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Representative Learning Design and Functionality of Research and Practice in Sport

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Egon Brunswik proposed the concept of "representative design" for psychological experimentation, which has historically been overlooked or confused with another of Brunswik's terms, *ecological validity*. In this article, we reiterate the distinction between these two important concepts and highlight the relevance of the term *representative design* for sports psychology, practice, and experimental design. We draw links with ideas on learning design in the constraints-led approach to motor learning and nonlinear pedagogy. We propose the adoption of a new term, *representative learning design*, to help sport scientists, experimental psychologists, and pedagogues recognize the potential application of Brunswik's original concepts, and to ensure functionality and action fidelity in training and learning environments.

Keywords: learning design, ecological dynamics, ecological validity, representative task design

Egon Brunswik proposed the term *representative design* as an alternative to *systematic design* more than half a century ago (Brunswik, 1956; Dhami, Hertwig, & Hoffrage, 2004). He advocated the study of psychological processes at the level of organism–environment relations, an ideal focus for sport psychologists interested in research and practice. His ideas have been allied with tenets of James J. Gibson's theory of direct perception (Gibson, 1979), although Brunswikian ideals have failed to be fully appreciated and integrated into the behavioral sciences. The impact of these concepts has begun to be acknowledged by some in experimental psychology research (e.g., Rogers, 2008), with principles of representative design gaining greater recognition (e.g., Dhami et al., 2004; Hammond, 2001). Perhaps the greatest acceptance of representative design has been in the study of adaptive movement behaviors in sport and physical activity (see Araújo & Davids, 2009; Beek, Jacobs, Daffertshofer, & Huys, 2003; Davids, 2008; Dicks, Davids, & Araújo, 2008; Fajen, Riley, & Turvey, 2009). However, despite the adoption of key aspects

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of representative design in practice (predominantly through striving for ecological validity), a principled theoretical analysis has yet to be articulated in detail to guide research and practice in sport psychology and sport science.

Over the years the concept of representative design has become entangled with another of Brunswik's terms, *ecological validity* (Araújo, Davids, & Passos, 2007), which has been inadvertently adopted to refer to the generalizability of experimental designs in sport psychology and other sports sciences. In this article, we clarify differences between the concepts of ecological validity and representative design, before discussing their relevance for the design of experimental tasks and learning environments in sport. As a task vehicle, we highlight current research on perception and action in sport, and demonstrate how representative design could be adapted to provide experimental psychologists, sport scientists, and pedagogues with a framework for assessing the functionality of experimental and learning designs.

Ecological Validity and Representative Design

Historically, experimental research designs have been inherently systematic in nature, affording high levels of control and manipulation of individual variables, as exemplified in sports science and motor learning research (Dhami et al., 2004). *External validity* came to refer to the generalization of research findings from the study of a specific sample, to either a larger population, often referred to as *population validity* (Bracht & Glass, 1968), or to behavioral situations beyond the experimental context and population studied (Lucas, 2003). In sport psychology, concerns over external validity are exemplified in studies of expert performance in sport, which have tended to examine behaviors of available participants such as skilled undergraduate students (e.g., the use of skilled university-level golfers in the study of expertise, Wulf & Su, 2007) rather than Olympians or elite athletes (e.g., the visual attention of truly elite balance acrobats, Wulf, 2008). Egon Brunswik (1956, p. 39) proposed that "proper sampling of situations and problems may in the end be more important than proper sampling of subjects." His ecological approach to studying cognition, perception, and action was implemented through the theoretical framework of probabilistic functionalism. This perspective proposed that performer–environment interactions are based on the pickup of multiple sources of imperfect information from the environment (for comprehensive reviews, see Hammond & Stewart, 2001, or Kirlik, 2009). *Ecological validity* was originally a Brunswikian term that has since been used frequently in sports science. It originally referred to the statistical correlation between proximal cues available in the environment (perceptual variables) and the extent to which they depict the distal criterion state of the environment (Brunswik, 1956). Put simply, individuals use a series of imperfect cues to infer events or aspects of some unobservable state of the environment (e.g., the way in which skilled performers in sport use advance information from opponents' movements to predict future actions before their own movements are initiated). After Ulric Neisser (1967), researchers have generally (mis)used the label *ecological validity* to refer to the external validity of research designs. In using the term in this way, researchers were actually alluding to aspects of Brunswik's (1956) highly significant concept of representative design (Araújo, et al., 2007). In sports science, ecological validity has generally been presented as the study of performance, learning, and behavior under sport task constraints—such as by contrasting simple, contrived laboratory tasks (a pointing or manual aiming task) with typical sports performance tasks (catching a ball or coordinating other multiarticular actions). (For examples of this misunderstanding, see Jobson, Nevill, George, Jeukendrup, and Passfield, 2008, and Jobson et al., 2007). Therefore, concerns of ecological validity have tended to focus on the generalization of observed behavior in experimental laboratory settings to "natural behavior in the world" (Schmuckler, 2001, p. 419). The misconceptualization is important to acknowledge since in downplaying Brunswik's original theoretical contribution, it is clear that some important nuances of representative design have been lost to researchers, and there is potential to harness further theoretical benefit from the original concepts.

