement. This differential rate (and the overall amount) of improvement is masked somewhat in Figure 1 by the fact that 15 trials are combined into a single trial block; when the average |CE| on the first trial is considered (i.e., 272 ms), the rapid improvement of the 1-trial condition, as compared with the 5-, 10-, and 15-trial conditions during Block 1, is evident. The block differences were largest through Blocks 3 and 4 and became considerably smaller by the end of practice (Block 6). Averaged over all blocks, the |CE|s for the four groups were 22.3, 31.8, 48.4, and 52.1 ms, respectively, for the 1-, 5-, 10-, and 15-trial conditions, significantly different from the 1- and 5-trial conditions. The Blocks x Groups interaction was also significant, F(15, 320) = 4.2, p < .05, seen in the general tendency for the groups to converge near the end of practice; a post hoc test showed that the block means at the end of acquisition were not significantly different (p > .05). As with Lavery's (1962) results, summary KR depressed performance during acquisition relative to immediate KR, slowing the rate of improvement, mainly in the first two thirds of the practice phase. These data extend Lavery's results by showing that the performance in acquisition (except for the end of the acquisition phase) was generally inversely related to the length of the summary-KR reports.

**Variable error.** VEs were analyzed in the same general way, but they revealed a different pattern of results. There was an overall decrease in VE with practice, F(5, 320) = 29.2, p < .05, but the four summary-KR groups performed very similarly in terms of their final asymptotes and rates of improvement across blocks. The VEs averaged over all blocks were 30.8, 26.6, 28.5, and 26.0 ms for the 1-, 5-, 10-, and 15-trial summary conditions, respectively, suggesting that the 1-trial summary condition may have been somewhat more inconsistent than the other three, perhaps because of the tendency for KR after each trial to encourage frequent changes in movement control. However, neither the groups effect, F(3, 64) = 1.5, nor the Groups x Blocks interaction, F(15, 320) = 1.2, was significant (ps > .05).

**Immediate-Retention Test**

**Absolute constant error.** The |CE| scores for the performances on the immediate (10-min) no-KR retention test, computed for all 25 trials, are shown to the right in Figure 1. Overall, the 1-trial summary condition (29.0 ms) had slightly greater error than the other conditions (26.7, 21.7, and 26.7 ms, respectively), but the trend was not systematic, and the effect was not significant, F(3, 64) < 1. There was no significant effect of the five 5-trial blocks, F(4, 256) < 1. There were small and irregular differential effects of conditions in two of the trial blocks, with a significant Groups x Blocks interaction, F(12, 256) = 2.3, p < .05, but these effects did not appear stable and are not emphasized here.

**Variable error.** Using VE as a dependent measure, there was no significant blocks effect, F(1, 64) < 1, but the Conditions x Blocks interaction (not shown in the figure) was significant, F(12, 256) = 1.8, p < .05. This interaction was due to a tendency for the 1-trial condition to increase VEs across blocks (by 3 ms) while the other conditions were decreasing them (by 2 ms), but these effects were very small and are of questionable importance. When VEs were averaged across blocks, there was a tendency for the 1-trial summary-KR condition (22.8 ms) to have a slightly larger VE than the other groups (20.2, 20.1, and 21.7 ms, respectively), but the differences were small and were not significant, F(3, 64) < 1. In general, for both |CE| and VE, there were essentially no important effects of summary-KR length in acquisition on immediate no-KR retention performance.

**Delayed-Retention Test**

**Absolute constant error.** The |CE| scores for the delayed (2-day) retention test are shown to the far right in Figure 1. There was no significant blocks effect in delayed retention, F(4, 256) = 1.1, p > .05, nor a Blocks x Conditions interaction, F(12, 256) = 1.6, p < .10, so all 25 trials were averaged to produce the values in the figure. Over all blocks, the |CE|s in delayed retention were markedly and systematically smaller with increasing summary-KR length in acquisition (50.6, 44.2, 34.1, and 25.7 ms, respectively), with the 1-trial summary condition having approximately twice the error of the 15-trial condition. This effect was significant, F(3, 64) = 2.8, p < .05. Although the interaction between conditions and blocks was not significant (p < .10), there was a tendency for the groups with shorter summaries in acquisition (1 and 5 trials) to increase
learning, which have held that KR variations making feedback more "useful" in acquisition will always benefit learning (e.g., Adams, 1971; I. M. Bilodeau, 1966; Newell, 1977; Schmidt, 1975). These results also reinforce the general learning–performance distinction (Salmoni et al., 1984) for KR, in that the performance levels seen during acquisition are not necessarily indicative of performance capabilities. Further, the most effective performance conditions for learning—at least as measured on delayed no-KR retention tests—are not necessarily those that produce the most effective performance during practice.

