Original Article

# Influence of three accuracy levels of knowledge of results on motor skill acquisition

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**ABSTRACT**

Núñez FJ, Gálvez J. Influence of three accuracy levels of knowledge of results on motor skill acquisition. *J. Hum. Sport Exerc.* Vol. 5, No. 3, pp. 476-484, 2010. This study analyse the influence of Knowledge of Results (KR) with different accuracy levels on the learning rate of a throwing skill of spatial non-vision accuracy, during the acquisition stage. We assessed the number of successful events, the distance from the target and the consistency of the responses obtained by 180 subjects. We applied three accuracy levels: KR1 – subjects were informed about reaching the target or not; KR2 – informed about the direction of the failure events; and KR3 – informed about the direction and quantification of the failure events. All groups improved their rate of success –15.56% in KR1, 14.45% in KR3 ($p<0.001$) and 14.16% in KR2 ($p=0.001$)– as well as their consistency level after the acquisition stage. After 15 minutes without KR, we found main differences related to the rate of success in the retention stage between KR2 and KR1 ($p=0.026$), and between KR3 and KR1 ($p=0.001$), but not between KR2 and KR3. We can conclude that, a less precise KR, aimed just to the direction of the failure events, resulted more efficient at an initial learning stage than a more precise KR, aimed to the direction and the distance of the failure events. **Key words**: MOTOR LEARNING, NON-VISION, THROWING SKILL, FEED-BACK.

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## INTRODUCTION

Considering "learning" as the ability to detect and correct failures, the Knowledge of Results (KR) was considered by many authors in 60's and 70's (Bilodeau, 1969) and, more recently, in 80's (Salmoni, Schmidt, & Walter, 1984), as one of the most important variables to control and acquire motor skills. Given the prominence acquired by the influence of KR on learning processes, it was even asserted that the more frequency, accuracy and immediacy when providing KR, the better learning rates would be reached (Salmoni et al., 1984).

Several studies qualified this direct and positive relation of KR with the learning of motor skills. Firstly, different researches showed that motor learning can occur without KR (Swinnen, Vandenberghe, & Van Assche, 1985). In fact, this kind of studies, instead of the lack of KR, demanded the importance of the inherent information obtained by the subject from his own movement when acquiring a skill (internal feedback or IFB). However, it has been proved that, in predominantly inherent time anticipation tasks, the subjects with 0% of KR learned at a lesser extent than those with 100% of KR (Young & Schmidt, 1990). Some studies even showed that providing KR during the acquisition of a skill (external feedback or EFB) had more influence than the subject's inherent information itself, although this could be enough to learn the task and the provided KR could be incorrect or redundant with the IFB (Buekers, Magill, & Hall, 1992; Buekers, Magill, & Sneyers, 1994; McNevin, Magill, & Buekers, 1994; Buekers & Magill, 1995). Secondly, the inclusion of retention tests when analysing the tasks showed that a precise KR, large and immediate, contributed to a positive effect on the acquisition, although was a negative influence on the retention of the tasks to be learned (Butki & Hoffman, 2003; Schmidt, Lange, & Young, 1990; Winstein & Schmidt, 1990). This is called the "double effect" of KR, which is not valid for every kind of tasks. Kohl and Guadagnoli (1996) carried out a research with three experimental groups provided with 100% of KR, 50% (6 repetitions with KR and 6 without), and 50% (12 with KR and 12 without KR), respectively. The analysis of the 6 and 12 first attempts showed that the third group was better than the first one, which was for its part better than the second group; moreover, the retention of the first group (100% of KR) was better than the retention of the second group (50% of KR). Also Badets, Blandin, Wright, and Shea (2006) as shown in the retention phase after learning, subjects who received half the KR show greater stability in the results.

We can then concluded that there is not an established pattern of improvement, at the same time questioning the double effect theory.

Given these aspects, Magill (1994, 2001) pointed out that KR can be essential when acquiring skills if the information provided by the IFB is not enough or cannot be used by the subject. It may not be required to acquire skills when the IFB is enough, evident and achievable, becoming the EFB a redundant information without usefulness. At the same time, it can help the acquisition of skills, without resulting essential or redundant, while accelerating the learning processes of basically inherent skills; it may also disrupt the skill acquisition by creating a dependence of the EFB which causes a reduction of performance (Winstein & Schmidt, 1990; Anderson, Magill, & Sekiya, 2001).

