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Knowledge of Results Precision and Learning:...

KNOWLEDGE OF RESULTS PRECISION AND LEARNING: A REVIEW

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PALABRAS CLAVE: Control y Aprendizaje Motor, Desarrollo Motor, Feedback, Precisión del Conocimiento de Resultados.
RESUMEN: La calidad de la información que el aprendiz recibe como consecuencia de la accion, en particular la precisión del conocimiento de los resultados, parece tener un efecto positivo en el processo del aprendizaje. En este articulo, de acuerdo con lo expuesto anteriormente y el análisis de la investigación realizada en el ámbito de la precisión del conocimiento de los resultados, enfocaremos la influencia de otras variables mencionadas, por ejemplo: las características de la habilidad motora, el nivel de desarrollo de la persona y su capacidad de procesar la información.

KEY WORDS: Motor Control and Learning, Motor Development, Feedback, Knowledge of Results Precision.
ABSTRACT: The quality of the information given to the subject after performance, particulary the Knowledge of Results (KR) precision, seems to have a positive influence on the learning process. In this article, we review the investigation produced in KR precision and emphasize the influence of some

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variables, like the task characteristics, the development level of subjects and their capacity to process KR information.

The Concept of Knowledge of Results

Feedback represents all the information received by the subject during or after performing a movement (Schmidt, 1988). Two types of feedback resulting from the produced action were identified: intrinsic and extrinsic feedback. The former is related to the task itself, since movement produces sensorial information (e.g., proprioceptive, visual, ...). The extrinsic feedback, also known as «artificial feedback» or «augmented feedback» (Drowatzky, 1975, p.89), corresponds to the additional external information given to the subjects by another individual, like the teacher for example.

Travers (1972) named the information that the subject receives after performing the movement by «knowledge of results» (KR) or «informative feedback», pointing out that sometimes the expression «feedback» is also used. This attitude is quite elucidative of the use of the different designations refering to the same concept - the KR (Table 1).

«Knowledge of results» is the most common expression. Schmidt (1988) defines the concept as:

> «..., KR is verbal (or verbalizable), terminal (i.e., post- response) feedback about the outcome of the movement in terms of the environmental goal» (Schmidt, 1988, p.426).

EXPRESSION	AUTHOR	DATE
	Judd	1903
Knowledge of Results	Dees y Grindley	1951
	Lavery y Suddon	1962
Knowledge of Performance	Gentile	1972
Achivement Information Feedback	Smode	1958
Reinforcing Feedback	Taylor y Noble	1962
Psychological Feedback	Payne y Hauty	1955
Reinforcement	Suppes y Frankmann	1961
	Taubman	1944

[1] Miller (1953) quoted by Elliot y Connolly (1974, p.138) and Holding (1956) quoted by Magill (1986,

Reward
Noble y Alcock
1958

Saltzman
1951
Information Feedback
Bourne
1957

Bilodeau
1966
Learning Feedback [1]
Miller 1953

Holding
1965

The actual result of the movement can be distinguished from «knowledge of performance» (Gentile, 1972), because of its reference to the critical aspects of the movement. Young and Schmidt (1992) proposed a more descriptive designation of knowledge of performance, naming «augmented kinematic feedback» to all extrinsic verbal information given to the subject after the performance of the movement, concerning the phases or the kinematic and kinetic aspects of the movement's pattern.

Knowledge of results and knowledge of performance are expected, in theory, to produce more relevant positive effects in performance and learning than the exclusive process of intrinsic feedbacks (subjective reinforcement) by the subject.

The Effectiveness of KR for Learning

Most of the studies reviewed by Salmoni, Schmidt and Walter (1984), Godinho (1992) and Mendes (1994), are characterized by the non inclusion of retention and transfer tests without KR in their experimental designs. This aspect does not allow decisive conclusions about the effects of KR in the learning process (lasting effects). However, these authors admited that KR is the most important learning variable, apart from practice itself.

