Review of Psychology
2000, Vol. 7, No. 1-2, 9-14 UDC 159.9

Decision-making time and precision of different speed movements

INA REIĆ and ILIJA MANENICA

The aim of this study was to examine the effects of movement velocity on various aspects of movement time and precision. The study was carried out on nineteen participants, 18-20 years old. The participant's task was to execute lower arm movements of different amplitudes (20, 40, 60 and 80 degrees) at three different speeds, i.e. paricicipant's suboptimal, optimal and supraoptimal speed on a kinaesthesiometer. The tasks were carried out without visual control.

The whole experiment was repeated under visual control, as well. The aim of this was to obtain the kinaesthetic information processing time (KIPT), which was defined as the difference between the movement time without visual control and movement time under visual control.

The task time, decision-making time (time from the signal onset to the start of movement), as well as the error magnitude (deviation from the target) were recorded for each trial in milliseconds and degrees, respectively.

As could be expected, the analysis of results showed significant effects of the movement velocity and the movement amplitude on total movement time for untrained and trained participants. The decision-making time (DMT) showed no effects of the level of training or amplitudes, while KIPT increased as the amplitude increased. The velocity of movements, however, had significant effects on DMT and KIPT, which increased as the movement velocity decreased. The level of training, as well as the movement velocity significantly affected movement precision. The smallest error was obtained for the optimal speed movements, rather than for slow movements, as it might have been expected.

Many working situations require visual control of working processes, which very often include skilled or unskilled arm (hand) movements. Logically, visual control of unskilled movements is more present in a task execution, than with skilled movements. Smaller need for visual control with skilled movements is due to the fact that during the training the movement control gradually transfers from visual to kinaesthetic control. During the period of training, together with the movement control transfer, some sort of movement execution programme develops, which is stored in long-term memory and retrieved when such a movement is needed. This programme seems to partly include certain aspects of the initial movement control, while the corrective part of movement control is based on kinaesthetic information elicited during the movement execution.

Ina Reić, Department of Psychology, Faculty of Science and Arts, Krešimirova obala 2, 23000 Zadar, Croatia (Correspondence concerning this article should be sent to this address); Ilija Manenica, Department of Psychology, Faculty of Science and Arts, Krešimirova obala 2, 23000 Zadar, Croatia.

Henry & Rogers (1960) showed that, during the period between the signal onset and the beginning of movement, trained participants used previously acquired motor programme for the control of outgoing nerve impulses, which suggested that such a movement was pre-programmed.

Although some studies have indicated the possibility that skilled movements carried out without visual control are pre-programmed (Fitts & Peterson, 1964; Glencross, 1972, 1973, 1976; Keele & Ells, 1971; Manenica & Penezić, 1995; Marteniuk & Roy, 1972), some other studies (e.g. Glencross & Gould, 1979) showed that kinaesthetic information, induced by the movement itself, may affect time and precision of the movement. This would imply that skilled movements are not completely pre-programmed, which means that certain aspects of theirs may be different depending on the velocity and the magnitude of movements. Accordingly, the movements of different amplitudes would not differ only in the execution time, but also in the time needed for central pre-processing, i.e. decision-making time (DMT) and/or time needed for the processing of kinaesthetic information elicited by the movement. DMT refers, therefore, to the time needed for the stimulus (situation) perception and the retrieval of the appropriate programme for the particular movement. The movement execution (time and precision) would also depend on kinaesthetic information elicited by the movement itself. This information also takes some time for processing, most probably by the movement programme itself. Movements of greater amplitudes would elicit more kinaesthetic information, requiring longer processing time, which would change as the movement amplitude changes. Therefore, decision-making time precedes the start of movement execution, while kinaesthetic information processing time (KIPT) is the time needed for processing of kinaesthetic information during the movement execution programme. If the hypothesis which assumes that skilled movements are completely pre-programmed (e.g. Corlett & Megaw, 1969) were true, than the KIPT would not change as the movement amplitude changes, because processing of this information would not be necessary in skilled movements.

