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Effect of Two Types of Feedback and Error Estimation on Error Detection Capability in Continuous Tracking task

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ABSTRACT: The present paper aimed to study the effect of two types of feedback and error estimation on error detection capability in a continuous tracking task. 50subjects participated in the study who were divided into four experimental groups and one control group according to the status of estimation (with estimation or without estimation) and the type of augmented feedback (KP or KR). The desired task was pursuit tracking task in which the subject was asked to follow a yellow circle on a blue background on the screen by moving the mouse. Error Estimation Accuracy was used for measuring error detection capability.

The results of one-way analysis of variance (ANOVA) indicated that there is a significant difference between the experimental groups and the control. Also, the results of two-way analysis of variance showed a significant difference between KR and KP groups ($p<0.05$).

The findings showed any type of augmented feedback affects error detection capability and error estimation improves error detection capability in the retention phase. The results also demonstrated that the combination of KR feedback and error estimation yields a better result than the combination of KP feedback and error estimation.

Keywords: Feedback; Error estimation; Error detection capability; Continuous task

INTRODUCTION

Learning, which is usually defined as relatively permanent changes in behaviors resulting from relationship with the environment and to acquiring new experiences, gives a distinctive feature to the all living organisms (Shoarinejad, 1999). However, learning is much more flexible in human than other creatures and the secret of human progress and success lies in his talent and ability in learning. In recent years, several studies have been conducted on learning and performance of motor skills, the aim of which was to identify the key factors affecting the performance and learning. Feedback is one of these important factors, as it is the basis of recent motor-control theories. According to Adams's closed-loop theory, no correct perceptual trace can be formed without feedback and according to Schmidt's schema theory, feedback is essential for the formation of recall schema and recognition schema. Depending on the place it comes from, feedback is divided into two categories of inherent feedback and extrinsic feedback. Also, augmented feedback falls into two sets; knowledge of results (KR) which focuses on the result of a movement in achieving the environmental objectives and knowledge of performance (KP) which emphasizes on the kinematic aspects of the motor pattern. Among a lot of studies carried out on feedback, KR has been mostly the focus of attention, as researchers believe that the terminal feedback prepares a person about the result of a movement and is a basis for correcting the errors in subsequent attempts. When the feedback provides information about the movement pattern, speed, time, and representation of the track, it is known as kinematic feedback which is one type of KP. It seems that the most important aspect of the kinematic feedback is that lets the learner be aware of some aspects of the movement pattern and it is impossible to receive such information without kinematic feedback. One of the components of the movement patterns is the track in pursuit tracking task.

Many variables have been studied about the augmented feedback, such as the magnitude of augmented feedback. In addition, many studies have been conducted on the feedback delay. However, the nature of the activities the subjects do in the delay of the augmented feedback is one of the issues that has recently attracted the attention of motor behavior researchers. Various activities have different effects on learning in the feedback delay of KR, some of which can be beneficial to the learning. One of these activities is that a person estimates their error before receiving the feedback which is called subjective error estimation.

In this regard, it has been stressed that according to response hypothesis, the extent of a person's involvement before receiving the feedback and the way of using it cannot be independent of each other, because after performing a movement, a person would actively get involved in comparing their performance with the criterion task and detecting their errors in order to use them in the next attempt. Hence, those who subjectively estimate their errors, according to response hypothesis, can have a better comparison and make more appropriate plans of future actions. Thus, providing the KR for the individuals who have to estimate their movement errors after performance would lead to further learning.