These learning effects were limited to the delayed-retention test, however, and they were completely absent on the immediate–(10-min) retention test. It is tempting to suggest that the long summary KRs may have operated to retard forgetting over the longer retention interval. The groups were nearly identical in performance at the immediate-retention test, which is one measure of the acquired capability for responding developed during the acquisition phase, and then regressed in performance over the longer retention interval as a function of the summary-KR length in acquisition. Thus, if we can consider the similar performances on the immediate-retention test as providing evidence of equated levels of learning at this point, then subsequent differential decrements in performance should be attributable to different amounts of forgetting that has occurred. The problem with this view is that we cannot be completely confident that the immediate-retention test is completely free of the temporary effects of the acquisition phase. But the possibility that the effects of the variable in acquisition may act to retard subsequent forgetting is an appealing one, and it deserves further study (see Footnote 2).

Lavery’s results were limited somewhat by the use of a percentage-correct measure, which tends to confound the CEs and VEs in responding (e.g., Schutz & Roy, 1973). With somewhat more modern analyses, we divided the overall errors into independent components of response variability (VE) and bias (|CE|). This analysis revealed that the effect of summary KR was limited to the |CE| measure and had only negligible effects on the VE statistic. Thus, at least for these relatively simple movements, summary-KR variations have their major effects on response bias, with the subjects systematically over- and undershooting the target movement time, with a relatively constant average response variability between groups. In the delayed-retention test, the benefit of the long summary-KR conditions in acquisition was evidenced as a smaller drift away from the target time, as if the subjects in the shorter summary-KR conditions did not have the capability to detect that they were producing movement times that were systematically too fast or too slow.

Both these results tend to argue against the hypothesis that the primary effect of the summary-KR variable was to increase the effectiveness of the movement control, per se, as if it led to more effective motor programs for this action. Such effects have usually been thought of as being indexed by shifts in VE, which did not change in response to the treatments in this experiment. A more likely possibility is that the effect was related to the longer summary-KR conditions having an increased capability to select movement parameters accurately. In the theory of generalized motor programs (Schmidt, 1975, 1985, 1988), parameters are the constructs that determine the particular expression of a given motor program (i.e., speed, amplitude, etc.), while the overall form of the action is...
preserved. That the effect was indicated by an increased biasing (|CE|) of performance suggests that the subjects in the shorter summary-KR conditions had lost the capability to remember the parameters used for the successful movements they made at the end of acquisition. Perhaps a major effect of long KR summaries is the generation of more effective error-detection mechanisms, as Schmidt, Shapiro, Winstein, Young, and Swinnen (1987) have argued.

We have clearly failed, however, to find an optimal summary-KR length for this task, which was the original motivation for this experiment. Such an optimum almost surely exists because practice in situations with very long summaries (e.g., 1,000 trials) should be highly ineffective for learning, as they would approximate no-KR conditions. In these simple tasks where subjects cannot detect their own errors without external feedback, no-KR practice generates essentially no learning (e.g., E. A. Bilodeau, Bilodeau, & Schumsky, 1959).

Thus, it seems reasonable that this optimum lies somewhere beyond the 15-trial summaries used here, perhaps near the 20-trial value that Lavery (1962) used. Also, Schmidt et al. (1987), in an experiment essentially identical to the present one except for the use of a somewhat more complex coincident-timing task, have found such an optimum with the 5-trial summary condition. It is tempting to suggest from these two experiments that the optimum summary length decreases as task complexity increases, with systematically more guidance being needed in initial practice if the task has more kinematic degrees of freedom to be controlled. But this is an across-experiments contrast, and there are countless differences between these two tasks other than complexity (which cannot be acceptably defined in any case) that could underlie the differences in the location of an optimum summary length for learning these two actions.

Implications for Current Learning Theory

If the improved performance seen in the longer summary-KR groups—usually indexed by increased performance on the retention test—can be seen as one type of enhanced learning, then these results (and those of Lavery, 1962) are very surprising in terms of both common motor-learning theories (e.g., Adams, 1971; Schmidt, 1975; Thorndike, 1927) and conceptualizations of how KR works to enhance learning (e.g., I. M. Bilodeau, 1966; Newell, 1977). These viewpoints emphasize that the learner must have some way to relate the results of a given movement to its KR, so that the performer can use the error information to modify performance from trial to trial, thus leading to the establishment of a permanent memory. How these memories are characterized differs in the various accounts of learning, of course, but all of these positions suggest that the learner must have clear information about errors in order that learning be maximized. With long KR summaries, however, the subject is probably without very much information about the earlier trials in the set, and it would seem that much of the practice is under essentially no-KR conditions until the summary KR is finally provided. This supposition is certainly supported by the performance during acquisition, where the 1-trial summary was far more effective in improving performance than the longer summaries.

The theoretical question of interest for us is how, relative to immediate KR (1-trial summaries), the relatively detrimental effects of longer KR summaries in acquisition can result in improved performance in retention. One viewpoint is that the long stretches of no-KR trials in acquisition in some way simulate the no-KR requirements in retention. In this view—similar to the encoding-specificity viewpoint from verbal learning (Tulving & Thomson, 1973) and the specificity-of-learning view in skills research (Schmidt, 1988)—the longer the summary length, the more the acquisition and retention conditions resemble each other, and the greater the tendency for the specific processes learned in acquisition to transfer to no-KR retention performance. Thus, under this view, at least, it is perhaps not surprising that the 15-trial condition performed more effectively in retention than the others. However, there are several reasons why this hypothesis appears inadequate.

