Human Movement Science 59 (2018) 66–80

Contents lists available at ScienceDirect

Human Movement Science

journal homepage: www.elsevier.com/locate/humov

Full Length Article

Transfer of a learned coordination function: Specific, individual and generalizable

Matheus M. Pacheco[a,*], Karl M. Newell[b]

[a] Department of Psychology, New York University, United States
[b] Department of Kinesiology, University of Georgia, United States

ARTICLE INFO

Keywords:
Skill acquisition
Transfer of practice
Dynamical systems

ABSTRACT

It is generally held that transfer of practice is a function of the similarity between the originally learned task and the subsequent transfer task. In the present paper, we examine the proposition that individuals learn a coordination function that is specific to the task, individual and yet generalizable, depending on the characteristics of the learned coordination function. Seventeen individuals performed for 5 days the task of learning to throw for accuracy to a target and then performed two transfer tests that differed in terms of the axis of variation that individuals could vary in task outcome. The results showed individual differences in terms of the acquired movement pattern even when a similar performance was achieved. Additionally, the coordination function characterized by principal component analysis and its projection into the landing plane predicted performance in the transfer tests. These results support the proposition that individuals learn a coordination function that is specific, individual and generalizable.

1. Introduction

Traditionally, the investigation of the transfer of practice is seen to allow an understanding of the related constructs of learning and retention (Adams, 1987; Hilgard & Bower, 1975). There is a long-held position in motor learning that transfer through learning occurs as a function of the similarity between the original task practiced and the transfer test task (e.g., Harlow, 1949; Holding, 1976; Osgood, 1949; Rosalie & Müller, 2012; Thorndike & Woodworth, 1901a, 1901b, 1901c). Nevertheless, there has been much debate as to the grounds on which transfer occurs (cf., Proteau, Marteniuk, & Levesque, 1992; Tremblay, Houle, & Ostry, 2008) and, in occurring, what the aspects of transfer are that must be similar (Schmidt & Young, 1987).

A current position holds that transfer occurs in terms of the similarity of features of the task space practiced during acquisition and those of the new task context (e.g., Adolph, 2005; Braun, Mehring, & Wolpert, 2010; Ranganathan, Wieser, Mosier, Mussa-Ivaldi, & Scheidt, 2014). The task space can be characterized by the function that relates performance in a task and the variables of the movement that affect performance. In accepting the task space as the source of differences between individuals, this position cannot address, however, why individuals performing the same task differ in their transfer test performances (e.g., Pacheco & Newell, 2015). In the present paper, we first discuss the issues pertaining to the principles of the similarity of task space and then offer a contrasting hypothesis that addresses the question of individual differences on transfer arising within the same task condition.

* Corresponding author at: 4 Washington Pl., Rm 403, New York University, New York, NY 10003, United States.
E-mail address: matheus.lacom@gmail.com (M.M. Pacheco).

https://doi.org/10.1016/j.humov.2018.03.019
Received 22 December 2017; Received in revised form 21 March 2018; Accepted 27 March 2018
0167-9457/

1.1. Individual search and redundancy in task spaces

A prevailing assumption is that during practice, individuals learn a *relation* that can be generalized to other contexts if these other contexts induce such a relation, or features of it. This relation (or function) is hypothesized to be one that coordinates elemental variables (e.g., degrees-of-freedom available to the individual to perform a task, such as joints, muscles, etc.) of the action in a specific way that can accomplish the task. For instance, the overhand throw involves several joints, but each joint motion is coordinated to the motion of other joints in a way that one can describe the collective movement pattern using fewer variables (a function of these joints) – even when some parameters are modified (distance of throw, velocity of the movement, etc.) Thus, in learning to throw, one would learn a function that relates all joint motions in a way that the task can be accomplished.

One current example of this line of thinking is the concept of structural learning (Braun et al., 2010; Wolpert & Flanagan, 2010). The idea is that learners, when practicing a task that involves many elemental variables, find and learn a structure that coordinates all these variables (i.e., a coordination function, low-dimensional structure) that suffices to achieve the goal of the task. If a new task can be performed using the same low-dimensional function, then transfer is observed. This idea is similar to a number of other propositions of transfer such as the traditional schema (Schmidt, 1975) and contemporary task synergy (Latash, 2010) frameworks. A common ground in these positions is the assumption that under the same task conditions individuals will learn similar relations during practice. In this vein, knowing the task being performed, we know how the transfer would occur.