Accordingly, the learner can detect the errors in their movement by practice which is known as error detection capability and gradually supplants the augmented feedback. According to Adams's theory, this capability is achieved through comparison of the feedback from the movement with the perceptual trace. Any difference between these two represents the existence of error that a person can report it to the examiner or gets use of it through subjective reinforcement. In the absence of the feedback, this subjective reinforcement can direct a person towards the desired goal. According to this theory, keeping the movement on the goal can lead to learning, because if the learning continues, the person can perform the movement correctly without feedback. Also, according to Schmidt's schema theory, error detection capability, which is the result of the evolution of recognition schema, is not responsible for the action in fast movements and evaluation of action correction is done only after the movement is performed. However, in slow movements, error correction process would be the real cause of action. Schmidt also believes that motor learning is subjected to the development of recall schema and recognition schema and states that KR strengthens the link between the results of movement and the sensory consequences and thereby develops recognition schema for error detection. The effect of KP on error detection capability can be also applied to the pursuit tracking task. Pursuit tracking task is a type of continuous motor skills in which a subject should follow a certain track. One of the computerized tracking tasks is to follow an animated spot on the screen. By showing the track the subjects have passed during the performance and the original track to them, a KP can be provided for them.

Potentially, the studies on error detection, depending on the type of task used, can be divided into three categories:

Studies with fast tasks: Shapiro, Schmidt, and Swinnen (1984) used a timing task in order to apply various combinations of error estimation and non-estimation in acquisition phase and transfer test. The results showed that error estimation in acquisition phase reduces the errors in the acquisition phase and transfer test.

Guadangoli & Kohl (2001) studied the relationship between the frequency of KR and error estimation in a force generation task. Based on error estimation and frequency of KR, the subjects were divided into four experimental groups including error estimation with a KR frequency of 100%, error estimation with a KR frequency of 20%, non-estimation of error with a KR frequency of 100%, and non-estimation of error with a KR frequency of 20%. The results of retention phase showed that there is a significant relationship between error detection in the acquisition phase and frequency of KR. Accordingly, the subjects who had estimated their error in the acquisition phase and received a 100% KR exhibited the best performance compared to other groups and the worst performance belonged to the group with non-estimation of error and a 100% KR.

Hogan & Yanowitz (1987) applied a ballistic task. Their findings showed that subjective error estimation increases error detection capability in the transfer test. Swinnen (1990) also showed the positive impact of error estimation on error detection capability. The task used in this study was moving the pyramids in a specified distance. The subjects who had done the error estimation in the acquisition phase showed better performance than others. Swinnen (1988) studied the role of error estimation in gymnastic performance and concluded that forcing the athletes to estimate their errors can leadtoa better performance of them.

Liu & Zhan (1993) studied the effect of subjective error estimation of movement production on learning an applied motor skill. The results indicated that subjective estimation of the movement errors improves learning of a skill and develops error detection capability. Carol (1996) studied the role of KR in error detection capability in learning the task of moving aleverina specified timing. In this trial, the effect of the way of presenting the KR (numerically or graphically) was the focus of attention. The subjects were asked to estimate their timing error in the acquisition phase. The results showed that error detection capability was better in the subjects who had estimated their errors numerically.

Schmidt and White (1972) used a throwing-timing task and asked the subjects to guess their subjective error rate. Then, their objective error was measured. By continuing the exercise, it was observed that the correlation between the subjective and objective error scores gradually increased.

Taheri *et al.* (2005) studied the effect of various methods of error estimation and reduced frequency of augmented feedback on error detection capability, performance, and learning of bimanual coordination task. In this study three types of error estimation including model, temporal, and combinative and two frequencies of augmented feedback (20% and 100%) were used. The results suggested that 100% model and 100% temporal estimation are better than other ones.

Studies with slow tasks: Schmidt & Russell (1974) conducted a trial similar to the one done by Schmidt & White (1972) but with a slow linear position task. Unlike the findings of Schmidt & White (1972), they reported a low interpersonal correlation between subjective error and objective error.

Studies with continuous motor tasks: Despite the importance and frequency of use of continuous tasks in performing motor skills, no study has been conducted on the relationship between error detection capability and continuous motor task. Unfortunately, there is no study available not only about the use of KP in these tasks and its influence on error detection capability but also about KR which has a broader research scope.

