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Persistent coordination patterns in a complex task after 10 years delay.

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Abstract

The aim of this experiment was to examine the qualitative behavioral reorganizations of a complex skill acquisition on a ski-simulator that occur after a long term delay. 10 years before, five subjects practiced for 39 sessions of ten 1-min trials on a modified version of the ski-simulator. In the present study, a retention test (10 years after) was conducted for 1 session of ten 1-min trials, with the same subjects in the same conditions. Analyses focused on the motion of the apparatus platform modeled as a self-sustained oscillator. At the beginning of the experiment, all subjects adopted a behavior that could be modeled with a moderate non-linear stiffness function, a van der Pol damping function, a frequency and amplitude values under the previous experiment. In the final part of the experiment we observed: a linear stiffness function, a van der Pol damping behaviour and frequency and amplitude values near but always under the previous study. The results indicate that the acquisition of expert pattern behaviour persists well over a long delay.

1. Introduction

Since the resumption of Bernstein's works [1], it's widely accepted that motor learning is a discontinuous, non-linear process, marked by deep qualitative behavioural reorganizations [2]-[3]. Moreover, motor learning is characterized by persistent change in behaviour over time [4]. Here, change and persistence are not opposite, but really complementary to analyse learning; change in performance exhibits both persistent and transitory properties which are the basis to determinate and understand laws of learning [4].

The persistent changes that characterize learning are relatively slow, occur over a single practice session, after several days, months or years [2] and improve performance within and even between practice sessions [5].

The dynamical system theory emphasizes the notion of qualitative reorganization in learning between the initial behaviour of the beginner (first stage), and the behaviour exhibited at the end of learning (skilled or expert behaviour's second stage). The first stage is characterized by first preferred coordination mode that is persistent and stable [6]-[7]. Practice is a major parameter to observe change in behaviour. Expert coordinations are characterized by efficiency and a maximal exploitation of the passive forces of the system [1]-[8]-[9]. A number of studies provided evidence for qualitative differences between novice and expert coordination modes in gross motor skill and each of them reveals much of behaviour stability [6].

In the Newell's new model [5] that examines learning and adaptation by time scales derived from a decomposition of the performance dynamics, it has been identified in motor learning two types of change: transient and persistent changes. This brings a new point of view on learning process and retention over time

The transient and persistent changes arise from stability and instability resulting from change and evolution of attractor landscape. The persistent change characterizes learning: it is relatively slow and occurs with practice. The transient change has been identified toward 3 types of rapid change: i- warm up decrement that occurs in the course of initial trials of practice session; ii- the drifting away from previous performance due to fatigue and decrement in attention; iii- trial to trial fluctuations have generally been interpreted as noise. When it plans to understand the learning process and these different fluctuations and stabilities it is essential to consider all the time scales [4]. However, such variables can be well studied across a long time of observation. Longitudinal studies are relevant to reveal both qualitative and quantitative changes in behaviour but few studies in learning and performance of motor skill assess the time evolution or the dynamic property of the change [4].

A longitudinal study [11] was conducted to examine the qualitative behavioral reorganizations that occur during the acquisition of a complex motor skill on ski simulator. Analyses focused on the motion of the apparatus platform, modelled as a self-sustained oscillator by the W-method proposed by Beek and Beek (1988). The aim was to provide macroscopic models that contain a small number of parameters and that capture the essential features of rhythmic movements. The rhythmic movements were modeled as oscillators obeying second-order ordinary differential equations of the kind: $m\ddot{x} + g(x) + f(x,\dot{x})\dot{x} = 0$ where x represents position. The dot notation indicates differentiation with respect to time. The first term expresses the inertia of the system, the second the system's stiffness (elastic properties of the system) and the third, the system's damping (injection and dissipation of energy). Two stages were evidenced during practice (390 trials of 1-min trials). On the one hand, it was observed an initial stage characterized by a highly non-linear stiffness function and a Rayleigh damping function which provide a prolonged dwelling time when subjects approach the reversal points of the movement. These behaviours contributed also to well control the reversal points. On the other hand, it was observed a final stage characterized by the linearization of stiffness and a van der Pol damping function. The decrease of non-linear stiffness reveals a better storing energy in the rubber belts and a van der Pol damping allows subjects to adopt high frequencies and large amplitudes that characterize skilled performance (expert behaviour in ski-simulator) [7].