Manenica & Penezić (1995) suggested that processing of kinaesthetic information in untrained participants was done outside the movement programme, i.e. "off-line", and then used for the movement control, which results in longer time. In trained participants, however, kinaesthetic information seems to have a direct access into the programme and is processed and used for the movement control "on-line". This also suggests that both, DMT and KIPT would be longer in untrained participants.

Different velocities of movement execution induce salvos of kinaesthetic information of various frequencies within given time, therefore, it could be expected that the velocity might affect movement precision, decision-making and kinaesthetic processing time.

According to Falkenberg & Newell (1980) movement velocity is one of the key parameters which affect decision-making time, while some other authors (Klapp & Erwin, 1976) claimed that increase of the movement velocity causes a linear decrease of DMT. Temprado, Proteau & Rousselle (1994) also showed that faster movements were initiated significantly faster in comparison with slower movements. Such effects of velocity on the DMT were attributed to the movement programming before its execution. This cannot, however, fully explain the relationship between the movement velocity and DMT. Some authors have tried to attribute it to the difference in the number of inhibited motor fibres, where in slower movements the number of such fibres would be greater than in faster movements. This means that lower speed movements require more control during their execution, which may be partly included in the programme, but the control of such movements would rely more on kinaesthetic information.

Some of the quoted studies indicated that kinaesthetic information is one of the mechanisms of movement control, acquired by training, which changes according to the movement velocity. If, however, skilled movements were fully pre-programmed, different movement velocities shouldn't affect the decision-making time, unless the movement velocity is a part of the programme itself.

The aim of this study was to check these hypothesis by assessing the effects of movement velocity and training on movement precision and decision making time, as well as the kinaesthetic information processing time.

METHOD

Nineteen participants, 18-20 years old, were trained in execution of semicircular horizontal movements of different amplitudes (20, 40, 60 and 80 degrees). Movements were executed by lower arm without visual control on a kinaesthesiometer, which consisted of a platform and the base with a semicircular scale marked in degrees from zero to 100. The platform was designed for putting on the lower arm of the subject, which could be rotated on a small wheel, around a pivot, in a semicircular way. All participants were trained in execution of the four amplitude horizontal movements at their own optimal speed without visual control. Four differently coloured lights, indicating four different amplitudes, served as the signals for the start of movement execution. Before start of the movement, the subject was told its velocity by the experimenter.

The light signal, given by the experimenter, indicated the start of the task, as well as the magnitude of the movement that subject had to execute. The signal also initiated two chronometers, which were connected in the circuit with two microswitches. One of the microswitches was activated by the start of the movement, and the other by the subject at the completion of the movement. Upon perceiving the signal, subject started the movement, which stopped one of the two chronometers. When the subject thought that he completed the given movement, he pressed the second microswitch in his right hand, which stopped the other chronometer. The time between the signal and the start of the movement (the first chronometer) was taken as decision-making time, while the time between the signal and the completion of the movement (second chronometer) was taken as the total movement time. Both times were expressed in milliseconds. The movement precision was defined as the deviation of the pointer from the target number at the completion of the movement, and it was expressed in degrees.

After participants were trained in execution of the movements, they were asked to do the same movements at three different speeds, i.e. optimal, suboptimal and supraoptimal speed of paricicipant's own choice. Optimal speed meant subject's own natural speed of movement execution. Suboptimal speed, however, was lower than optimal, while supraoptimal speed was a higher speed than optimal.

In order to obtain the kinaesthetic information processing time, the experiment was repeated, where the participants also executed three different velocities and four different amplitude movements under visual control. By subtracting the total movement time obtained in this way from the total movement time without visual control, kinaesthetic information processing time was obtained.

The experimental situations were rotated between the participants and within the participants according to the Latin square design.

RESULTS AND DISCUSSION

The total movement time changed, as expected, according to the velocity of movements and magnitude of amplitudes, i.e. an increase in the amplitude and decrease in the velocity was followed by an increase in the total movement time in untrained and trained participants. Total movement times were found "en bloc" smaller in trained participants, for all the situations (see Figure 1, Table 1).