Given the fewness of studies on the timing of KP and also not using the continuous tasks in studies related to error detection, this question arises that firstly, whether the augmented feedback is effective in error detection capability in tracking task or not, secondly, if it is, which type of augmented feedback (KP or KR) is more effective, and thirdly, whether there is a difference between the effects of two types of augmented feedback on error detection capability or not. Hence, the objective of the present paper is to study the effects of two types of feedback (KP and KR) and error estimation on error detection capability in a continuous tracking task.

METHOD

The present research is a quasi-experimental and fundamental study. Pretest with 4 experimental groups and a control was used in this study. The sample included 50 male students of guidance schools in Aran-Va-Bidgol and Kashan in the academic year 2012-2013. The subjects took part in this trial voluntarily and with full consent. All subjects, who aged12-15years (13.46±1.87), were unaware of the purposes of the study and all were right-handed (to ensure that the subjects are right-handed, Briggs-Nebes scale was used). In addition, none of them had a history of doing such task.

A laptop was used for performing the task and also a computer and its accessories (mouse, the mouse pad, etc.) was used for controlling the effective factors. There was no unnecessary software on the computer systems. A software written in Borland Delphi programming software was used in this trial. This software includes a part for recording the personal data of the subjects and entering the program, which was filled by the examiner at the beginning of the trial. The main part of the program includes a moving ball and a mouse. The moving ball (in yellow) moves on a specified track on the screen with a blue background. In order to determine the coefficient of reliability of the study tool and resolve the possible problems, a preliminary study was conducted as a pilot, in which the coefficient of reliability of the tool was obtained 0.87 by test-retest method.

The task was to click on the ball and start, follow it by the mouse, and keep the mouse fixed on the target. The total time of passing the track was 10 seconds and 40 hundredths of a second. The track was fixed in all efforts and the ball and mouse were visible to the subject.

Before starting the trial, the subjects were provided with some information on the way of performing the task, purpose of trial, and their duties. Then, they were trained on how to work with the software and subjects practiced it five times. After ensuring the full understanding of the subjects about how to perform the task, the main trial began. 5 seconds after the task finished, for error estimation groups, a white rectangle appeared on the screen, in which the subject should enter his error rate in percentage. Then, for the KR groups, a quantitative KR feedback (error rate of the subject in performance) was displayed on the middle of the screen as a text message. In addition, for KP groups, the track of the ball in green and the track passed by the subject in red were displayed on the screen. Both types of feedback (KP and KR) were displayed for the subjects for 5 seconds. Then, the text was disappeared and the Start Button appeared for the next attempt. Error estimation process and feedback provision were not done for the subjects in the control group. This trial consisted of 2stages ofacquisitionincluding90attemptsin 6 steps of 15. There was a 20 seconds rest after each step. 24 hours later, the retention test was performed which consisted of 15 attempts without feedback.

After collecting the required information (data) from experimental groups, frequency distribution, mean, and standard deviation of the age and the scores of subjects were calculated. In addition, inferential statistics including Kolmogorov-Smirnov test (to determine the normal distribution of data), Mauchly's test of sphericity, Epsilon test, Greenhouse-Geisser test, one-way analysis of variance, Tukey test, and two-way analysis of variance (to determine the difference between the mean values) were used at a significance level of $p \leq 0.05$. All analyses were done in Excel and SPSS 18 software.

Error estimation accuracy as the error detection capability, based on the difference between the actual and subjective scores, was calculated as follows:

ADE = (Subjective score - Actual score)

ADE (Absolute Difference Error) can be considered as the estimation error which has an inverse relationship with error estimation accuracy; the lower the ADE, the more accurate the error estimation. In order to investigate the specific objectives of the retention phase, one-way analysis of variance and 2 (type of feedback) × 2 (estimation error) analysis of variance were used. One-way analysis of variance and 2 × 2 analysis of variance were also used, respectively, to investigate the independent influence of the variables and their influence simultaneously.

RESULT

Figure1showsthe progress of subjects at different stages of trial (acquisition and posttest). As the figure shows, the error decline trend is linear in all studied groups. Fig. 2 shows the performance of different groups in the posttest based on ADE. The results of one-way analysis of variance about comparison of different groups in terms of error detection capability are shown in Table 1.