The aim of the experiment reported in the present paper was to verify if the expert pattern of coordination persists after a long delay. It's expected that retention of motor skills over long delays is good [12]-[13]. Subjects typically show a reduction in performance of just 20 % and recover rapidly their previous skill after a few practice trials [13]-[14]. In our knowledge, the longest delays go to 1 year to 5 years in essentially perceptivo–motor tasks as pursuit rotor, button-pushing tasks, or memory tasks [13]-[15]-[14]. Few recent studies deal with retention in gross motor skill (tossing, walking, postural stability task) but their interest is centred on pathological point of view [16] or re-acquisition after disturb task [17]. In the present study, we have chosen to analyse a complex motor skill on ski-simulator. This apparatus allows subjects to perform slalom-like cyclical movements, and was early used in many experiments, mainly devoted to the analysis of the evolution of motor coordination and performance with practice (e.g. [18]-[9]). A recent study [19] has tested the retention in these cyclical movements under different conditions (with or without dangerous conditions). The participants were the same (less one) as the ones of the longitudinal study of skill acquisition [11] after 5 months rest. The results show that the coordination mode adopted during the previous study was highly stable and persistent overtime. The participants were able to reach the amplitudes as during the last trial (5 months before) and adopted the same van der Pol damping behaviour under control condition (without stress). So, what happens 10 years later?

2. Method

2.1 Participants

Four males and one female (mean age: 39.2 years ± 6.3, mean weight: 73.2 kg ± 8.46; 71.6kg ± 4.5 in the previous experiment; mean height 179.6 cm ± 3.5) volunteered to take part again in this experiment (the same subjects as in Nourrit et *al.'s* experiment [11]. None had training on the ski-simulator during 10 years.

2.2 Experimental device

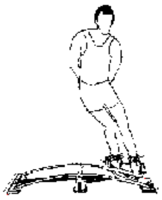


Fig 1

The task was executed on a slalom ski-simulator (Skier's Edge Co., Park City, UT) which consisted of a platform on wheels which moved back and forth on two bowed, parallel metal rails (Figure 1). We used a version modified in mono-ski as well as in the former experiment [11] that presented more difficulties to oscillate.

2.3 Procedure

All subjects were submitted to identical instructions and procedures given in the previous longitudinal study [11]. They were told to make their movements "as ample and frequent as possible". They performed a complete session of ten 1-min trials. In the previous longitudinal experiment, each session consisted of ten 1-min trials, with a 1-min break between trials. Each participant practiced for 3 sessions per week, during 13 weeks, for a total of 39 sessions or 390 trials

2.4 Data collection

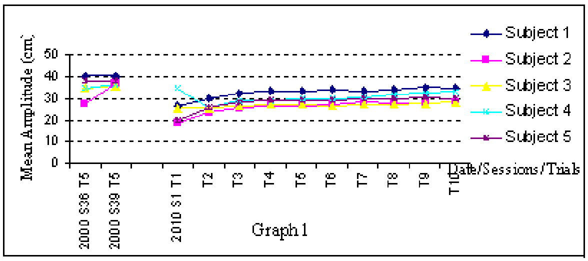
Participants were equipped with passive markers, whose positions were recorded in three dimensions by a VICON motion analyzer (Biometrics) with seven cameras. The acquisition data was collected over 30 seconds, namely from 15th to the 45th second of each trial.

The position time series were filtered with Butterworth filter (dual-pass), at a cut off frequency of 10 Hz. Cycle frequency (in Hertz) was defined as the inverse of the time between two successive right reversals. Cycle amplitude (in centimetres) was defined as the mean of the maximal deviations of the platform from the rest position, at the right and left reversal points of the cycle. The dynamical modelling of platform's motion was performed according to the following procedure (for further details, see [20]-[21]-[11]). In a first step, each sample was summarized in an *average normalized cycle*. The first and second derivatives were computed from the averaged normalized cycle, and then rescaled to the interval [-1; 1]. We used the graphical methods proposed by Beek and Beek (1988) for determining the terms to include in the model. Then the coefficients (c*ij*) were determined by using a stepwise multiple regression procedure of all relevant terms:

$$(x, c_{10}\dot{x}, c_{30}x^3, c_{50}x^5, c_{01}\dot{x}, c_{03}x^3, c_{21}x^2\dot{x}) \text{ onto } \ddot{x}$$

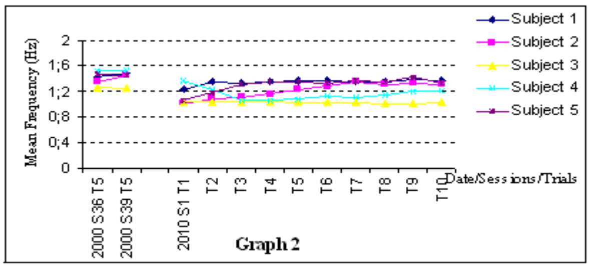
3. Results and Discussion

3.1 Amplitude and Frequency



Graph 1: Amplitude of platform motion for all subjects, with 10 years delay (2 last sessions of longitudinal study and 10 trials of retention test 10 years later).