Thorndike (1931) and Trowbridge and Cason (1932) studies are historical documents, giving origin to the KR investigation. Although Thorndike's (1931) work dealt mainly with animals and verbal tasks learned by humans, the famous drawing lines experiment exalts the importance of KR in motor learning. Trowbridge and Cason (1932), as well as Thorndike (1931), used the drawing lines task to investigate the KR precision in four conditions (no KR, nonsense KR, qualitative KR in a right-wrong way, and quantitative KR about the length of the drawn lines). The authors concluded that the nature of the information received by the subject produces some learning effects, confirmed by the fact that the group which has received quantitative KR shows better results in the acquisition phase (the only phase considered in this study).

Most of the studies developed later, often using similar tasks (drawing line / linear positioning), assure the learning dependence of KR. The Bilodeau, Bilodeau and Schumsky (1959) study is a classical example of

the KR experimental investigation. Bearing in mind that the learning process depends on KR, these authors formulated the hypothesis that when the KR presentation is excluded in different moments of a trials sequence of the same skill (angular positioning), different performance levels could be expected. This hypothesis was strengthened by the fact that the group with KR in all trials had the best results, followed by the group without KR after the second trial, the group without KR after the sixth trial and the group without KR after the twentieth trial.

Despite the conclusion later confirmed in other experiments, that KR is a variable which affects learning, there are still some doubts. Archer, Kent, and Mote (1956), and Pearson and Hauty (1959) were the first to point out the subject's capacity to learn without KR. Similar results were observed in linear positioning tasks by Adams and Dijkstra (1966), Wrisberg and Schmidt (1975) and Newell (1976). The latter, verified that only the group performing ballistic movements without KR had the capacity to improve its performance level, underlining the relevance of the task characteristics to a better understanding of KR.

According to the Closed Circuit (Adams, 1971) and Schema (Schmidt, 1975) theories, the explanation of the possibility to learn without KR is based on the subject's ability to use intrinsic feedbacks. This phenomenon is reinforced by the fact that the practice itself helps to develop an error detection mechanism (error labelling schema, according to Schmidt, 1975).

In the present, the study of KR corresponds mainly to the experimental manipulation of its quantitative aspects (absolute and relative frequency of KR, summary KR and trials delay design), temporal aspects (KR delay, post-KR delay and intertrial interval), precision aspects, and other alternative forms of presentation of KR (video KR and video knowledge of performance, kinematic and kinetic KR, ...). The «guidance» role of KR was summarized by Salmoni, Schmidt, and Walter (1984):

> «... the improved performance that results from (a) both increased relative and absolute frequency of KR, (b) longer post-KR delay, (c) increased KR precision, (d) fewer interpolated activities in KR delay and post-KR delay, and (e) perhaps decreased KR delay» (Salmoni, Schmidt, y Walter, 1984, p.380).

The most recent studies point out this variable analysis in terms of retention and transfer, that is to say, the lasting effects.

The positive influence of intrinsic and extrinsic feedback in the learning process is not questionable, although it must be carefully perceived. More investigation considering simultaneously other variables effect, such as the developmental level (e.g., Newell y Kennedy, 1978 and Mendes, 1994) or the type of task used (e.g., Mendes y Godinho, 1993), is required.

Functions of KR

The KR importance in the learning process depends on the different KR functions.

According to Schmidt (1988, p.452-

453), the KR influence in learning is ascribed by three functions: (1) guidance, (2) motivational and (3) associational.

The guidance role for KR proclaims the importance of KR information in leading the subject towards the objective of movement. This information will be useful as a basis to correct the next execution.