The level of training, as could be expected, significantly affected the error magnitude, which decreased in the course of training (see Figure 2). Furthermore, movement velocity also had significant effects on the movement precision, therefore one could expect smaller error for the suboptimal speed movements, where subject had more time for movement execution and its correction. The results showed, however, the best precision in execution of movements at optimal speed. These results could be explained by the fact that participants were trained only in optimal speed movements. It could be assumed, therefore, that this speed became a part of the programme for movement execution, which partly contributed to a higher precision.

Contrary to expectations, the results did not show changes in movement precision for different amplitudes, although in some previous studies smaller errors were associated with smaller movement amplitudes (Manenica, 1988; Manenica & Penezić, 1995). Although the amplitudes in their experiments increased from ventral towards lateral position, the authors have tried to attribute those differences to a higher differential sensitivity of the proprioceptors affected by the ventral movements in comparison with those affected by the lateral movements.

Decision-making time (DMT) in trained participants showed no relationship with the movement amplitudes (Table 1), which means that programmes for learned movements may be retrieved at the same time, regardless of their complexity. These results seem to support the hypothesis of pre-programmed movements, which was also supported by some previous studies (Corlett & Megaw, 1969; Glencross, 1972, 1973, 1976; Keele & Ells, 1971; Manenica & Penezić, 1995).