These changeable results when applying KR seems to depend on the complexity of the task. According to Swinnen (1996), the complexity of the task is related to the richness of the provided IFB – the more complexity of the task, the more richness of the IFB; he also asserted that the tasks with a simple IFB (less complex tasks) could be more vulnerable to the negative effects of KR than the tasks with a complex IFB. To go into this aspect in more depth, we analysed the different variables of application of KR on simple and complex tasks. Wulf, Shea, and Matschiner (1998) studied the influence of the KR frequency on learning the complex skill of skiing slalom; they found out that the group with 100% of KR had a better performance than the group with 50%, and this one performed better than the group with 0% during retention tests without KR. Anderson et al. (2001) used a simple linear-positioning task without vision, offering a KR without delay or with a 2-attempts delay. The results showed that, in the acquisition stage, the groups without delay had a better performance than the groups with some delay; however, this trend changed during the retention stage, although this effect did not always appear at the same extent. The same study showed that the inclusion of a spring (to avoid the static positioning of the implement) caused difficulties when using the IFB and reduced the effect of handling KR. Guadagnoli, Leis, Van Gemmert, and Stelmach (2002) compared the effect on acquisition and retention of a linear-positioning task with time requirement and two different frequencies of KR (20% and 100%), both in healthy subjects and in Parkinson's patients with clear proprioception difficulties (use of IFB). The results showed that the healthy subjects of the group with the reduced frequency obtained better values in the retention stage than the healthy subjects of the group with 100% of KR; on the other hand, the Parkinson's patients did not follow the same trend, since, both during the acquisition and retention stages, the group with a 100% was better than the one with 20% of KR. We could reach the conclusion that a high frequency of KR improves the acquisition while reduces the retention in simple tasks, although when these tasks are complex and less consolidated, a high frequency of KR would lead to improvements during the acquisition and retention stages (Anderson et al., 2001).

One of the variables of the application of KR more often analysed is the accuracy of the information provided to the trainee. As well as for the assessment of the frequency variable, there are several studies asserting that it cannot be established a direct relation between the accuracy level and learning (Wright, Smith–Munyon, & Sidaway, 1997). The studies by Rogers (1974) raised the theory of an ideal accuracy level of KR, above and below which the learning rate is reduced. Nevertheless, some replicas made of these studies argued that, if the subjects know the meaning of the units used to provide KR, there would be no differences in learning between the groups with a higher or lower accuracy level of KR (Salmoni, Ross, Dill, & Zoeller, 1983). Reeve and Magill (1981) carried out a study about the influence of providing information related to the distance or direction of the failure events in a simple positioning test of a blind implement. These authors' conclusion established that KR about the direction of the failure events (less precise) is more useful in the initial stage of the learning process, while KR about the distance of the failure events (more precise) requires a certain level of experience in the subjects, so they can acquire it as useful information. By providing significant KR to the trainee and carrying out retention tests, Magill and Wood (1986) obtained similar results in a study about the influence of providing quantitative or qualitative KR in a complex task of reproduction of a specific movement. There were no main differences between the groups during the acquisition stage, while in the retention stage, the group with quantitative KR was better than the group with qualitative one. These results confirmed that both kinds of KR would be useful at the same degree, since they provided information about the direction of the failure events (less precise) at the initial learning stages; moreover, at the end of the acquisition stage and during retention, the quantitative information would be more useful than qualitative, since it provided information about the magnitude of the failure events (more precise). Reeve, Dornier, and Weeks (1990) came to a similar conclusion asserting that the precision of KR influenced on learning in a way that, at the earlier learning stages, a high accuracy level could be negative but, from a significant and durable point of view, the more accuracy provided, the more learning would be reached. Moreover, Chiviakowsky, and Wulf (2007) pointed out the importance of providing more information about success events than about failures. Wright et al. (1997), concluded that quantitative KR was useful when the failure was high, but that it was impossible to assert that qualitative KR would be more useful at long-term than quantitative when correcting small failure events.