First, this specificity hypothesis cannot account for results in another of our experiments (Lange & Schmidt, 1988), in which subjects were transferred from 1- and 5-trial summary conditions in acquisition to 1-trial summary conditions (KR after each trial) in a retention test. Here, this specificity view would predict that the 1-trial summary condition in acquisition would be more effective than the 5-trial summary condition for retention, as the feedback conditions in retention are identical to those for acquisition for this group and are changed for the 5-trial group. Yet, there was still a slight advantage for the 5-trial condition on the 1-trial retention test, which does not support a specificity view. Second, this hypothesis does not explain how the 5-trial condition in acquisition could be optimal for retention (i.e., more effective than the 1-, 10-, or 15-trial conditions) in the more complex coincident-timing task discussed earlier (Schmidt et al., 1987).

Here, the 10- and 15-trial conditions—because they supposedly simulate the no-KR retention conditions more closely than the 5-trial conditions—should have produced more effective performance in retention than the 5-trial condition. Third, at the limit, the specificity hypothesis holds that for no-KR retention tests, never giving KR in acquisition will always be optimally effective. Of course, this prediction violates results from several published experiments showing that no-KR conditions in acquisition are certainly not optimal for no-KR retention (e.g., Trowbridge & Cason, 1932). Overall, there may be some sense in which increased similarity, per se, of the practice and retention conditions enhances retention performance, but the data suggest that this is not the entire answer and that other alternatives need to be considered.

A Guidance Hypothesis for KR

Another viewpoint is the guidance hypothesis, discussed earlier (Annett, 1969; Holding, 1965; Salmoni et al., 1984).
This view begins with the notion that a powerful effect of KR is its informational capability to guide or direct performance when KR is present in an acquisition phase. But this hypothesis goes on to suggest that the subject comes to develop a kind of dependence on immediate KR, as learners follow its very effective guidance properties when it is present. The problem is that this reliance on KR may block other information-processing activities that could result in the capability to perform this response when feedback is withdrawn on a retention test. Longer KR summaries, on the other hand, lack the strong guiding properties of KR after each trial and force learners into various alternative information-processing activities in order to maintain reasonably effective performance in acquisition. These activities result in more learning—or perhaps in something fundamentally different being learned—in the longer summary-KR conditions, with the effects of this differential learning being manifested when the conditions are equated (i.e., KR being withheld) on the delayed-retention tests. This hypothesis places considerable emphasis on the no-KR trials and the processes that they generate. Similarly, the question does not concern why summary KR is so effective for learning—or what special information summary KR provides—but rather why KR after each trial is so detrimental (see also Salmoni et al., 1984). This is certainly in sharp contrast to the emphasis of the earlier viewpoints about KR.

The guidance hypothesis is vague in terms of the particular processes that are affected, or in terms of what is learned differently, but several possibilities can be mentioned. An old idea in KR research (I. M. Bilodeau, 1966) is that providing KR tends to make subjects change their movements, and withholding it tends to force subjects to repeat previous movements (see also Sherwood, 1988). One hypothesis is that long sequences of trials, with KR after each one, encourage subjects to make "maladaptive short-term corrections" after each trial, and thus subjects fail to learn to move consistently. This hypothesis is supported here, as VEs in acquisition were systematically smaller as the summary lengths increased. On the other hand, longer KR summaries, which provide increased trial-to-trial stability in acquisition, could provide a stronger basis for the use of summary KR when it is finally presented, allowing the learner to relate KR to more stable response tendencies demonstrated over several trials. Alternatively, Winston (1988) argued that more no-KR trials may allow performance to deteriorate sufficiently that when summary KR is finally given, the nature and direction of the errors is more easily detectable, and the information can be more effectively used for corrections.

Another possibility is that summary KR leads to the acquisition of the capability for the subjects to detect their own errors (Schmidt & White, 1972; Schmidt et al., 1987). In this view, a series of no-KR trials forces the learner into a strategy of processing his or her own response-produced feedback in order to assess his or her own behavior as a substitute for KR; on the other hand, providing KR on every trial gives the learner sufficient information about his or her progress, reducing (or even eliminating) the need for this information to be generated subjectively and decreasing the involvement of these subjective-evaluation processes. The activities involved in the generation of this subjective reinforcement (Adams, 1971; Schmidt, 1975) may leave the subjects with heightened sensitivity to their own errors. This capability would be strongly beneficial for performance when KR is withdrawn later, providing a basis for performance maintenance, or even additional (re)learning, on the retention tests. The results from the delayed no-KR retention tests support this view, in that subjects with short summaries tended to drift away from the goal movement time, as if they were not aware of their own errors.

The evaluation of these various hypotheses for summary KR must await future research efforts, as present data cannot discriminate among them. However, regardless of which one(s) of these views is eventually supported, the data suggest that earlier viewpoints about the functioning of KR for skill learning are not adequate and that the positive and negative influences of the guidance-like processes for acquisition and retention performance should be a part of theorizing in this area.

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