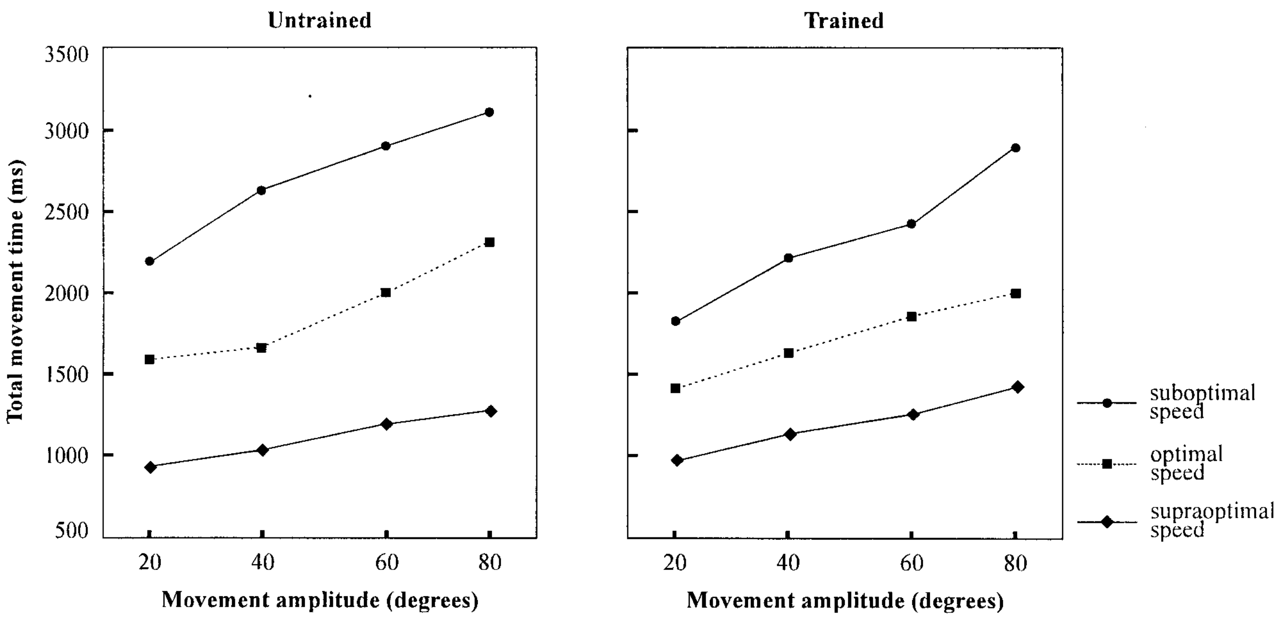

Figure 1. Total movement time for untrained and trained participants

Table 1

MANOVA of the effects of movements on time and precision

Effects	Variable		*df*	*F*	*p*
movement velocity	total movement time	untrained	2	52.76	p< 0.00
		trained	2	98.86	p< 0.00
	kinaesthetic information processing time (KIPT)	trained	2	29.49	p< 0.00
	decision-making time (DMT)	untrained	2	23.75	p< 0.00
		trained	2	51.02	p< 0.00
	error magnitude	untrained	2	3.44	p< 0.05
		trained	2	0.83	p> 0.05
movement amplitude	total movement time	untrained	3	36.37	p< 0.00
		trained	3	103.66	p< 0.00
	kinaesthetic information processing time (KIPT)	trained	3	10.54	p< 0.00
	decision-making time (DMT)	untrained	3	3.9	p< 0.05
		trained	3	2.26	p> 0.05
	error magnitude	untrained	3	1.26	p> 0.05
		trained	3	5.24	p< 0.05

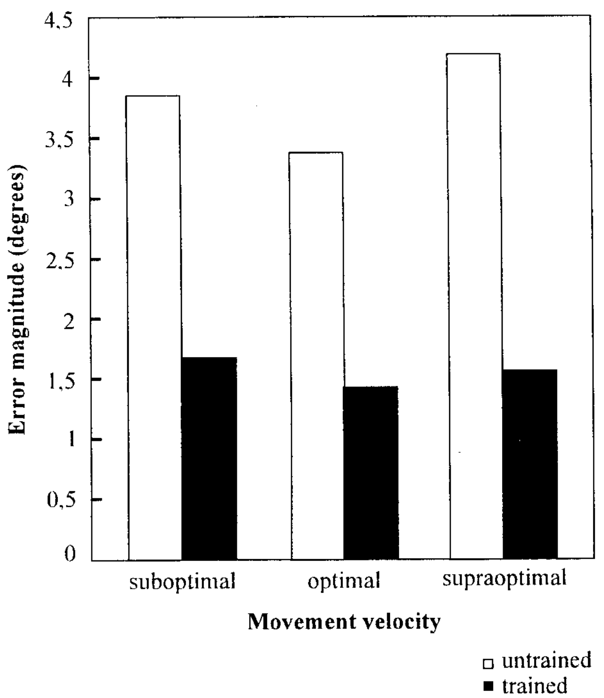

Figure 2. Error magnitude for untrained and trained participants

Kinaesthetic information processing time (KIPT) showed a difference between untrained and trained participants, which confirms the assumption that kinaesthetic information is used and processed differently in untrained and trained participants, as suggested by Manenica and Pezić (1995). It could be argued that kinaesthetic information is processed outside the movement programme in untrained participants, while in trained participants it is sequenced and processed directly by the programme itself, although in both cases it is used as a control mechanism during the movement execution.

While DMT was not affected by the movement amplitude, KIPT increased as the movement amplitude increased at suboptimal and optimal speeds, but it was not affected by the movement amplitudes at supraoptimal speed (Figure 3). This finding throws a shade of doubt on the hypothesis of fully pre-programmed skilled movements.

It seems that kinaesthetic information is used as a separate control mechanism during the movement execution. Although the amount of kinaesthetic information elicited by movements of different velocities should be similar, the lack of the amplitude effects at supraoptimal speed on KIPT could be explained in terms of lacking the processing