In the present study, we aimed to analyse the influence of KR with different accuracy levels on the learning rate of a throwing skill of spatial non-vision accuracy, during the acquisition stage and after a period without applying KR.

## MATERIAL AND METHODS

### *Participants*

One hundred eighty university students (n=180, 74% male-26% female) subjects volunteered for this study after providing informed consent approved by the University Pablo de Olavide (Seville) Ethics Committee. Their average age ± SD was 19.2±1.2 yrs. Subjects were students of physical education, and were chosen to have sufficient motor maturity; Then, the results were due solely to the effect of KR on motor learning learning.

### *Experimental approach to the issue.*

In this study we analysed the influence of a KR with three accuracy levels on the learning rate of a throwing skill of spatial non-vision accuracy. The accuracy levels of KR were: KR1 (n=60) – subjects were provided with information about their successful or failure events; KR2 (n=60) – subjects were provided with information about the direction of the failure events, pointing out if the throwing went past or did not reach the target; and KR3 (n=60) – subjects were provided with information about the direction and quantification of failure events, pointing out if the throwing went past or did not reach the target, and the centimetres of separation.

### *Procedures*

The situation of assessment and acquisition (see Figure 1) involved the throwing of a tennis ball with the eyes covered, trying to put it inside a target 36 cm deep, 3 meters away. We registered the centimetres of distance between the final position of the ball and the target in each throwing: the deviation was negative when the ball did not reach the target and positive when it went further. We applied a previous assessment (Pre-Test) involving 6 shots without any provided KR. The acquisition stage consisted of 4 sets of 6 shots, with the KR which corresponded to each experimental group (KR1, KR2 and KR3). It was carried out a later assessment, under the same conditions than during Pre-Test and just after the acquisition stage (Post-Test), as well as after 15 minutes without activity (Re-Test).

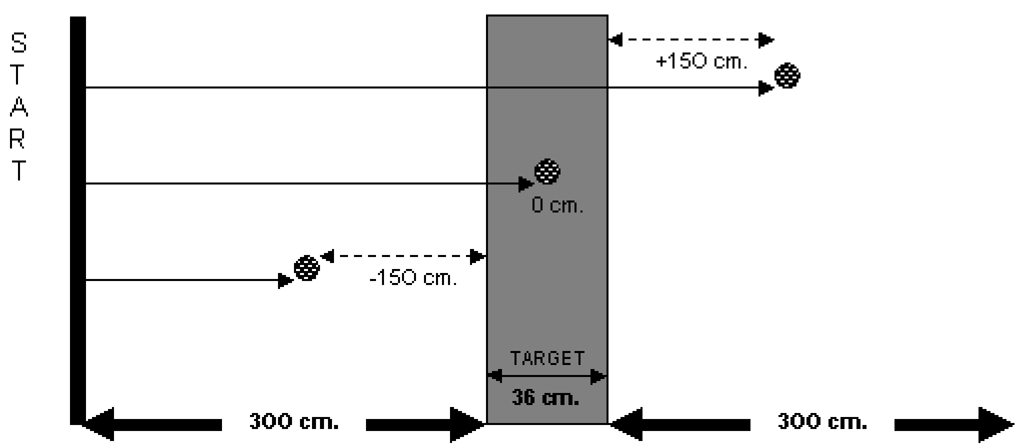



***Figure 1.*** *Situation of assessment and acquisition of the throwing skill of non-vision accuracy.*

***Dependant variables and analysis***

We analysed two accuracy variables in the subjects' response: on one hand, the "separation distance" variable, measured through the median of centimetres between the final position of the ball and the target in every shot (by subject and assessment set); and, on the other hand, the "success" variable, measured through the times that the ball was placed inside the target (by subject and assessment set).

We then registered a variable of response consistency, the "diffusion". To obtain it, we measured the median of 75 and 25 percentiles on the data of centimetres between the final position of the ball and the target in every shot (by subject and assessment set); from the 75 percentile, we subtracted the 25 one, resulting the diffusion of the response.

To compare intragroup results we used the Wilconson test for signal ranges, with a reliability index of 95% ($p<0.05$). When analysing the intragroup results we used the Kruskal-Wallis H test of variance, with a reliability index of 95% ($p<0.05$), to apply then the Mann-Whitney U test to the significant variables.