According to Table 1, there is a significant difference between the studied groups in terms of error detection capability (F=28.248, P=0.001). Coefficient of impact is equal to 0.71 which means that 71% of variations in the dependent variable is associated with error estimation. In order to study the differences between the groups, Tukey test was used (Table 2).

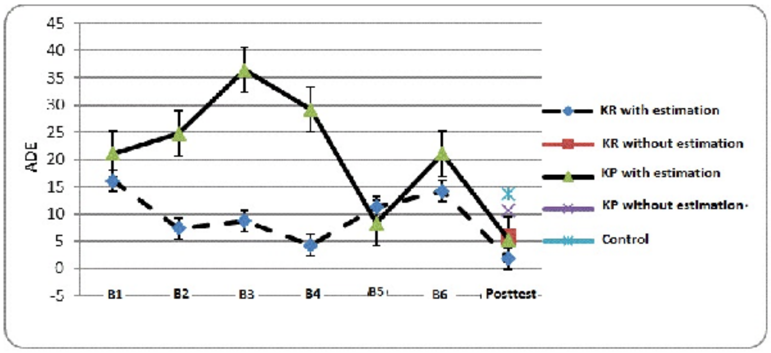

Fig.1. Mean results of ADE (Error estimation accuracy index) in attempt steps and posttest for each group.

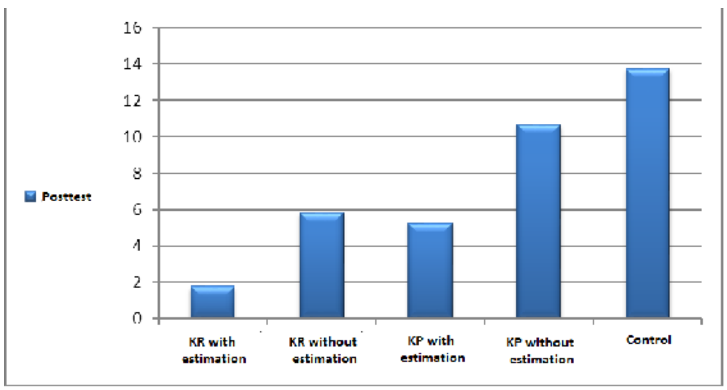

Fig. 2. Mean performance of different groups in the posttest based on ADE.

Table 1: Results of one-way analysis of variance for comparison of different groups in terms of ADE.

Source of variations	Mean squares	Df	F	P	η^2
Within-group Between-group	234.94 7.96	4 45	28.24	*0.001	0.71

P≤0.05

Table 2: Results of Tukey test for comparison of the studied groups based on ADE.

Group (I)	Group (J)	Mean difference (I-J)	Standard error	P
KR -with estimation				
	KR-no estimation	4/06-	1/26	0/019*
	KP -with estimation	-3/48	1/26	0/061
	KP-no estimation	-8/91	1/26	0/001*
	Control	-11/99	1/26	0/001*
KR-no estimation	KP -with estimation	0/58	1/26	0/99
	KP-no estimation	-4/85	1/26	0/003*
	Control	-7/93	1/26	0/000*
KP- with estimation	KP-no estimation	-5/43	1/26	0/001*
	Control	-8/51	1/26	0/000*
KP-no estimation	Control	3/08	1/26	0/12

P≤0.05

According to the results of this test, the KR with estimation shows a significant difference with the KR without estimation (P = 0.019), the KP without estimation, the KR without estimation, and the control (P = 0.000). Also, the KP with estimation exhibits a significant difference with the KP without estimation (P = 0.001) and the control (P = 0.000). The KR without estimation has a significant difference with the KP without estimation (P = 0.001) and the control (P = 0.001). However, no significant difference was observed between the KP without estimation and the control. Mauchly's test of sphericity was used in order to evaluate the homogeneity of covariance. According to the results of this test and the value of Chi-square (X^2 = 78.64), Mauchly's assumption was rejected, so two-way analysis of variance was used for studying the error estimation accuracy index (Table 3). The results of two-way analysis of variance showed that error estimation is effective in ADE (F (1, 36) = 33.45; P = 0.000; η^2 = 0.48). There was also a significant difference between the effects of KP and KR feedbacks on error estimation accuracy (F (1, 36) = 25.77; P = 0.000; η^2 = 0.41). However, the effect of interaction between errors estimation and feedback type was not significant on error estimation accuracy. In other words, the main effects of error estimation and feedback on error estimation accuracy are dependent of each other.