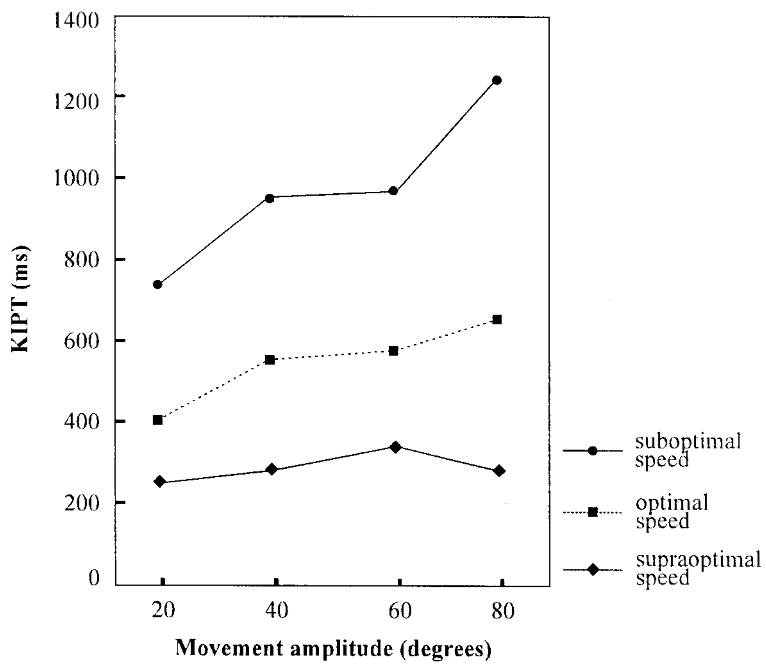

Figure 3. Kinaesthetic information processing time

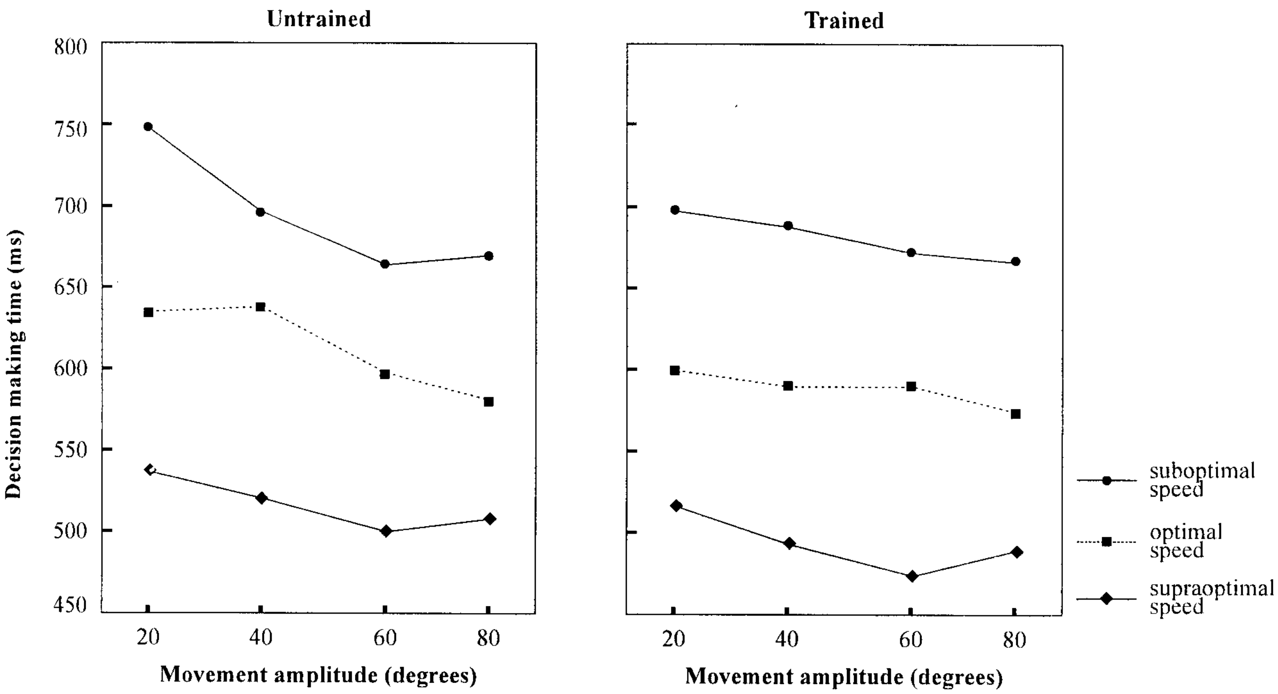

Figure 4. Decision-making time for untrained and trained participants

time for kinaesthetic information. It appears that the higher velocity movement execution control relies more on pre-set movement programmes, while kinaesthetic information is used more in the execution control at lower speeds. This is partly suggested by the curve shapes in Figure 3, as well as by the error magnitude at supraoptimal speed, especially in untrained participants (see Figure 2).

