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A new method to learn to start in speed skating: A differencial learning approach

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The aim of this study was to examine whether it is possible to utilize the fluctuations in human motor behaviour to induce a self-organizing process in the athlete, which takes advantage of individual movement and learning characteristics. This recently developed approach is known as differencial learning and is compared to traditional learning. For that purpose, thirty-four recreational skaters participated and practised the speed skating start. A pre- post-test design was used together with a one week intervention period that included three practice sessions of one hour each. The pre- and post-test consisted out of 5 starts, and for each start, the finish time was recorded at a distance of 49 m, which included split time registrations at 5 m, 10 m, and 25 m. Based on the finish time in the pre-test, the participants were equally distributed over three practice groups: a differencial learning, learning by instruction, and control group. Analyses revealed a significant improvement for the differencial learning group in comparison to the control group. It is concluded that differencial learning is an effective method to teach the skating start to novices.

KEY WORDS: Differential learning, Traditional learning.

Introduction

For numerous skills, it has been shown that many repetitions are needed in order to achieve perfection. For instance, the classic Crossman learning

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study (1959) of cigar-making indicated that even after 1 million repetitions of this skill, improvement was still possible, that is, a quicker time could be achieved. The common idea of learning is to repeat a particular movement as much as possible, accompanied with feedback from an expert. The desired outcome is based on an ideal movement pattern.

The Russian neuroscientist Bernstein (1967) noted that consecutive movements never repeat themselves exactly. He made cyclograms of rhythmic movements of an experienced smith who used his hammer on a stationary photographic plate. Bernstein discovered that every movement repetition was slightly different from the next. In other words, even in a relatively simple task such as hammering, the movements produced were never exactly the same (Bernstein, 1967). In sport, most tasks are complex with coaches and athletes repeating the desired movements a number of times in practice in order to improve the performance outcome. Ericsson (2005) described this as follows: "The crucial factor leading to continued improvement and attainment of expert performance is the engagement in special practice activities that allow performers to improve specific aspects of their performance with problem solving and through repetitions with feedback" (Ericsson, 2005, p 237). Underlying this definition is the assumption that there is an ideal way of performing a skill that applies to everybody. Second, any deviation from the required ideal performance is considered as an error (Schöllhorn et al., 2006).