Annett (1972) underlines the

AUTHOR	DATE	TASK	KR PRECISION	N	SUBJECTS	TRIALS			RESULTS		
						A	R	T	A	R	T
TROWBRIDGE, M. & CASON, H.	1932	Line Drawing	No KR, O KR, Verbal KR, QL KR, QT KR	60	Adults	100 + 100			+		
BILODEAU, E.	1953	Knob Turning	Erroneous versus True scores	200	Adults	16			+		
LINCOLN, R.	1954	Turning a Handwheel	Proprioceptive and Visual KR, QT KR	60	Adults	15	10		-	=	
NOBLE, C. & BROUSSARD, I.	1955	Knob Turning	Erroneous versus True scores	96	Adults	20			+		
BOURNE, L. & PENDLETON, R.	1958	Concept--Identification	Visual KR, QL KR	54	Adults	*			+		
HUNT, D.	1961	Tracking Task	Visual KR, QL KR	64	Adults	30			+		
LAVERY, J.	1964	Linear Positioning	A: Visual KR, QL KR R: No KR	36	Adults	120	80 + 120		=	+	
MALINA, R.	1969	Overarm Throwing a Ball	No KR, Verbal and Visual KR, QT KR	55	Young	**			+		
SMOLL, F.	1972	Duckpin Bowling Ball	Verbal KR, QL KR, QT KR	45	Adults	60			+		
ROGERS, C.	1974	Knob Turning	Verbal KR, QL KR, QT KR	80	Adults	10			+		
ROGERS, C.	1974	Temporal Precision	Verbal KR, QL KR, QT KR	45	Adults	10			U		
GILL, D.	1975	Linear Positioning	Verbal KR, QT KR	40	Adults	42	21		=	=	
McCONNELL, A.	1976	Pursuit Rotor Task	Verbal KR, QT KR	24	Adults	40			+		
SHAPIRO, D.	1977	Linear Positioning	Verbal KR, QL KR	42	Children	30			= >+		

Legend:
A/ R/ T Acquisition/ Retention/ Transfer
QT/ QL/ O Quantitative KR/ Qualitative KR/ Other form of KR
+/ -/ = Positive/ Negative/ Without effect by an increase in KR precision
U «U» effect (best score by intermediate KR precision)
>+ Tendency to a positive effect (positive but not significative)
***** Criterion: 16 consecutively correct identifications

AUTHOR	DATE	TASK	KR PRECISION	N	SUBJECTS	TRIALS			RESULTS		
						A	R	T	A	R	T
LITOW, L. & LEVINE, S.	1978	Concept - -Identification	Visual KR, QL KR	77	Children	48			=		
NEWELL, K. & KENNEDY, J.	1978	Linear Positioning	Verbal KR, QL KR, QT KR	160	Children	21			U >+		
WILLIAMS, I. & RODNEY, M.	1978	Linear Positioning	A: Verbal KR, QT KR R: No KR	44	Adults	16	20		+		
BENNETT, I., VINCENT, W. & JOHNSON, C.	1979	Pursuit Rotor Task	No KR, Verbal KR QL KR, QT KR	100	Young	10			+		
THOMAS, J., MITCHELL, B. & SOLMON, M.	1979	Linear Positioning (Angular)	A: No KR, Verbal KR QL KR, QT KR R: No KR	54	Children	40	19		-	-	
SALMONI, A.	1980	Line Drawing	Verbal KR, QL KR, QT KR	60	Children and Adults	20			+		
JENSEN, B., PICADO, M. & MORENZ, C.	1981	Coincidence - - Anticipation	A: Verbal KR QL KR, QT KR R: No KR	90	Adults	24	12		=	=	
REEVE, T. & MAGILL, R.	1981	Linear Positioning	Verbal KR, QL KR, QT KR	48	Adults	30			+		
SALMONI, A., ROSS, D., DILL, S. & ZOELLER, M.	1983	Knob Turning	A: Verbal KR, QL KR, QT KR R: No KR	80	Adults	11	10		+	+	
SALMONI, A., ROSS, D., DILL, S. & ZOELLER, M.	1983	Knob Turning	A: Verbal KR, QT KR R: No KR	40	Adults	36	15		=	=	
BENNET, D. & SIMMONS, R.	1984	Linear Positioning	A: Verbal KR, No KR, O KR, QL KR, QT KR R: No KR	40	Adults	30	30		+	+	
RAMELLA, R.	1984	Temporal Anticipation	Verbal KR, No KR, QL KR	46	Children	15			+		
MAGILL, R. & WOOD, C.	1986	Temporal Precision	A: Visual KR, QL KR, QT KR R: No KR	19	Adults	100	20		=	+	