One of the hypotheses in this study was that different movement velocities shouldn't affect DMT, unless the velocity is a part of the movement programme. The results showed, however, that movement velocity had significant effects on DMT, which linearly decreased as movement velocity increased (see Figure 4). This is in accordance with results of Falkenberg and Newell (1980), Klapp and Erwin (1976) and Temprado, Proteau and Rousselle (1994), who also showed that decision-making time decreased as the movement velocity increased.

Results obtained in this study could be explained on the basis of differences in the programmes for the three different movement velocities, where velocity became an integral part of the movement programme, making thus the DMT longer for slow movements and shorter for fast movements. Accordingly, programme for slower movements, as it "runs slower", is also retrieved slower in comparison with programmes for faster movements. It could be said, therefore, that movement velocity represents a temporal aspect of movement execution programme, or that the velocity itself induces a general set of "slowness or fastness", which affects decision-making time.

CONCLUSION

In conclusion, it could be said that the results of this study did not confirm the hypothesis of fully pre-programmed movements. It was shown that the programmes, which are acquired by training, contain spatial and temporal aspects of the movements, i.e. the movement magnitude and execution velocity. Furthermore, the movement execution control seems to be partly pre-set in the acquired programme, and it partly relies on kinaesthetic information elicited by the movement. Although this processing needs time, the movement control at higher velocities relies less on this information, because of lack of processing time. Therefore, the role of this information seems to be more prominent in movement execution control at lower speeds, with more processing time. This also may be reflected on movement precision. In other words, same major spatio-temporal features of movements are pre-programmed, while their execution control, which relies on kinaesthetic information, is not.

REFERENCES

CORLETT, E. N., & MEGAW, E. D. (1969). The role of visual and kinaesthetic feed-back in the control of apparatus by a pedal. *Ergonomics of Machine Design*, Vol. 1. Geneve: ILO .

FALKENBERG, L. E., & NEWELL, K. M. (1980). Relative contribution of movement time, amplitude and velocity to response initiation. *Journal of Experimental Psychology: Human Perception and Performance, 6*, 257-265.

FITTS, P. M., & PETERSON, J. R. (1964). Information capacity of discrete motor responses. *Journal of Experimental Psychology, 67*, 103-112.

GLENCROSS, D. J. (1972). Latency and response complexity. *Journal of Motor Behavior, 4*, 251-256.

GLENCROSS, D. J. (1973). Response complexity and the latency of different movement patterns. *Journal of Motor Behavior, 5*, 95-104.

GLENCROSS, D. J. (1976). The latency of aiming movements. *Journal of Motor Behavior, 8*, 27-34.

GLENCROSS, D. J., & GOULD, J. H. (1979). The planing of precision movements. *Journal of Motor Behaviour, 11* (1), 1-9.

HENRY, F. M., & ROGERS, D. E. (1960). Increased response latency for complicated movements and a "memory drum" theory of neuromotor reaction. *Research Quarterly, 31*, 448-458

KEELE, S. W., & ELLS, J. G. (1972). Memory characteristics of kinaesthetic information. *Journal of Motor Behaviour, 4*, 127-134.

KLAPP, C. T., & ERWIN, C. I. (1976). Relation between programming time and duration of the response being programmed. *Journal of Experimental Psychology, 2*, 591-597.

MANENICA, I. (1988). Proprioceptive interaction with movement programmes. *Revija za psihologiju, 18* (1-2), 1-7.

MANENICA, I., & PENEZIĆ, Z. (1995). Effects of training procedures and target positions on lower arm movements. *Radovi, 34* (11), 67-77.

MARTENIUK, R. G., & ROY, E. A. (1972). The codability of kinaesthetic location and distance information. *Acta Psychologica, 36*, 471-479.

TEMPRADO, J. J., PROTEAU, L., & ROUSSELLE, A. (1994). Combined effects of movement velocity and duration on programming time – Spijkers (1989) revisited. *Journal of Motor Behaviour, 26* (3), 267-272.

Received October 2000
Accepted November 2000