Inspired by Bernstein's hammering example, Schöllhorn investigated whether elite athletes could produce precisely the same movement twice. He studied two elite discus throwers and concluded that during a one-year period, the athletes did not produce the same throw twice (Schöllhorn, 2000), revealing highly individual characteristics of movement (Schöllhorn & Bauer, 1998; Schöllhorn, Nigg, Stefanyshyn, & Liu, 2002). For instance, Schöllhorn and Bauer (1998) were able to identify individual throwing patterns in world class javelin throwers, even across several years of championship experience. Evidence for a larger variability of international throwing patterns in comparison to national throwing techniques led him to question the idea of a person-independent ideal technique. In the study of Schöllhorn et al. (2002), 13 female participants could be identified (and separated) on the basis of biomechanical data during a single ground contact point within a gait cycle, even with differing heel heights of up to 5.4 cm. Most interesting was the fact that the best (100%) recognition rate was achieved in extreme conditions with an 8.1 cm heel height. Therefore, it is not logical to believe in one optimal motor pattern to which all learners should aspire. Based on these findings, Schöllhorn (1999) suggested a learning theory that opposes the repetition of movement based on an ideal movement pattern: differencial learning. Differencial learning utilizes the fluctuations in human motor behaviour to induce a self organising process to the learner that takes advantage of individual movement and learning characteristics. Therefore, during the acquisition phase, the learner is confronted with a variety of exercises that extend the whole range of possible solutions for a specific task. In other words, an athlete should practice a particular skill in many different ways, and as a result, s/he will discover an individually specific optimal way for her/him to perform the particular skill. Because differencial learning is also associated with no repetition of an exercise, it is also claimed that a more adequate adaptation to constantly changing conditions will be achieved. One theoretical explanation for why differencial learning would work is based on the dynamical systems theory. In this theory, fluctuations are considered as necessary for functional adaptation to changing environmental contexts and, the prevention of loss of system complexity as constraints change (Schöner & Kelso, 1988). Fluctuations can also be considered as noise in a system. Counter intuitively, this noise can enhance performance due to a phenomenon called stochastic resonance. In this phenomenon, the addition of noise can make a weak signal detectable (Moss et al., 2004). Through the addition of noise, in this case movement fluctuations during the learning process of a movement, one can detect the ideal movement or solution better, by adapting faster to the new situations in a more adequate way. Stochastic resonance has two important qualities: the signal cannot enhance itself, and secondly, the signal cannot spontaneously arise from the noise. Furthermore, there is an ideal level of added noise to the signal. Too much, or too little noise results in a weaker enhancement of the signal. In humans, it has been shown that interactions between noise and signal can improve sensori-motor integration and stochastic resonance effects. This has been reported in human studies of memory retrieval, perception, neuronal activity, and the peripheral nervous system (Cordo et al., 1996; Collins, Imhoff & Grigg, 1996; Nozaki et al., 1999; Wenning & Obermayer, 2003). By adding noise to a certain target movement, it can be assumed that a broader area of a potential space of solutions will be covered. Due to the assumption that no movement will be repeated twice (Bernstein 1967), it can be followed that in future situations, the probability to provide a known area of solutions for the athlete is higher which will result in faster and more adequate reactions in these new situations. The constructive influence of noise was also found in robot research by Miglino, Lund, and Nolfi (1995). When a robot is moving in a noisy (changing) environment during its training phase, the robot will work harder in the application phase (post training), as well as in totally different environments. However, a robot that has been trained in a constant environment will subsequently fail in an altered environment. Artificial neural nets that are derived from biological neurons act in a similar way (Hertz, Krogh & Palmer, 1987).

In the current study, differencial learning was compared to traditional learning in the acquisition of a new task: the speed skating start. The official rule of the speed skating start is as follows: one has to stand still, and every variation in posture is allowed. The variation in posture provides opportunities for the application of differencial learning. Second, speed skating research carried out by De Koning et al. (1992) indicated that the acceleration in the first second of a speed skating race correlates highly (r = -0.75) with the eventual 500 m time. For this reason, it seems obvious and beneficial to improve the start in order to achieve a fast final time.

In the current study, the effectiveness of the differencial learning method is compared with the traditional learning method (learning by instruction), which are both applied to the skating start. The start was measured in time over 5, 10, 25 and 49 meters (m). It was hypothesized that the 5 m and 49 m times would correlate significantly, as predicted by the findings of De Koning et al. (1992). It was expected that the differencial group would show more progress than the traditional and control groups.

Methods

Participants

In this experiment, 34 adult (28-60 years, mean 44.2 ± 9.8) recreational male skaters, all of whom skated the 100 m no faster than 13 seconds (s), participated. All participants signed a written inform consent form before the start of the study. The institutional ethical committee approved the study.

Apparatus

The recording of performance took place on a 400 m ice rink. A track of 49 m long and 2 m wide was created on one of the straight sections of the ice rink. Five photoelectric reflex switches (Omron E3s-R1E4 & Sick WL 18-2P430) were placed on this ice track; one at the start line, and one each at the 5 m, 10 m, 25 m, and 49 m distances (Figure 1). The photoelectric reflex switches were attached to a SCXI1100 32 channel differential multiplex from National Instruments. From the SCXI1100, the signal went to a module (National Instruments) that was connected to a laptop. The data acquisition took place in LabVIEW.

