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Persistent coordination patterns in a complex task after 10 years delay Subtitle: How validate the old saying "Once you have learned how to ride a bicycle, you never forget!"

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ABSTRACT

Motor learning studies have for a long time focused on performance variables (in terms of speed or accuracy) in assessing learning, transfer and retention of motor skills. We argue, however, that learning essentially resides in changes in coordination variables (in terms of qualitative organization of behavior) and that relevant tests for assessing the effectiveness of learning and retention should consider these variables. The aim of this experiment was to test the retention of a complex motor skill, after a long-term delay. Ten years ago, five participants were involved in an experiment during which they practiced for 39 sessions of ten 1-min trials on a ski-simulator. All participants volunteered for a retention test, ten years after, for one session of ten 1-min trials. Analyses focused on the oscillations of the platform of the simulator. Performance was assessed in terms of amplitude and frequency. Coordination was accounted for by an analysis of dynamical properties of the motion of the platform, and especially the nature of the damping function that was exploited for sustaining the limit cycle dynamics. Results showed a significant decrement in performance variables. In contrast, all participants adopted from the first trial

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onwards the coordination mode they learned 10 years ago. These results confirm the strong persistence of coordination modes, once acquired and stabilized in the behavioral repertoire. They also support the importance of coordination variables for a valid assessment of learning and retention.

1. Introduction

Motor learning is defined as a permanent change in behavior in a specific task, resulting from practice (Schmidt, 1982). This definition emphasizes the importance of retention tests for assessing learning: a change in behavior should be proven to have a certain stability over time, in order to be considered a valid indication of learning.

Behavior changes, during learning, are not restricted to these long-term and permanent modifications. Changes occur at different levels and following diverse time scales. According to Newell, Liu, and Gottfried (2001), the evolution of behavior during learning is also affected by transitory changes, as, for example, the warm-up decrement, a systematic decrease in performance that occurs at the beginning of each practice session, with respect to the level of performance reached at the end of the previous session, the alterations of behavior that could occur during a session, due to fatigue and drop in attention, and finally to trial-to-trial fluctuations, generally interpreted as random variability.

However, the nature of the changes observed during learning is dependent on the characteristics of the to-be-learned task, and also on the variables that are used for describing behavior. It seems useful, at this level, to distinguish between two categories of variables, commonly used in motor learning experiments.

Performance variables focus on the outcomes of behavior, with respect to the goal of the task, in terms of speed (reaction time, movement time) or accuracy (absolute and variable errors, etc.). In contrast, *coordination variables* aim at accounting for the functional organization of behavior. These variables generally describe the spatio-temporal relationships between body parts, or between the body and the environment, in terms of relative phase (Kelso, 1995), or by means of dynamical models capturing the essential features of oscillatory behaviors (Beek & Beek, 1988).

In most motor learning experiments, up to the 80s, learning was assessed through performance variables. The first reason was related to the fact that the dominant paradigm, considering motor learning as an optimization of information processing, was primarily interested in problems of speed and accuracy (Abernethy & Sparrow, 1992). Experimental tasks were generally quite simple (linear positioning, target reaching, etc.), involving a few number of degrees of freedom. More recently, the development of the dynamical systems approach and the focus on coordination, as a property emerging from a complex set of constraints during the performance of the task, have motivated the use of coordination variables (Beek, Peper, & Stegeman, 1995). Generally, these experiments analyzed learning in more complex tasks, requiring at least the coordination of two body segments (Zanone & Kelso, 1992, 1997), and often in gross motor skills involving a huge number of degrees of freedom (Delignières et al., 1998; Nourrit, Delignières, Caillou, Deschamps, & Lauriot, 2003; Vereijken, 1991).

These two contrasting approaches yielded different conclusions about changes during learning. Experiments focusing on performance variables in simple tasks generally considered learning as the progressive and continuous refinement of information processing. Performance variables were often showed to evolve, during the learning process, following a power law. According to Newell (1991), this power law that was for a long time considered a powerful and universal principle, could represent an artifact due to the simplicity of the tasks, and the nature of the variables used. The author showed that learning in more complex tasks, involving multiple degrees of freedom, presented in contrast a discontinuous character, marked by abrupt changes in behavior during the course of learning.

Another important point is that motor learning experiments could strongly differ, in terms of scientific aims and practical interests. At least two categories could be distinguished: in the first category experiments seek at understanding the process of acquisition of a novel motor skill: participants are