Tabla 2. *KR Precision: synthesis of studies (II).*

AUTHOR	DATE	TASK	KR PRECISION	N	SUBJECTS	TRIALS			RESULTS		
						A	R	T	A	R	T
REEVE, T., DORNIER, L. & WEEKS, D.	1990	Linear Positioning - - Temporal Precision	A: Verbal KR, QL KR, QT KR R: No KR	48	Adults	31	10		=	+	
GODINHO, M.	1992	Isometric Force	A: Visual KR, QL KR, QT KR R: No KR T: QT KR	30	Adults	16	6 + 6	6	+	=	=
MENDES, R. & GODINHO, M.	1993	Linear Positioning - - Isometric Force	A: Visual KR QL KR, QT KR R: No KR T: QT KR	30	Adults	16	6 + 6	6	=	=	=
MENDES, R.	1994	Linear Positioning (Angular)	A: Visual KR QL KR, QT KR R: No KR T: QT KR	40	Children and Adults	16	6 + 6	6	=	=	=

Table 2. *KR Precision: synthesis of studies (III).*

informative function of KR considering the following main functions: (1) incentive, (2) reinforcement and (3) information, contrasting with Bilodeau (1966, p.257) perspective: (1) directive, (2) motivating and (3) reinforcing. Motivational function has an important role in the management of the subject's interest by the task he/she performs.

Schema theory (Schmidt, 1975) is a good example of the KR associational function, since it considers that the motor response schema formation comes, apart from other sources, from KR. According to Schmidt (1975) this information arises from KR and/or subjective reinforcement that the subject obtains from other sources of feedback.

KR Precision

The quality of the information given to the subject after the performance, particularly the KR precision, seems to have a positive influence on the learning process (e.g., Magill y Wood, 1986). The level of accuracy of the information given to the subject influences the learning process and

[2] By acquisition phase it is meant the amount of trials or practice sessions in a skill, taking for granted that the level of the subject's performance in this phase corresponds to the performance, to say, to the temporary effects. The inclusion of experimental designs with transfer and retention tests is an essential criteria to infer the learning, to say, to the lasting effects (Salmoni, Schmidt, y Walter, 1984).

EFFECTS OF AN INCREASE IN KR PRECISION	ADULTS			CHILDREN		
	ACQUISITION	RETENTION	TRANSFER	ACQUISITION	RETENTION	TRANSFER
POSITIVE	16	5	0	2	0	0
WITHOUT	8	7	3	3	1	1
NEGATIVE	1	0	0	1	1	0
"U" EFFECT	1	0	0	1	0	0
TOTAL OF STUDIES	26	12	3	7	2	1

leads to changes in the behaviour. However, the subject's capacity to process information is also a relevant variable in the learning process, stressing central processing when high level of KR precision is used (e.g., Thomas, Mitchell, y Solmon, 1979, with children, and Jensen, Picado, y Morenz, 1981, with adults).

KR precision has been the aim of several studies summarized in Table 2. From the review of the 31 listed studies it is possible to conclude that:

1.- The performance level in the acquisition[2] phase is usually improved when the KR precision is increased (e.g. Trowbridge y Cason, 1932).

2.- There is some discussion regarding the effects of the increase in KR precision during the learning process. This conclusion is limited by the fact that only three studies have used transfer tasks (Godinho, 1992; Mendes y Godinho, 1993 and Mendes, 1994) and just 12 included a retention phase (see Table 3).

