Relative Frequency of Augmented Feedback and Motor Skill Learning

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Abstract - The present article will discuss the contribution of relative frequency of augmented feedback for the optimization of motor skill learning. Optimal conditions are required to optimize motor learning. With the provision of more augmented feedback, the recall and recognition schema can be strengthened. Two types of scheduling variables of augmented feedback are absolute frequency and relative frequency. The absolute frequency is the absolute number of times feedback is given in an instructional progression, while relative frequency is the total number of times feedback is given relative to the total number of trials attempted. Several studies over the past decade have revealed that variations in augmented feedback scheduling which reduce the relative frequency of feedback during acquisition prove to be more beneficial for long-term skill retention than practice conditions with feedback provided more often. On the contrary, many studies revealed that an increase in relative frequency of feedback not only promotes acquisition, but also helps to frequently evaluate the movement.

1. Introduction

In the field of motor learning it is well known that, aside from practice itself, information feedback about the performer's success is one of the most powerful variables affecting the acquisition of a new skill. The augmented feedback information guides the learner to accurate performance [1] . However, practice must be optimized if efficiency of the learning process is the goal. It is a form of feedback that informs the learner about the result of a movement and Information which related to movement execution is usually available to the learner through his own sensorial sources (intrinsic feedback). However, there are situations in which that information is absent or, when present, the learner may have difficulties in using it. In those conditions, an external source becomes necessary to provide the learner with that information (extrinsic feedback or augmented feedback).

The role of augmented feedback to facilitate skill acquisition and learning is a widely accepted axiom [2] . Many professionals from the areas of motor learning and pedagogy can investigate to the strength of augmented feedback to promote skill performance and learning. In fact, one key role a sport

instructor or physical educator can play is that of delivering augmented feedback regarding the characteristics of a movement pattern or the movement result to a student attempting to acquire a motor skill [3]. Without augmented feedback, the skill can be learned to a limited degree; however, the availability of augmented feedback based on limb movement characteristics enhances the level of performance achieved. In these situations, what becomes critical to facilitate learning is determining what information to give as augmented feedback, how and when to give it [4]. Evaluating the augmented feedback that will be provided in a situation to determine if the feedback may attract the learner's attention is very important. It would be a good situation if the instructor knows how different forms and the scheduling of augmented feedback influence learning a particular skill. Preparing effective augmented feedback clearly requires physical education teacher or coach's knowledge of both the skill and augmented feedback.

The presence of augmented feedback attracted attention to such an extent that incorrect information was not evaluated as incorrect but was used as the basis for performing the skill. What this means is that instructors must provide suitable information when giving feedback. Augmented feedback is a form of information to the learner about his or her performance of the skill being learned. With regard to the quality of practice, a potential way to support the motor learning process is to provide a student or athlete with augmented feedback that supplements the response – produced inherent feedback obtained from vision, audition, and proprioception [5]. The learner can achieve a certain skill of level with task-intrinsic feedback, but in order to attain a higher level of expertise, augmented feedback is needed. While augmented feedback has long been regarded was a variable instrumental to efficient motor skill learning, the past decade has seen renewed interest in the effects of variations in format, timing, and scheduling of augmented feedback to determine the conditions under which motor skill learning is optimized. Augmented feedback has traditionally been classified into two broad categories: knowledge of results (KR) which focuses on the outcome of movement in terms of the environmental goal, and knowledge of performance (KP) which is concerned with kinematic aspects of the movement pattern [6]. In most practical skill acquisition environments, KR is obtainable by the learner without the need to depend on an outside agent for its delivery. Furthermore, in an instructional situation, it is very important to determine what relative frequency of augmented feedback should be given to the students. Unfortunately, the degree of frequency of feedback delivered by many physical educators is less than desirable [7]. The present article will discuss the contribution of relative frequency of augmented feedback for the optimization of motor skill learning.

2. Relative Frequency of Knowledge of Result

Knowledge of results (KR), which gives augmented feedback about the outcome of performing a skill or about achieving the goal of performance, is important information when learners acquire motor skills [4]. In theory, knowledge of results provides learners with information about the discrepancy between the goal and results of performance, which is then used to correct the discrepancy in subsequent performance. In research on motor skill learning, the method of presenting knowledge of results has been considered as one of the most important factors influencing the effectiveness of learning [8]. In the last few years, the results of a number of studies have demonstrated that various manipulations that reduce the purported usefulness of augmented feedback, or knowledge of results (KR), can enhance motor learning, compared with conditions in which feedback can easily be used to make corrections on the next trial [9]. For example, reducing the proportion of trials with feedback has been shown to result in better learning than providing feedback after every single trial [10].