Here, we adopt the position that through practice individuals are searching through the space of movement possibilities (i.e., task-space) to find a solution for the task (the goal-space)[1] (Newell, Kugler, Van Emmerik, & McDonald, 1989; Newell & McDonald, 1992; Newell, Mcdonald, & Kugler, 1991). This search is revealed by the change in aspects of the action performed in each moment of practice (e.g., trial-to-trial, within-trial, etc.). From this theorizing, one of two properties must occur for the position of similarity between task-spaces for transfer to hold. Either the goal-space is over-constraining in that learning the task would result in the availability of only a single possible relation (i.e., coordination function, low-dimensional structure) to be learned or individuals are highly similar in that they start and perform the search similarly between them – resulting in a single relation. In both scenarios, in knowing the task, one knows what is learned and, then, one knows how transfer would occur.

We propose, however, that these two possibilities cannot hold. First, individuals bring different tendencies of action to the task (i.e., their initial state differs). These tendencies are the individual's intrinsic dynamics (Kelso, 1995) or preferences in approaching the task (e.g., King, Ranganathan, & Newell, 2012) that can change how the individual interacts with the task (see, Kostrubiec, Zanone, Fuchs, & Kelso, 2012; Zanone & Kelso, 1992, 1994). The nature of the intrinsic dynamics can alter the type of change that the individual must go through to reach the task goal (Thelen et al., 1993). Second, studies that have investigated the search strategy on a trial-to-trial basis have revealed that individuals do not search similarly: individuals differ in their search patterns (Pacheco & Newell, 2015) and in their use of information in the search (Pacheco, Hsieh, & Newell, 2017; Pacheco & Newell, 2018). These findings point to the position that learning needs to be considered at the level of the individual.

It is useful to consider if tasks can be over-constraining to the degree that they cannot be performed differently by different individuals. Although this, in principle, might hold for situations in which a common movement pattern is predetermined implicitly or explicitly by the task (e.g., some tasks of gymnastics), we note that most tasks are defined in terms of a goal that does not directly constrain the movement pattern. This means that these tasks afford several means of solution for the same outcome (i.e., redundant tasks). Although there is agreement on the idea of task redundancy (cf. Sternad, Huber, & Kuznetsov, 2014), it is usually considered that individuals will converge to similar patterns by assuming that knowing the task conditions would be enough to predict transfer (but see Al-Abood, Davids, & Bennett, 2001). Nevertheless, in many studies, the results have not conformed to this expectation (Ranganathan & Newell, 2010; Schmidt & Young, 1987; van Rossum, 1990; Wu, Truglio, Zatsiorsky, & Latash, 2015).

1.2. Special-purpose devices: Specific, individual and generalizable

The coordinative structure approach (Kugler, Kelso, & Turvey, 1980, 1982) holds that, in learning, individuals enhance the coordination between perception and action (Shaw & Alley, 1985). From this, emerges what Newell (1985) called a "coordination function" – a function that relates all elemental variables of the system into a functional unit assembled for the task at hand (also referred as a "special-purpose device", Bingham, 1988; Fowler & Turvey, 1978). The coordination between perception and action occurs as a function of the search through the perceptual-motor workspace (Newell & McDonald, 1992; Newell et al., 1989, 1991). That is, individuals, in trying to improve performance in a given task, alter the aspects of action or variables that are picked up by perception to act. This affords new ways of acting and reveals other informational variables to guide action. The process leads to a coordination solution that is functional to the task at hand and is tuned to a reliable informational variable (a specifying variable, cf. Jacobs & Michaels, 2007).

The confluence of different intrinsic dynamics, search-strategies and redundant solutions might lead individuals to different

[1] The task-space is defined here as the function that relates the performance (in our case, error) to the variables that influence performance (elemental variables). For example, in a throwing for precision task, considering only two dimensions, the target to be at the same height of the release position and error evaluated as the distance to the target at that height, the function has the following format $E = ((2v_x v_y)/g)-d$, where E is error, v_x and v_y are the release velocity in the x and y axes, g is gravity, and d is the distance of the target from the release position. The goal-space is defined as the relation between variables that that result in the goal being achieved: in our example, $d = (2v_x v_y)/g$. The goal-space is contained in the task-space. Finally, the coordination function is the function of the elemental variables employed by the individual to accomplish a task. While task and goal-spaces are defined by task, the coordination function relates to how (which movement pattern) the individual performs such a task.