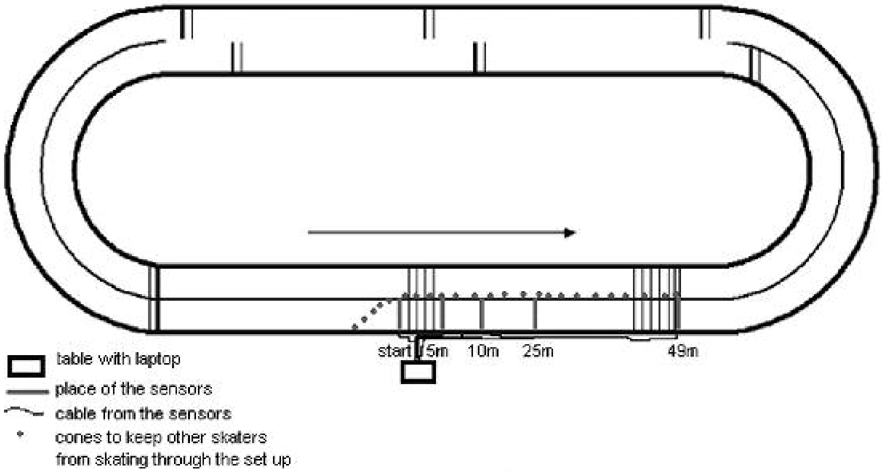

Fig. 1. - Bird eye view of the skate track. See text for further explanation.

PROCEDURE

The task was to skate the 49 m as fast as possible, from a stand still position (the start). A pre- post-test design was used, with an intervention of three training sessions, each being one hour in length. Four days before the pre-test, all participants took part in an introductory lesson which lasted one hour on the ice track. This was done in order to explain the procedure, as well as familiarise them with the required 'motion' of the start, that is, to stand still. No explicit rules were given about the transition from the point of standing still to the point of starting to skate.

In the pre-test, participants were instructed to skate the 49 m trial a total of 5 times within a one hour period, as fast as they could from a standing start. The time was recorded at 5 m, 10 m, 25 m, and 49 m. After the 49 m trial, the participants completed a 400 m lap, at a slow pace, in order to prevent them from standing still in the cold and to minimize the chance of an injury.

Based on the pre-test results, participants were randomly divided into one of three groups: the differencial learning, the traditional learning, and the control group. All groups received the intervention of three sessions of practice in one week, each being one hour in length. Prior to each lesson, they participated in a 15 minute general warm-up session which was carried out next to the ice track. The lessons on the ice track consisted of a 10 minute specific warm up, followed by 50 minutes of practice.

The differencial learning group began every start in a different posture. In appendix 1, the different postural positions are presented for each start and practice session. The participants did not receive any feedback about their performance. After the start, participants completed a 400 m lap at a slow pace, which resulted in 14 practice trials per session.

Because of its similarities to some traditional learning approaches, that is, variability of practice (Schmidt, 1975) and contextual interference approach (Magill & Hall, 1990), it is worth noting that the changes of posture during the start can be associated with massive variations of the invariants 'relative forces' and 'relative timing' during the acceleration phase, which should have been kept constant in accordance with the variability of practice approach. The variability of practice approach recommends (at least for simple laboratory tasks) keeping the invariants constant while varying the variable parameters (Schmidt, 1975). According to the contextual interference approach (Magill & Hall, 1990), blocked, serial, and random order practice are distinguished. In the majority of the reported experiments, the order of practice is related to a discrete number of at least two or three different tasks that vary in their invariants or, in their variable parameters (Wulf & Shea, 2002). However, in differencial learning, the random application of increased fluctuations (stochastic perturbations) is not only related to the order, but also to practice content. Here the variations were provided to induce some level of noise to help learners *to explore* different movement solutions.

The traditional group (learning by instruction) was taught to assume the postural start position that is described as the most ideal in the handbook of skating (Gemser & van Ingen Schenau, 1987). In appendix 2, the instructions given to the participants are presented with this group receiving feedback on their starting posture. The control group skated a total of three times in one week and participated in regular practise sessions. This group, however , did not practise the start. The post-test consisted of five trials, three days after the final practice session.