Frequency of knowledge of results (number of knowledge of results supplied in relation to the total number of trials) has been considered one of the most important variables that affect the acquisition of motor skills and, as such, has received the attention of many researchers [11]. For a long period of time, it was believed that frequent knowledge of results yielded better learning [12]. However, this scenario changed drastically after the publication of a seminal paper in 1984, in which those early studies were criticized because they did not use a transfer or retention test to separate the transitory effects of

performance from more permanent effects of learning. In fact, many studies[13], using the latter methodological approach, have found favourable results for low frequencies of knowledge of results, or at least have indicated that learning is not hindered by reduced frequencies. These results have been interpreted differently by means of three hypotheses: specificity, consistency, and guidance. The specificity hypothesis refers to the similarity between the task practiced in the acquisition phase and in the retention test. In that sense, it questions the experimental design in relation to the retention test (accomplished without knowledge of results), which could facilitate the task for the subjects who are already familiar with low knowledge of results frequencies. The consistency hypothesis is based on the assumption that constant performance corrections induced by frequent knowledge of results could inhibit the acquisition of consistency in the execution of movement, which would make retention more difficult. Finally, according to the guidance hypothesis, frequent knowledge of results could act as a guide for the learner toward the goal of the task during the acquisition trials. This orientation could generate a certain amount of dependency of the learner in relation to external information, inhibiting or interfering with other processing activities such as detection and correction of errors and elaboration of the motor plan. To explain the degrading effects of frequent and immediate feedback on delayed retention and transfer tests, in contradistinction to traditional beliefs about the role of augmented feedback for motor learning [14], researchers have promulgated the guidance hypothesis. According to that hypothesis, feedback guides the learner to the correct response. However, frequent KR is also argued to have several side effects that degrade learning. For example, learners seem to become too dependent on the information provided by the augmented feedback and to neglect the processing of intrinsic feedback. Most of the studies on knowledge of results frequency were carried out using relatively simple tasks in a laboratory environment. However, the necessity of more studies which focus on complex tasks and pay more attention to ecological validity has been pointed out [15]. The relationship between frequency of knowledge of results and complexity of the task was initially explored in studies that used summary knowledge of results. Study using a simple task, found better results for large numbers of trials [16]. On the other hand, in a study involving a more complex task, found favourable results with small knowledge of results summaries [17]. A study compared the size of the knowledge of results summary, the complexity of the task, and the learning phases [18]. The results showed an interaction between the size of the summary and the complexity of the task only for the groups at initial phases of learning. In relation to the groups at advanced phases, the interaction between summary of knowledge of results and complexity of the task was only partially confirmed. Using a task that involved the control of several degrees of freedom, Wulf, Shea, and Matschiner investigated the frequency of knowledge of results effects (control, 100, and 50%) in the learning of a slalom movement in a ski simulator. The results showed better learning for the 100% frequency group in relation to 50% and control groups. In another study with variations in task complexity and arrangements of knowledge of results controlled by the experimenter as well as self-controlled, found no interactions. However, as the amount of practice differed for the groups, the analysis of the true effects of the task complexity was difficult to measure. In summary, the effect of relative frequency of knowledge of results considering task complexity on motor skill acquisition has not been thoroughly studied yet.

Since task complexity is defined by the number of elements and their interactions, complex tasks would require higher motor control, and as a consequence the possibility of performance errors increases. This could imply the need for more corrections and, therefore, demand for more information about the results of the movement (higher frequencies of knowledge of results). In early research conducted to understand the relationship between feedback and learning, it was traditionally believed that knowledge of results given during or after every practice trial (i.e., 100% relative frequency) was the most effective method for learning. This maximum frequency was considered best because knowledge of results was assumed to guide learners to more accurate and stabilized movement by helping them detect errors and correct these. The effects of two KR-scheduling methods, absolute frequency of knowledge of results, and relative frequency of knowledge of results, using a task on which subjects were required to turn a knob to a target position without vision. They compared four groups with different KR frequencies-100% KR, 33 % KR, 25% KR, and 10% KR. All participants were

