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Transfer as a function of exploration and stabilization in original practice

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ABSTRACT

The identification of practice conditions that provide flexibility to perform successfully in transfer is a long-standing issue in motor learning but is still not well understood. Here we investigated the hypothesis that a search strategy that encompasses both exploration and stabilization of the perceptual-motor workspace will enhance performance in transfer. Twenty-two participants practiced a virtual projection task (120 trials on each of 3 days) and subsequently performed two transfer conditions (20 trials/condition) with different constraints in the angle to project the object. The findings revealed a quadratic relation between exploration in practice (indexed by autocorrelation and distribution of error) and subsequent performance error in transfer. The integration of exploration and stabilization of the perceptual-motor workspace enhances transfer to tasks with different constraints on the scaling of motor output.

1. Introduction

The effectiveness and efficiency of the conditions of practice on learning and transfer is a central issue in the study of motor skill performance (Adams, 1987; Lee, 1988; Newell, 1996; Shea, Kovacs, & Panzer, 2011). However, the identification of practice conditions that provide flexibility to perform successfully in new task situations is still an open question (Schmidt & Young, 1987; Tani et al., 2014). Transfer has traditionally been understood in terms of the similarity between tasks (Holding, 1976; Osgood, 1949; Proteau, Marteniuk, & Levesque, 1992), but theories of motor learning and transfer have had problems defining the relevant properties of similarity.

Another general hypothesis of motor learning and transfer holds that a greater range of movement experiences during practice will enhance the learner's capacity to transfer to new task situations (Schmidt, 1975; Schöllhorn, Mayer-Kress, Newell, & Michelbrink, 2009). However, evidence for this assumption about the positive role of variability of practice is generally inconsistent (e.g., Sherwood & Lee, 2003; Van Rossum, 1990). The prevailing approach to the variability of practice has the effectiveness of learning in practice a function of the level of task variability in the original practice condition (e.g., Proteau et al., 1992; Schmidt, 1975).

In a dynamical systems account of learning, transfer is characterized as being due to the similarity of the practiced regions of the perceptual-motor workspace and their relation to the requirements for the new task (Newell, Kugler, Van Emmerik, & McDonald, 1989; Ranganathan, Wieser, Mosier, Mussa-Ivaldi, & Scheidt, 2014; Zanone & Kelso, 1992). Contrary to the idea of

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more variation through practice, an optimal schedule would involve the processes of both exploration – resulting in more variability – (Fowler & Turvey, 1978; Newell & McDonald, 1992; Newell et al., 1989) and stabilization – improving consistency – (Kelso, 1995; Zanone & Kelso, 1992) of the possible spatio-temporal movement patterns. In redundant tasks, the learner has the potential to explore different motor solutions that afford the desired goal (Arutyunyan, Gurfinkel, & Mirskii, 1969).

Although the role of the search during practice has been postulated theoretically (Fowler & Turvey, 1978; Newell et al., 1989), experimental work has been limited either to inducing practice in specific strategies (e.g., Buchanan & Dean, 2010), or having only one possible solution for the task (e.g., Newell & McDonald, 1992). The former represents a guided exploration and its efficiency may be highly dependent on the stage of learning for a given individual (Schöllhorn et al., 2009). The latter does not address the continuum of exploration and stabilization during the task (it only emphasizes the exploration part). The outcome is that the resulting studies have compared different learning and transfer conditions but cannot explain how differing performance in a new task (transfer) occurred within a given condition. Thus, the question of how different motor solutions for a given goal are learned in conjunction with their influence on retention and transfer is still an open issue.

Furthermore, the term exploration has received a number of definitions in the literature being sometimes assumed to be the same as more variability (in a dispersion distributional sense) during learning. This can be an insufficient index and even misleading given that variability can occur when individuals are not actively exploring. For instance, the task space may allow different levels of variability (see, for instance, Müller & Sternad, 2004). Here, exploration is viewed as the motion within the perceptual-motor workspace for new movement solutions. This can be operationalized as a positive feedback loop process in the execution variables of the motor output. That is, a deviation from a starting point is increased provided that a new point is aimed for. This motion through the perceptual motor-workspace would provide information about topological properties of the perceptual-motor workspace (Fowler & Turvey, 1978; Newell et al., 1989).

In this context, Ranganathan and Newell (2010a, 2010b) proposed that a central feature to understand learning and transfer was to determine the "relevant parameters" of the task. This is consistent with the idea of uncovering task dynamics and the essential/non-essential variables of the task itself (Gel'fand and Tsetlin, 1962). The non-essential variables are the working parameters and changes in these lead to significant modifications in the resulting performance. The essential variables are a smaller group usually represented by a function of the working parameters. For instance, when throwing a dart, the initial angle and velocity are the non-essential variables given that a change in these leads to different outcomes. The function that describes the task – that relates the goal, angle, velocity in a single function – can be said to be the essential variable – in other terms, the topological properties of the perceptual-motor workspace. In certain tasks, this information is not directly available and exploration (induced or self-regulated) provides information about it. In self-regulated search, the individual is able to uncover the dynamics by searching a myriad of different motor solutions for the task – facilitating transfer to a new solution of the task.

In spite of this role of exploration, motor learning is only achieved when new movement patterns are stabilized (Kelso, 1995). Zanone and Kelso (1994) considered learning as modifying existing coordination tendencies of the individual through practice. This process would then create new stable coordination patterns affecting the initial tendencies. These coordination tendencies are referred to as the intrinsic dynamics (the attractor layout) and the creation of new stable coordination pattern as stabilization. New stable movement patterns of the attractor layout are not only a function of exploration processes but also of practice of the same movement pattern. That is, a certain amount of practice of a given task solution needs to occur for the pattern to become stable. In contrast to exploration, stabilization is characterized as a process where the individual is trying to make a given movement pattern consistent. This process can be operationalized as a negative feedback loop in the execution variables that corrects the outcome from trial to trial. This approach to exploration and stabilization reflects a different line of interpretation from studies that consider the dispersion of the data to classify variability and learning. Therefore, the capacity to perform more than one solution for a given goal requires a search strategy that encompasses both exploration and stabilization.

Here, we investigated the hypothesis that individuals showing a balanced exploration/stabilization strategy during practice will produce a better performance in transfer under changes in the constraints of the task. To test this hypothesis, we examine the relation between exploration and stabilization in original practice and subsequent performance in the transfer conditions. We anticipate that polarization in the exploration continuum (e.g., high level of exploration/no stabilization or vice versa) would be associated with a lower level of performance in transfer, as this reflects a greater emphasis on only one process namely, either stabilization or exploration. Thus, the relation between exploration and performance in transfer will be nonlinear – a quadratic – characterizing a potentially optimal point where the amount of exploration will be intermediate and performance higher with the extremes of exploration having a lower performance.

2. Methods

2.1. Participants

Twenty-two healthy self-reported right-hand individuals (aged 18–35 years) volunteered as participants in this study. There were 10 females and 12 males. Informed consent was provided prior to participation with approval from the Pennsylvania State University Institutional Review Board.