Table 3: Results of two-way analysis of variance for ADE.

Source of variations	**Sum of squares**	**Mean squares**	**Degree of freedom**	**F**	**P**	**η^2**
Error estimation Feedback	225/15 173/47	225/15 173/47	1 1	33/45 25/77	*0/000 *0/000	0/48 0/41
Error estimation*	4/69	4/69	1	0/69	0/40	0/019
Error feedback	242/3	6/73	36			

DISCUSSION

The present paper aimed to study the effect of two types of feedback and error estimation on error detection capability in a continuous tracking task. Hence, a computer pursuit task was used in which the subjects were asked to follow an object with eye and by a mouse. In addition, in order to demonstrate the effect of error estimation, typographical error estimation recording by the subjects themselves was applied. The overall result of this study indicates the effect of error estimation and feedback on error detection capability in tracking tasks. The results of this study are consistent with the findings of Schmidt& White(1972), Hogan &Yanowitz (1978), Swinnen (1990), Shapiro, Schmidt, and Swinnen (1984), Swinnen (1988), Liu & Zhan (1993), Carol (1996), Zobair *et al.* (1999), Guadangoli & Kohl (2001), and Taheri *et al*. (2005), but inconsistent with the findings of Schmidt & Russell (1974). The task they used in their study was a slow linear position with no retention test, while the task of the present study was a pursuit tracking task with a retention test. Appearance of no retention test in the above-mentioned study makes it difficult to compare the results of the present study with the findings of that study. However, the difference between the results of these two studies can be probably due to the different tasks used in each of them and the use of two types of feedback (KP and KR) in the present study.

By comparing the KP and KR groups with the control, it was found that the augmented feedback is effective in the error detection capability. In fact, the major effect of augmented feedback in these groups makes a significant difference between them and the control group. This is theoretically consistent with Adam's theory, according to which no correct perceptual trace can be formed and used without feedback and it is the perceptual trace that gives the error detection capability to a person in the absence of the augmented feedback in the retention test (Schmidt and Timotidi, 2008). In the present study, it was also observed that the subjects of two groups who received feedback had a better performance than the control group. It seems that their better performance is due to the formation of a correct perceptual trace and using it in the absence of augmented feedback, so that they showed a better performance in the retention test. However, the conflict between the present study and Adam's theory is that according to this theory, in correct movements will negatively affect the perceptual trace and the error detection capability (Schmidt and Timotidi, 2008); while, in the present study, it was observed that even the errors made during a performance can be beneficial for learning the error detection capability, which is consistent with Schmidt's schema theory. It seems that moving on a correct perceptual trace does not increase learning, but it is more comparison between inherent feedback and extrinsic feedback that improves learning. Also, schema theory indicates that error detection capability will not be acquired after performing a slow movement, and it can be achieved by a person after quick movements. At the first glance, the findings of the present study are in contradiction with this theory, because pursuit movements are basically classified as slow.

However, it should taken into account that firstly, many pursuit movements are performed quickly and suddenly and secondly, schema theory has a great emphasis on GMP, while pursuit movements have no special GMP and are mostly based on a chase or movement compensation, that is to say, error detection and correcting it. Undoubtedly, providing a person with an augmented feedback could be very helpful in this regard.