Dependent variables and statistical analysis

As dependent variables total skating time was split up into a finish time, as well as split times. The finish time was defined as the total time recorded between the start and the distance of 49 m. The split times were defined as the time recorded between the start and the 5, 10, and 25 m distances. The progress time was defined as the time difference between pre- and post-test for each distance separately (i.e. 4 progress times).

The correlations between the 5 m and the 49 m times were calculated and compared with the reported findings of De Koning et al. (1992). For skating time, a 3(group: differencial vs. traditional vs. control) by 4(distance: 5 m vs. 10 m vs. 25 m vs. 49 m) by 2(test: pre vs. post) ANOVA with repeated measures on the last two factors was carried out. A 3(group: differencial vs. traditional vs. control) by 4(distance: 5 m vs. 10 m vs. 25 m vs. 49 m) ANOVA with repeated measures on the last factor was carried out for progress time.

Results

From the 34 participants, 27 were included in the analysis. From the seven dropouts, five were ill or injured during the post-test. One of the dropouts admitted that he practiced a total of 16 times per week while being part of the control group. The final dropout was considered an outlier as he improved more than 2 x SD in comparison to the rest of the group.

The findings are reported in Table I and II The correlation between the 5 m and 49 m times are high, as well as significant for all three of the groups

TABLE I
The Correlations Between The 5m And 49m Time For Pre- And Post Test

Group	Correlation pre-test 5m-49m	Correlation post-test 5m-49m
Differencial	0.848 (p<0.01)	0.968 (p<0.01)
Traditional	0.808 (p<0.01)	0.897 (p<0.01)
Control	0.886 (p<0.01)	0.963 (p<0.01)

TABLE II
The Skate Times For Pre- And Post-Test And Function Of Distance And Practice group. All means And Standard Deviations Are In Seconds. (,^ And + Indicate That These Values Are Significant From Each Other).*

Distance	Group	Pre-test		Post-test	
		Mean	Sd	Mean	Sd
5 m	Differencial	1.74	0.16	1.65	0.17
	Traditional	1.74	0.18	1.67	0.19
	Control	1.76	0.19	1.66	0.19
10 m	Differencial	2.73	0.27	2.61	0.26
	Traditional	2.76	0.26	2.69	0.31
	Control	2.77	0.30	2.67	0.28
25 m	Differencial	5.11	0.45	4.92	0.48
	Traditional	5.15	0.48	5.00	0.53
	Control	5.20	0.40	5.01	0.43
49 m	Differencial	8.25 *	0.63	7.93 * ^	0.68
	Traditional	8.35 +	0.77	8.10 +	0.86
	Control	8.32	0.44	8.20 ^	0.57

for both tests, which is in agreement with the findings reported by De Koning et al. (1992).

In Table II, the results of the pre- and post-test per group are presented for the skating times. The ANOVA revealed main effects for distance ($F(3, 24)= 38.81$, $p<0.01$), and for test ($F(1, 24)= 20.22$, $p<0.01$). Significant interactions were found for distance by test ($F(3, 72)= 14.87$, $p<0.01$) as well as group by distance by test ($F(6, 144)= 2.612$, $p=0.024$). Within group subjects contrast shows that the last interaction is caused by differences between the groups for 25 m and 49 m distance. In Table 2, it can be seen that up until 25 m, minimal differences between the three groups existed. However, at 49 m, the differencial group had a significantly faster skating time at the post-test in comparison to both other groups.

In Table III, the findings per group for progress time are presented with the ANOVA revealing a significant interaction for distance by group ($F(6, 144)= 2.612$, $p=0.024$). The contrast analyses showed that the distance by group effect was caused by a difference between the groups between 25 m and 49 m. The control group did not progress over the final part of the track,

TABLE IIII
The Progress Time As A Function Of Distance And Practice Group. All Means And Standard Deviations Are In Seconds. (And ^ Indicates That These Values Are Significant From Each Other).*

Distance	**Group**	**Progress time**	
		Mean	**Sd**
5 m	Differencial	0.09	0.09
	Traditional	0.07	0.14
	Control	0.10	0.15
10 m	Differencial	0.12	0.13
	Traditional	0.07	0.16
	Control	0.09	0.18
25 m	Differencial	0.19	0.21
	Traditional	0.15	0.21
	Control	0.20	0.20
49 m	Differencial	0.32 *	0.24
	Traditional	0.24 ^	0.26
	Control	0.12 * ^	0.18

in contrast to the differencial learning and traditional learning groups, who both improved over the final part of the track.