provided KR 10 times during practice. Analysis showed that the different relative frequency conditions did not affect the acquisition performance when the absolute frequency of KR was the same. Researchers interpreted these results to suggest that absolute frequency of KR, but not relative frequency, is important for learning. The view that relative frequency of knowledge of results does not affect motor learning. Since the common definition of learning suggests that it involves a relatively permanent change, they pointed out that many earlier experiments of the effect of knowledge of results on learning did not conduct retention or transfer tests. The results of several experiments including retention and transfer tests in the experimental design showed that conditions of lower relative frequency of knowledge of results produced learning effects as large as a 100% KR condition, and some found that these reduced frequency conditions produced even more learning than the 100% condition. The study of the effects of varying the relative frequency of knowledge of results while holding the absolute number of trials constant on a positioning task in which the participant was required to stop a ball running on two parallel rods at a target line without vision. Analysis showed no significant differences between groups during acquisition or on an immediate retention test without KR and on a delayed retention test conducted the following day [19].   The results of a follow-up experiment using a more difficult task showed there were no significant differences between groups during acquisition on the magnitude of absolute error (AE) although in an immediate retention test groups with the least frequent KR had higher absolute errors than the groups with more frequent KR (100% and 33 %), and the trend of increased absolute error in the immediate retention test was reversed in delayed retention. These results suggested that reduced relative frequency of knowledge of results leads to better performance at retention. The guidance hypothesis provides one explanation about how feedback operates to influence learning, and specifically, how frequent feedback operates (1)(12). This hypothesis suggests that the role of knowledge of results is to guide the learner's correction of performance during practice (a positive effect). However, if learners are provided too much knowledge of results, then they will become dependent on it but not make optimal use of the information when it is provided (a negative effect). This phenomenon is a dependency-producing effect of feedback because, should learners depend on external feedback information too much, then it becomes disadvantageous for self-detection and correction of errors. Schmidt, Lange, and Young (1990) concluded that subjects in the trial condition became more sensitive to their own movement-produced feedback and that this sensitivity facilitated performance at retention compared to the other groups. Since most of the previous research on the relative frequency effects of knowledge of results have used fine motor skills, it is important to discover whether the advantageous effects of reduced frequency of knowledge of results appear also in learning a gross motor skill. This is particularly important that there are numerous implications for practical situations, such as the design of training settings, which generalize from knowing how several feedback variations affect the learning process. Many experimenters reported applying the relative frequency of knowledge of results to learn a gross motor skill. The effects of presentation of augmented knowledge of results and intrinsic feedback to learners in three groups' performance on a golf-putting task, showed participants who received a 50% schedule of the final ball location performed better than two groups' participants, one group's participants practiced normally on all of the trials, and the other one was presented a 50% KR schedule of the ball's path and a 50% KR schedule of the final location of the ball on two retention tests administered 5 min. and 24 hr. after completion of acquisition trials [20].

3. Relative Frequency of Knowledge of Performance

As mentioned above, several KR studies over the past decade have revealed that variations in KR scheduling which reduce the relative frequency of feedback during acquisition prove to be more beneficial for long-term skill retention than practice conditions with feedback provided more often. For example, when long-term retention tests are given, groups receiving less than 100% KR outperform groups receiving KRon a 100% relative frequency basis. Furnishing KR more frequently is temporarily more beneficial to practice performance than providing it less frequently. These beneficial effects

however, may not be advantageous to learning, as assessed by no-KR retention tests, due to an increased chance that the learner develops a dependency on KR to support performance. In contrast, infrequent KR does not possess the strong guidance properties of 100% KR, and therefore forces the participant to undertake various alternative information-processing activities during acquisition to maintain effective performance. The end result is more effective performance in the absence of KR, such as in a retention test, than for participants who have not had a chance to explore these skills in acquisition due to KR being constantly present. The interpretation for this somewhat surprising outcome is that 100% KR is viewed as being too guiding, causing the learner to become too reliant on this external reference to support performance. This excessive reliance on KR may obstruct the processing of significant task-related details and, therefore, impede the formation of error detection and correction capabilities necessary at the time of retention and transfer. This idea is termed the guidance hypothesis. It is more common in a nonlaboratory learning environment to provide the learner with KP. However, it is not well established whether the beneficial learning effects of reduced relative frequency of KR will generalize to the use of KP. In one of the few studies to examine scheduling frequency of KP, Young and Schmidt manipulated the scheduling of augmented kinematic feedback as a form of KP. The task was a single degree of freedom back swing then forward swing of a fixed lever to a specific spatiotemporal point coincident with illumination of lights on a Basin anticipation timer.

