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Skill transfer specificity shapes perception and action under varying environmental constraints ☆

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ABSTRACT

Using an ecological dynamics framework, this study investigated the generality and specificity of skill transfer processes in organisation of perception and action using climbing as a task vehicle. Fluency of hip trajectory and orientation was assessed using normalized jerk coefficients exhibited by participants as they adapted perception and action under varying environmental constraints. Twelve recreational climbers were divided into two groups: one completing a 10-m high route on an indoor climbing wall; a second undertaking a 10-m high route on an icefall in a top-rope condition. We maintained the same level of difficulty between these two performance environments. An inertial measurement unit was attached each climber's hips to collect 3D acceleration and 3D orientation data to compute jerk coefficient values. Video footage was used to record the ratio of exploratory/performatory movements. Results showed higher jerk coefficient values and number of exploratory movements for performance on the icefall route, perhaps due to greater functional complexity in perception and action required when climbing icefalls, which involves use of specific tools for anchorage. Findings demonstrated how individuals solve different motor problems, exploiting positive *general* transfer processes enabling participants to explore the pick-up of information for the perception of affordances *specific* to icefall climbing.

1. Introduction

Skill transfer emerges from the influence of prior experiences under a particular set of interacting constraints on performance under a different set of conditions compared to those where the skills were originally acquired (Newell, 1996; Issurin, 2013; Rosalie & Müller, 2012). Little attention has been paid to the issue of *specificity-generality* of transfer. *Specificity* of transfer can emerge under practice task constraints where existing intrinsic dynamics (i.e. performance disposition or tendencies) of an individual *cooperate* with the dynamics of a new task to be learned, facilitating emergence of successful performance behaviours. On the other hand, *general* transfer can occur when intrinsic and task dynamics do not cooperate closely and the individual athlete only has the potential to further develop general capacities that exist in as part of their

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current intrinsic dynamics, such as perceptual skills, like anticipation and visual search, strength, or postural stability. Thus, general transfer occurs when general processes that support performance behaviours are used under a new set of performance constraints. This suggests that general transfer may supported by processes that help learners adapt existing coordination functions to use exploratory or transitional behaviours (Newell, 1996).

Therefore, *specificity* and *generality* of transfer are influenced by the particularities and commonalities of the environmental and task constraints faced, in interacting with the specific intrinsic dynamics of each individual learner. Intrinsic dynamics, reflecting the individual's current system architecture (i.e. developmental status) and previous history of activity (i.e. learning and experience) (Thelen, 1995), are shaped by continuous interactions of personal, task and environmental constraints. These theoretical ideas have implications for training design since transfer processes could constrain the degree and rate of performance improvement, as suggested in previous studies of coordination of finger movements (Zanone & Kelso, 1997). This is an important issue in science and training due to major questions that exist over discrepancies in the time for expertise acquisition in activities like chess, where the same master level status has been reached by individuals reporting to practice for 3200 and 23,000 h (McNamara, Hambrick, & Oswald, 2014). Despite these questions, there have been few empirical studies of transfer processes during coordination of multi-articular actions in different sport performance environments (Rienhoff et al., 2013; Rosalie & Müller, 2012). Here, we sought to examine whether the intrinsic dynamics of climbers who practice regularly on an indoor climbing wall might cooperate or compete with the constraints of climbing on a frozen waterfall (an icefall).

On an indoor climbing wall, routes consist of holds composed of similar smooth synthetic materials, which afford gripping with the fingers in an unchanging internal environment (e.g. ambient temperature remains the same during ascent and the climbing surface is relatively constant). In ice climbing, properties of an icefall require use of tools on the feet (crampons) and in the hands (ice tools), and performance conditions (e.g., weather, temperature and surface) can change markedly within and between climbs (Batoux & Seifert, 2007; Blanc-Gras & Ibarra, 2012). *General* transfer between indoor and icefall climbing might involve the coupling of perceptual and action systems to seek out ascent routes, to manage weight with respect to the environmental constraint of gravity and the discovery of surface properties with exploratory finger and feet actions. *Specific* transfer processes, on the other hand, enhance the stability of specific perception-action couplings, which are refined through regular practice under highly particular task constraints to enhance performance, exemplified in icefall climbing by the way that particular tools are used to ascend the surface. In indoor climbing such tools play no part in ascending a surface but are necessary to explore the physical properties specific to the icefall environment, such as ice fragility. In both contexts, exploratory behaviour functions to reduce uncertainties that emerge during the process of perceiving and utilising climbing opportunities (or affordances) (Pijpers, Oudejans, Bakker, & Beek, 2006). Thus, an important research challenge is to effectively characterise different performance ecologies along each axis of transfer (specific and general), in order to predict how processes of skill transfer might support performance, shortening the potential timescales of learning.

The question we addressed here concerned how affordances (i.e., action opportunities offered by the environment; Gibson, 1979) might be designed into practice landscapes (Rietveld & Kiverstein, 2014), which facilitate their utilisation, and the transfer of behaviours such as perceptions and actions. It is possible that some practice task constraints might be pitched at a level, which is too *general* for a particular individual, thereby lacking functionality and slowing the learning process. In this way, generality of transfer in learning design might exhibit too much non-specifying information, being too far from the intrinsic dynamics of an individual learner for these variables to be adapted to support performance (i.e., practice task designs might exhibit a less rich landscape of affordances). In cases of transfer between contexts, which are highly dissimilar, the individual benefits from experience in an activity that appears to have little (or more precisely very general) resemblance to the transfer context. Thus, a possible advantage of general transfer may be that performance in a new context is facilitated through the ability to abstract commonalities in behaviours that are effective across different contexts. For example, adaptations that support exploration in new tasks may help the individual to locate specific informational constraints that improve performance.

1.1. How indoor climbing supports skill transfer to ice-climbing

The multi-articular actions of climbing offer rich landscapes of affordances for studying effects of *generality* and *specificity* of skill transfer. This performance context is characterised by varying environments (variations in surfaces, e.g. smooth synthetics, rock or ice; surrounding conditions, e.g. variations in ambient temperatures, wind, available light, dryness/wetness; textures, e.g., smooth, rough, rocky, and slippery; and tool use, e.g., use of hands, feet, gloves, boots, ice tools, crampons, chalk). Previous findings have suggested that experienced rock climbers, with previously acquired multiple, fluent movement and coordination patterns, can transfer this large range of skills to the novel task constraints of ice climbing (Seifert, Wattebled, et al., 2013). However, previous research has not examined *which* specificities of ice climbing (i.e. tool use; variability and temporary distribution of icefall properties; freely chosen climbing path) might best induce *specific* transfer effects from climbing an indoor wall to an icefall.

In particular, three main properties might support *general* transfer of climbing experience between the constraints of rock and ice climbing (Seifert, Wattebled, et al., 2013): (i) unpredictability of performance environments requiring some level of exploratory behaviour, (ii) alternation between maintaining body equilibrium (stability) and climbing quickly up a vertical surface (transitioning), and (iii), use of quadruped locomotion patterns involving extremities of each limb to negotiate an ascent. Constraints of ice climbing reveal at least two particularities in comparison to rock climbing which might induce