The significant effect of error estimation on the error detection capability in the continuous tracking task was another finding of this study. By comparing the groups with error estimation with those with no error estimation and the control, it was found that those with error estimation had a significantly better performance than others. Also, it was statistically demonstrated that the main effect of error estimation and augmented feedback are independent of each other. This is consistent with the findings of Guadangoli & Kohl (2001), Hogan & Yanowitz (1987), Swinnen (1990), Swinnen (1988), and Schmidt & White (1972). This is also consistent with the theoretical foundations, because an athlete would actively get involve in some learning activities such as understanding the inherent feedback of a task and creating a foundation for the error detection capability in the feedback delay (Taheri, 2005, Swinnen *et al.,* 1990).). Meantime, if one do an activity that gets them more involved in these processes, learning would be better and easier. One of these activities is subjective error estimation.

In addition, the groups that both had error estimation and received an augmented feedback showed a significantly better performance than other groups. This is also true theoretically. According to response hypothesis, the extent of a person's involvement before receiving the feedback and the way of using it cannot be independent of each other, because after performing a movement, a person would actively get involved in comparing their performance with the criterion task and detecting their errors in order to use them in the next attempt (Taheri, 2005). Hence, those who subjectively estimate their errors, according to response hypothesis, can have a better comparison and make more appropriate plans of future actions. Hence, providing the KR for the individuals who have to estimate their movement error after performing a movement would lead to further learning (Kohl and Guadagnoli, 2001).

Another finding of the present study was the higher effect of error estimation than feedback on the error detection capability. This result is also consistent with response theory, because error estimation encourages comparison more than feedback and this more comparison activity would be followed by more improved learning. In fact, feedback has the highest effect when it is accompanied by error estimation. In other words, it is the error estimation that gets one more involved in internal activities and efficient use of feedback. This result was also obtained in other studies. For example, in a study conducted by Guadangoli& Kohl (2001), the subjects who had estimated their error in acquisition phase and received a 100% KR showed the best performance compared with other ones and the worst performance was belonged to the group with no error estimation and a 100% KR. This suggests the greater impact of error estimation than the augmented feedback. This result is also consistent with the findings of Taheri *et al.* (2005).

Superiority of KR over KP in the error detection capability in a continuous tracking task in retention phase was another finding of this study. The group KR with estimation performed better than the group KP with estimation and also the group KR without estimation had a better performance than the group KP without estimation. The prevailing view is that quantitative information is preferred over qualitative information in learning. In fact, the type of feedback depends on the stage of learning a person is in. People who are at the beginning of learning pay attention only to qualitative information, even if quantitative information is available to them. The advantage of this is that provides a simpler way for getting closer to the desirable movement. In other words, using such information, a learner can control different degrees of freedom and perform almost close to what is desired. After the learner reached such an approximation, they will need quantitative information to more modify their performance and effectively achieve the objective. According to Gentile's learning steps model, qualitative information can lead a person to recognizing the concept of a movement, but in the next step, they need quantitative information to achieve fixation or diversification goals (Miguel, 2007). Therefore, those who are in retention phase, those who are in the retention phase, as they have understood the concept of a movement by practice, try to fix or diversify their movement. Accordingly, those who receive KR have a better performance than others. Perhaps, one reason for the lower performance KP groups is their inability in interpretation of such information, because KP information was displayed to them on the screen in the kinematic form and a relatively high level of expertise is required for correct and efficient use of such information. More skilled individuals can benefit from more sophisticated kinematic data (Miguel, 2007).

According to the findings of the present study, it is recommended that teachers and instructors encourage and force the learners to subjectively estimate their error in order to improve their error detection capability. For this purpose, in addition to providing an augmented feedback, teachers and instructors can make learners design a hypothesis or, in other words, a subjective estimation of their attempt, so that they get most of the feedback provided to them. In such tasks that their cognitive aspect is more highlighted, it's better to use KR feedback instead of KP one. Additionally, since a 100% absolute frequency of feedback was used in this study, it is recommended that feedback planning and relative frequency of feedback to be also taken into account. Also, the effects of feedbacks and error estimation on learning and performance can be a goof area of research for future studies.

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