The study contrasted feedback schedules after every trial (100% relative frequency) or as averaged information after every set of five trials (20% relative frequency). Their results did not support the prediction of the guidance hypothesis for acquisition in that the mean acquisition performance of groups was statistically equal. However, their retention results paralleled earlier KR work in that a reduced frequency of KP was more beneficial for retention performance than 100% relative frequency [21]. Although single degree of freedom tasks have been the mainstay of studies examining the benefits of reduced relative frequency of augmented feedback, the need exists to study variations in feedback schedules for both KR and KP in other skills which involve establishing coordination between multiple limbs. KP given frequently may encourage the learner to switch attention to a different aspect of form each trial so that no single aspect of form receives concentrated attention. In this manner, each new administration of augmented feedback may motivate the performer to change an aspect of performance, with many of these changes resulting in over- or under compensations to the movement pattern. In contrast, form was presumably enhanced by the occasional application of KP by encouraging the learner to maintain focus on a particular aspect of form for several trials, thus allowing exploration and experience with a single aspect before shifting attention to another aspect on the next administration of KP [22]. Thus, reduced KP frequency may have reduced trial-to-trial variability in the coordination among limbs, benefiting development of a stable memory representation. The lack of support for the acquisition prediction of the guidance hypothesis is in accordance with the results of who also examined KP scheduling effects. Because the results of this study and their study indicate superior acquisition form under reduced relative KP frequency, the guidance hypothesis may need to be modified to reflect the fact that form seems to benefit under reduced relative frequency conditions even in acquisition. In the retention tests, the inferior form ratings of the 100% KP group supported the stated research hypothesis and the guidance hypothesis, which proposed that the strong guiding properties of augmented feedback can become a referent on which performance is based external to the learner. This implies that in relative frequency conditions of less than 100% KP, the no-KP trials force the learner to engage in information processing activities that support developing an internal reference to support performance. Thus, while augmented feedback is essential and useful in the beginning phases of learning, KP (and as several studies show, KR) given too frequently can undermine valuable task-related processing, such as the capability to recognize errors intrinsically. Although this task-related processing explanation has heretofore been applied to studies showing reduced relative frequencies of KR being beneficial to learning, the results of this experiment demonstrate that KP may operate in a similar manner, with high KP frequencies possibly replacing intrinsic assessment of form. Thus, as with KR, reducing the relative frequency of KP in acquisition possibly eliminated a dependency on KP to guide performance. This was evidently beneficial for maintaining form in the absence of KP, as indicated by performance on retention

tests. From a motor skill learning perspective, the increased opportunities for task-related processing provided by a reduced relative frequency schedule may benefit the skill acquisition process by allowing for the development and refinement offeror detection and correction capabilities in the early stages of learning. That is, when feedback is not available, the performer must rely on intrinsically gained feedback to assess current performance and generate a plan for the next response. In this manner, the performer learns to use sensory feedback in acquisition to support performance so that when this capability is required in a retention or transfer situation, the performer has practiced this capability. In contrast, the relatively poorer performance of the 100% group in retention and transfer supports the notion that too much KP, like too much KR, encourages the performer to inordinately focus on augmented feedback to support acquisition performance. In summary, receiving KP at a 33% relative frequency was superior to a 100% relative frequency for developing and maintaining prescribed form. This was true whether conditions were similar to those experienced in acquisition, as in the retention tests, or whether new conditions were introduced, as in the transfer tests. Reducing KP relative frequency may have similar proposed benefits to reducing KR: while KP guides the learner to optimal movement patterns, infrequent KP assists in developing intrinsic abilities to maintain form in the absence of KP rather than developing dependencies on KP as an external referent. That this effect was obtained in children indicates the motor skill learning effects of reduced relative frequency of augmented feedback may work similarly in adults and children, a speculation awaiting further examination.

4. Conclusion

Frequency of knowledge of results has been considered one of the most important variables that affect the acquisition of motor skills. Too much KP, like too much KR, encourages the performer to inordinately focus on augmented feedback to support acquisition performance. Receiving KP or KR at a 33% relative frequency was superior to a 100% relative frequency for developing and maintaining motor skill learning.

Acknowledgment

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