Discussion

The aim of the experiment was to compare two learning methods: the effectiveness of the differencial learning in comparison with learning by instruction (traditional group). For that purpose, we examined the ice skating start for two reasons: First, the start in the 500 m ice skating is not defined, except for the fact that one has to stand still, which leaves room for testing a number of types of variations in posture. Second, de Koning et al. (1992) showed that the acceleration in the first second of skating correlated highly with the final skating time at 500 m. Therefore, it was assumed that improving the start time would be beneficial to the skater. Our findings are in agreement with the results of de Koning et al. (2002) since a high correlation ($r > 0.8$) was found between the first 1-2 seconds, and the final time of the race over 49 meters.

With respect to differencial learning, the interaction effect group by test by distance revealed that significant differences between the differencial learning, traditional learning, and control group arose between 25 m and 49 m. The effect is caused by the difference between the two learning groups and the control group. The first 10m was skated at a similar, fast speed by all participants of the three groups. The video recordings of the start showed that the control group could make the transition from standing still, to a sort of running-like technique, in an identical manner to both experimental groups. As a consequence of the control participants being able to apply this transition technique, the differences were very small in the initial 10 m. However, for the first few strokes of a speed skating start, a running-like technique is useful, but after these first few strokes, a gliding technique is more effective (De Koning, Thomas, Berger, de Groot, & van Ingen Schenau, 1995). De Koning and co-workers (1995) concluded from their research with elite level skaters that the transition between these two techniques has to take place at 4 m/s for men, and 3.7 m/s for women. After this point, the maximal push off velocity is lower than the skating velocity and therefore, a gliding technique has to be used to achieve a higher maximal velocity. In other words, the maximal velocity that can be reached with a running-like technique is lower than the maximal velocity reached with the gliding technique. In the current experiment, the differencial group was trained to start from all kinds of positions, which forced them to find optimal acceleration from a much larger variety of body positions. This helped them to adapt to the practice circumstances and, as a consequence, they probably made this transition more easily. In contrast, the control group did not receive specific start training and did not make this transition. This observation would explain why the control participants were slower over the final part of the track in comparison to the other groups. At these speeds, the running-like technique is less energy efficient which may cause the phosphocreatine supply to run out at a faster rate (Wilmore & Costill, 1994), making it difficult to keep up the speed with this technique. This suggestion could explain the poor performance of the control group between 25 and 49 m.

There were no significant differences between the traditional and differencial groups, a quite remarkable finding since the differencial group did not receive any *specific* feedback or exercises. In fact, they were asked to obtain starting postures that, according to traditional methods, were completely incorrect. In contrast, the traditional group was given instructions on the proper technique and received feedback on performance. One would expect that this group would show the most improvement in performance, which was not the case (Table 3). In fact, the differencial learning group showed the most improvement in performance, which was quite impressive considering the small amount of practice undertaken: about 14-16 starts per session and thus, between 55-60 starts in total. This observation is in line with previous reported findings where traditional learning is compared with differencial learning. For instance for tasks such as shot put (Beckmann & Schöllhorn, 2003), hurdle sprint training, and soccer (Schöllhorn et al., 2006) a significant advantage is reported for the differencial learning in comparison to traditional learning group.

How can we explain these findings? As Bernstein (1967) has already pointed out, two consecutive movements never repeat themselves exactly. Differencial learning seems to exploit this capacity and utilizes the fluctuations in human motor behaviour to induce a self-organising process in the learner that takes advantage of individual movement and learning characteristics. As a consequence, the learner is confronted with a variety of exercises in the acquisition phase and, will find out what is the most optimal way for her/him to perform the particular skill through exploration. This way of learning has a huge effect on the performance of skating, which is to skate faster.