## RESULTS

Table 1 shows the results obtained for each analysed variable. The three experimental groups improved their accuracy levels of throwing after the acquisition stage, regarding the separation distance variable; however, the KR2 group was the only one with significant differences ($p=0.006$). During Re-Test, the KR3 group significantly reduced its distance from the target ($p=0.045$), while the other groups showed no significant differences. Nevertheless, the KR2 group maintained significant values compared to Pre-Test ($p=004$). There were no main intragroup differences for the separation distance variable.

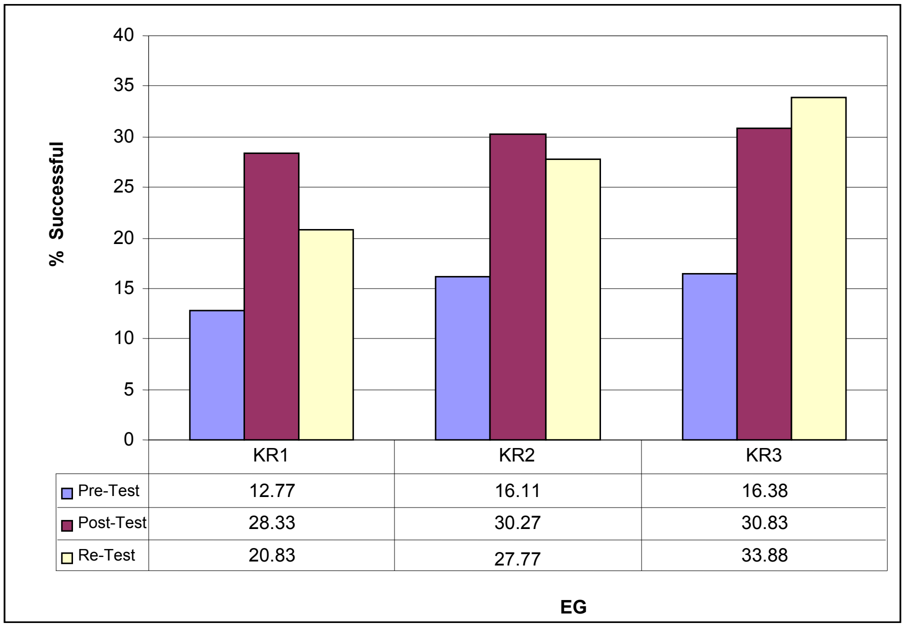
***Table 1.*** *Results of accuracy and consistency variables for responses during the assessment tests, by experimental group.*

| | | Pre-Test | | Post-Test | | Re-Test | |
|---|---|---|---|---|---|---|---|
| | | Average | SD | Average | SD | Average | SD |
| Separation Distance (cm) | KR1 | 31.65 | 119.60 | 16.11 | 113.96 | 15.43 | 113.06 |
| | KR2 | 39.41 | 105.75 | -7.02 | 22.43 | -10 | 23.74 |
| | KR3 | 32.13 | 101.38 | 3.33 | 25.55 | -2.32 | 27.32 |
| Diffusion (cm) | KR1 | 85.46 | 59.16 | 45.3 | 38.5 | 50.94 | 37.45 |
| | KR2 | 82.79 | 52.72 | 49.93 | 38.68 | 40.87 | 24.73 |
| | KR3 | 84.37 | 56.05 | 48.98 | 47.69 | 36.97 | 26.93 |

*Note: SD = Standard Deviation*

The three groups showed a significant improvement in the accuracy level of the throwing after the acquisition stage for the success variable: 15.56% in KR1 and 14.45% in KR3 ($P<0.001$), while 14.16% in KR2 ($p=0.001$). During Re-Test, the number of successful throwings decreased -7.5% in KR1 and -2.5% in KR2, while the value of the KR3 group increased a 3.05%; however, none of them reached main differences compared to Post-Test. The number of successful shots was still significantly higher than in Pre-Test for the three groups: KR1 ($P=0.003$), KR2 ($p=0.001$) and KR3 ($p<0.001$). We also found main differences related to the success events during Re-Test between KR2-KR1 groups ($p=0.026$) and KR3-KR1 ($p=0.001$) groups, while there were not main differences between KR2-KR3 groups.