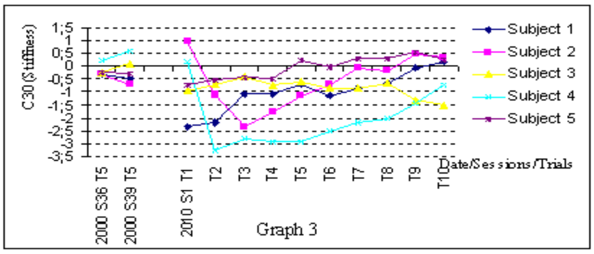
All participants reached a mean amplitude of about 30 cm (SD=2.4) (graph 1) with a decrease of 17.66% (in comparison with the last trial of each experiment). The individual evolution of the amplitude of platform motion was quite regular for 3 subjects (subject 1; 2; 3) with an increase of 19%; 27%; 29% respectively, between first and third trial, excepted the subject 4 who exhibited an amplitude near the previous value in first trial and decreased in second trial to a regular increase later. One of them (subject 3) exhibited steady amplitude value.



Graph 2: Frequency of platform motion for all subjects, with 10 years delay (2 last sessions of longitudinal study and 10 trials of retention test 10 years later)

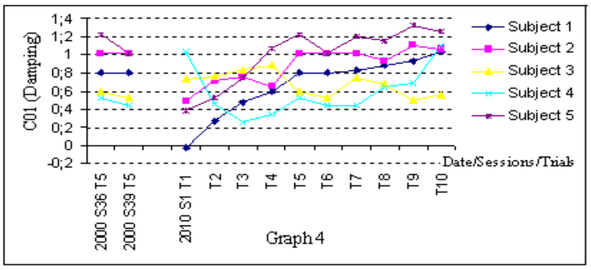
Frequency was around 1.25 Hz (SD=0,14) with a decrease of 12.6% (in compared to the last trial of each experiment). The individual frequency of platform motion revealed 2 stages for 5 subjects (subject 1; 2; 3; 4; 5): an increase during first and third trial (a trend inverted for subject 4), followed by a steady state in 3 last trials. One of them (subject 3) exhibited steady frequency value.

3.2 Stiffness and Damping



Graph 3: Stiffness coefficient c30 for all subjects, with 10 years delay (2 last sessions of longitudinal study and 10 trials of retention test 10 years later).

As can be seen, c_{30} (the stiffness) presented low negative values and reached values near zero (excepted subject 3) which corresponds to a linearization of the stiffness function. One could note that the c_{30} coefficients were around zero (in absolute values) for subject 5. Finally, we observed some anomalous values (positive or near zero) during the first part of the experiment for subject 2 and 4.



Graph 4: Damping coefficient C01 (Rayleigh damping) for all subjects, with 10 years delay (2 last sessions of longitudinal study and 10 trials of retention test, 10 years later). C01(Rayleigh) is the linear damping coefficient obtained with this forcing procedure. C01(Rayleigh) is negative when the limit cycle is sustained by a Rayleigh behavior, and positive for a van der Pol behavior.

Concerning damping function, as soon as the first trial, all subjects adopted a van der Pol behavior (positive value of $c_{01(\text{Rayleigh})}$) and reached absolute value near 1 which indicates a stability of van der Pol behaviour (excepted subject 3). Only subject 4 began the experiment with high value and decreased until third trial.

4. Discussion and Conclusion

The main aim of this experiment was to study the persistence of qualitative behavioral reorganizations after a long time delay. We observed two major results.

On the one hand, the values of amplitude and frequency (performance variables) lower than those of the longitudinal experiment, confirms that subjects show a reduction in performance around 15 % in the first trials on the retention test [12]. Nevertheless, after a few practice trials (10 trials), none of them reached the previous value like stipulated in the literature [12]-[13]-[14]. It could be explained by the nature of the task. Oscillating on a mono-ski-simulator is a global task, involving whole body motion and requiring more control of degrees of freedom than tasks classically used in retention experiments (perceptivo–motor tasks as pursuit rotor, button-pushing tasks, or memory tasks). Moreover the ski-simulator is a body-building and re-adaptation apparatus, which solicit muscular and cardio-vascular skills [22]. After a long time rest, it could be expected a decrease of these skills. Finally, the weight gain could be another explanation. Even if we observed an increase of 1.6 kg only, the standard deviation was 8.46. Only one subject had lost weight and all others put on weight. This weight gain could require additional effort to rapidly stretch the rubber belts of ski-simulator, and so generate a lower frequency [9].

On the other hand, the exploitation of the previous damping behavior, the van der Pol damping, appeared quite durable during the time. This behavior is the signature of expert coordination mode [11], and was unchanged during 10 years. It confirms the persistence of qualitative reorganizations after learning. The persistent change arises from stability of attractor landscape [4]-[5]: the adopted coordination mode is highly stable [11]-[6] and it was confirmed by the linearization of the stiffness. One allows us to validate the hypothesis (or the old saying): “Once one learns to ride a bicycle, one never forgets that skill”.

Even if performance, generally measured by amplitude and frequency variables in motor learning experiment, was quite altered after a long time without practice, skilled motor coordination remained unchanged. A fine understanding of motor learning evolution requires a relevant choice of variable (collectives and performance variables) and a consideration of time scales [5].

5. References

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