A model for the explanation of this phenomenon is provided by artificial neural nets (ANN) (Haykin, 1994); Horak, 1992) and robot like machines (Miglino et al., 1995). When a robot or ANN is trained in a fixed environment, it will have very limited areas of application in the subsequent test phase. When the robot or ANN is confronted with a continuously changing environment, it will be able to move in most environments, with which it is confronted during the subsequent testing phase. Similarly, once an ANN is trained in a narrow area, it will only reveal satisfying results when the stimuli that are offered in the test phase are very similar to the previously presented ones. This characteristic is assigned to the ability of interpolation, which the ANN are relatively successful at. ANN's are much less successful in extrapolating towards an area that is outside the trained area. By training an ANN or robot, a lattice-like structure of neurons is formed (Bishop, 1995). The training of the ANNs by repetition of very similar data will lead to a very fine-grained mesh size only in a certain area of the net. This outcome is associated with an oversampling in the specific area, and an under-sampling just outside this area. Only if the mesh size, as well as the area is optimal, will the net be able to succeed in the subsequent test and application phase. The latter phase usually implies a test with data that have not been given to the net during the training phase (Schöllhorn, 2004). By giving the skaters the possibility to start from different starting positions, they were trained in a much bigger area, which allows them to interpolate in a broader spectrum.

In conclusion, the findings suggest that differencial learning is an effective method to learn the skating start as a novice. Future research should investigate whether the same holds true for experts and, whether a longer training period results in a greater distinction in performance between the two groups. In addition, from a perception-action coupling perspective (e.g. Caljouw, van der Kamp & Savelsbergh, 2004; Van der Kamp, Bennett, Savelsbergh & Davids, 1999), it would be very interesting to examine which type of information the differencial learners couple their movement behaviour to (Savelsbergh & Van der Kamp, 2000).

Appendix 1

STARTING POSITIONS FOR THE DIFFERENCIAL LEARNING GROUP.

Lesson 1:
The skates parallel to the left with hips to the front.
Three point start.
With two hands on the ice with the skates in a V-shape.
The skates parallel to the right with hands and arms moved backwards.
The skates leaning on the outside with the right arm in front.
The arms beside the body and make a jump before the start.
The skates in a V-shape with the arms in front.
The left skate in front and look downwards.
All the weight on the hind leg with the hips to the back.
The hips to the back with one step to the right before the start.
Make a 180° turn before the start.

Lesson 2:
Approach skating on the left leg.
Straight knees with the skates leaning on the inside.
The hips to the front and back straight up.
Weight on the front leg and look to the end of the track.
Step to the left before the start.
The right leg in front with right arm in front.
Skates parallel to the track with upper body horizontal.
The right hand on the ice.
Make very small steps.
Put your skates as perpendicular to the track as possible while performing running action.
Make an initial large step.
Regarding arm movement, only make use of the forearms.
Do not move the arms.
First step parallel to the track.

Lesson 3:
Knees bent and weight in the centre.
Take big steps.
Left foot in front with right arm behind.
Make wide steps.
Make narrow steps.
Take the first step very small.
Skates parallel to the left with hips to the front.
The left hand on the ice with right foot behind.
The right foot and left arm in front.
The skates parallel to the right with knees bent deep.
Both arms in the air.
Tap one skate with the other before the start.
Perform a pirouette before the start.
Touch a skate with one hand before the start.
Feet close together.

Appendix 2

STARTING POSITION FOR THE TRADITIONAL LEARNING GROUP.
(Deduced from 'Het handboek wedstrijdschaatsen (Handbook Ice skating), by H. Gemser and G.J. van Ingen Schenau')

Hind skate at a 60° angle to the track.
Bend knees.
Weight in the middle.
The hips to the front.
Make little movements with the arms.
Make small steps in the beginning.

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