***Figure 2.*** *Percentages of success during the assessment tests, by experimental group (EG)*




In the analysis of consistency of performance for every group, every group significantly reduced their diffusion values after the acquisition stage: KR1, KR2 and KR3 ($p<0.001$). During the Re-Test, KR2 and KR3 reduced also their diffusion, while KR1 increased it. None of the groups showed a statistically remarkable change compared to Post-Test, although the differences compared to Pre-Test were still significant ($p<0.001$). There were no main intragroup differences for the diffusion variable.

## DISCUSSION AND CONCLUSION

We could consider this skill as a complex task (Swinnen, 1996), with a high frequency of application of KR, in which we combined different levels of accuracy of KR during the acquisition stage. The proposed learning situation was clearly dependent on an EFB, since the information provided by the IFB was not, a priori, enough to acquire the skill. In that situation, the KR was defined as essential (Magil, 1994, 2001) or as an accelerator of the learning process (Winstein & Schmidt, 1990). Nevertheless, we could prove (as Butki & Hoffman did, 2003) that the rate of success and the consistency of the proposed skill after the learning stage showed a significant improvement in every group, but at a higher extent in the group with less information. Although these differences of information between the groups are not significant, we can conclude that KR provided to the KR1 group is almost irrelevant to the proposed learning situation, since we did not provide enough information to acquire the skill, unless the subject reached a success event. The only main information for the subjects of this group was the provided IFB from a successful execution of the task. These results would agree with the findings by Swinnen et al. (1985), according to which the motor learning could occur without KR, claiming the importance of inherent information obtained by the subject from his own movement when acquiring a skill; however, in our study, the information provided was really minimal, given the lack of vision. On the other hand, those findings would disagree with the results obtained by Young and Schmidt (1990), since the subjects with less KR learned at a higher extent than subjects with a more precise KR. When analysing the retention levels, we could see that, even without main intragroup differences, the KR3 and KR2 groups obtained rates of success significantly higher than KR1. It seems that our results, regarding success events, would disagree with the "double effect" theories (Schmidt et al., 1990; Winstein & Schmidt, 1990), given that the precise KR did not reach a more positive effect on acquisition than a less precise one; at the same time, and opposite to the meaning of that effect, there was a positive effect on the retention of the task to be learned. In the present study, we could not confirm the existence of an optimal level of KR accuracy, as Rogers (1974) did, although it seemed impossible to establish a direct relation between the accuracy level and learning, such as other authors asserted (Wright et al., 1997).

A similar procedure was followed by Ishikura (2008) applied to putt in golf. However, this time, the subjects with reduced KR could see part of the path followed by the ball, but the end result, and obtaining results similar to ours.

According to the results by Reeve and Magill (1981), and Magill and Wood (1986), the more qualitative and less accurate information provided to the KR2 group, aimed to the direction of the failure events, was more useful in an initial stage; this is the only group obtaining a significant reduction in the separation distance from the target after the learning period. Nevertheless, the more quantitative and more accurate information given to the KR3 group, aimed to the distance, obtained better results after the retention stage, being the only group with main differences for the separation distance variable after the period without KR. Our study would be an example of the conclusions by Reeve et al. (1990), according to which the accuracy of KR affects the learning in a way that, in the earlier stages, a high level of accuracy can be negative but, from a significant and durable point of view, the higher accuracy of KR means the higher learning reached.

Given our results, we cannot agree with the assertion that, the more frequency, accuracy and immediacy when providing KR, the better rates of success can be obtained (see Salmoni et al., 1984). The results related to a throwing skill of non-vision accuracy confirmed the theories by Kohl and Guadagnoli (1996), asserting that there is not an established pattern of improvement, questioning with it the double effect theory.

However, we can conclude that, in a non-vision situation, with less precise KR providing significant information to the trainee and aimed just to the direction of the failure events, was more efficient in the earlier stages of learning than a more precise KR, aimed to the direction and the distance of the failure events. Nevertheless, the rate of success acquired through the provision of less accurate and qualitative KR remained less time than the rate of success obtained through the provision of more accurate and quantitative KR.

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