3.- Low levels, as well as high levels of KR precision (e.g. about the movement goal) provided to the subject after performance, may have a negative influence on the learning process - «U» effect (e.g., Rogers, 1974, with adults, and Newell y Kennedy, 1978, with children).

4.- Some studies with children showed an inexistence or a negative relationship between the increase of KR precision and age (e.g., Thomas, Mitchell, y Solmon, 1979), probably because of children information-processing deficit.

5.- The few studies (seven) with children and the nature of their experimental designs do not allow us to fully clarify the effects of KR precision in motor tasks acquisition and learning - only two studies used the retention phase and one study (Mendes, 1994) included a transfer task.

Table 3. *KR Precision: Acquisition, Retention and Transfer in Adults and Children (synthesis of Table 2).*

Discusión

At the end of this analysis about the

importance of the KR variable, and mainly about KR precision, we emphasize six major points:

1.- **Subjective Reinforcement**: the results of the reviewed studies raise some objections to the probable positive effects of an increase in KR precision in performance and learning. The hypothesis which was stated was that the lesser the KR precision, the greater is the subject's tendency to engage himself in intrinsic feedback and so, better results will be expected in retention and transfer phases. However, and until now, the observed results are not statistically significant. More important than the KR precision it seems to be the subject's level of engagement in the available information process, namely the one which refers to its own sensations.

2.- **Type of Task**: in a previous investigation (Mendes y Godinho, 1993) we observed that the type of task might interfere with the learning process when the precision of KR is identical. Task analysis and other variables and techniques (e.g., electromyography) may benefit the study of this problem.

3.- **Development Level**: the emergent notion of investigation with children, is that the KR precision increase may not influence significantly and positively the acquisition of a motor task (e.g., Newell y Kennedy, 1978; Thomas, Mitchell, y Solmon, 1979). It is credible that the explanation for the unexpected results found by Mendes (1994) - quantitative KR groups were worst than qualitative KR groups of the same age level -, is in fact that children do not have enough capacity to process the KR information in the same period of time. This explanation is particularly relevant for children, strengthening the Newell and Kennedy's (1978) sugestion that the capacity to process information and, specifically, to process KR, improves when the subjects become older. The probable difficulty of the subjects, namely children, to process the given external information in the same period of time (post-KR delay) may be the basis of the few studies which showed a positive effect in the acquisition of motor skills. One may expect that the experimental maintenance of time to process KR at different age levels, results frequently in a decrease of the performance level in younger subjects (Thomas, Mitchell, y Solmon, 1979; Newell y Kennedy, 1978).

4.- **Acquisition**: the acquisition process is different in children and adults. The former show usually high values of error measures (e.g., absolute error) and continual oscillations shown in the performance precision (absolute error) and stability (variable error) during the acquisition phase. Mendes (1994) underlined that the differences between age levels may be due to:

A.- the functional development of the perceptual-motor mechanisms and the subjects capacity to receive and discriminate information by the use of their own sensory system (intrasensory discrimination), as well as to simultaneous use of other sensorial information (intersensory integration); these aspects clearly benefit adults (e.g., Williams, 1983).

B.- the fact that children and adults profit differently from practice due to the

schema characteristics. The former may still be in a phase in which the correspondent schema would not be yet formed, and the adults could only transform an already attained schema (Van Rossum, 1987).

5.- **Initial Level**: a central point is the influence that the level of proficiency of the subject at the onset of a task practice has on the acquisition phase (e.g., Magill, 1989).

6.- **KR as a Discrete Variable**: it is important to emphasize the probable subjects interpretation of KR information. The hypothesis which is stated here is that the subject, because of the KR complexity, and difficulty to interpret and to use it in the correction of the next trial, transforms the continuum variable (quantitative KR, the most accurate) into a categorical one (e.g., Mark y Vogele, 1987).

This change involves the subject's cognitive engagement, filling up totally or partially the post-KR delay, and reduces the time for the effective use of KR in the attainment of response schema.

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