Brunswik (1956) advocated that for the study of organism–environment interactions (such as those observed in visual anticipation in sport research), "cues" (or perceptual variables) should be sampled from the organism's typical environment so as to be representative of the environmental stimuli from which they have been adapted, and to which behavior is intended to be generalized (Brunswik, 1956). In sport psychology, this definition of representative design emphasizes the need to ensure that experimental task constraints represent the task constraints of the performance or training/learning environment that forms the specific focus of study. In representative design, there is a strong emphasis on the specificity of the relations between the participant and the environment, which is often neglected in traditional approaches to behavioral sciences (see, e.g., Dunwoody, 2006).

Brunswik's (1956) ideas are a particular concern for the study of human performance and behavior in sport, with representative design being fundamental to generality of experimental results. Just as participants of an experiment must be representative of those to which the study wishes to generalize, the experimental task constraints must also represent the environmental (performance) constraints to which they are to be generalized. In this context, Brunswik (1956) used the term *represent*, when originally defining representative design as the arrangement of constraints in an experimental design so that they represent the behavioral setting to which the results are intended to apply (see also Hammond & Stewart, 2001). Generalization of findings outside defined experimental conditions, besides underplaying the role of the environment on human behavior, can be problematic in studying the adaptability of performers in dynamic performance contexts. This weakness emphasizes the need to adequately sample environmental constraints to provide experimental designs that can shed insights into functional human behaviors. The prominence of designing task constraints that emphasize *functionality* of behavior has been articulated by researchers in medical education (Wigton, 2008), motor learning (Davids, Button, Araújo, Renshaw, & Hristovski, 2006), and judicial contexts (Dhami et al., 2004), among others. Here we examine the importance of these ideas for the creation of experimental *and* learning designs in sport.

Representative Task Design in the Study of Perception and Action in Sport

In the study of perception and action in sport, representative design has been acknowledged as the generalization of task constraints in experimental designs to the constraints encountered in specific performance environments (Araújo, Davids,

& Hristovski, 2006; Davids, 2008). Despite technological and methodological advances, questions still exist over the representative design of many experimental designs in sports science research. Ensuring that task constraints of experiments are representative is not a trivial matter since, in sport studies, small changes in task constraints can lead to substantial changes in performance outcomes and movement responses (Hristovski, Davids, Araújo, & Button, 2006). This argument can be exemplified by the analysis of research on visual anticipation processes in sport.

In sport, the ability for performers to use information from the environment to support actions is predicated on an accurate and efficient relationship between perceptual and motor processes (Le Runigo, Benguigui, & Bardy, 2005), referred to as *perception-action coupling*. A recent comprehensive analysis of common experimental design modes in the visual anticipation literature demonstrated how many previous studies had failed to implement recent developments in behavioral neuroscience. For example, a significant weakness is captured by the tendency of some psychologists to confuse processes of perceptual discrimination between two or more sources of visual stimulation with processes of decision making, which in dynamic performance environments like sport involve processes of cognition and action (e.g., Drugowitsch & Pouget, 2010; Stanford, Shankar, Massoglia, Costello, & Salinas, 2010).

A major limitation has been that little attention has been paid to the complementary contributions to performance of both ventral and dorsal cortical visual systems, and the functionality of perception *and* action processes in many studies (Milner & Goodale, 1995, 2008; van der Kamp, Rivas, van Doorn, & Savelsbergh, 2008). By emphasizing the importance of movement control in perception of information for action, van der Kamp and colleagues (2008) questioned the efficacy of the ubiquitous occlusion methodologies and video simulation tasks in research studies that have typically required participants to respond with verbal, written, button pressing, or micromovement responses. Research has highlighted significant differences in participant perceptual (Dicks, Button, & Davids, 2010) and movement behaviors (Farrow & Abernethy, 2003; Ranganathan & Carlton, 2007; Shim, Carlton, Chow, & Chae, 2005) under varying experimental task constraints that have manipulated the degree of perception–action coupling. For example, (Dicks et al., 2010) examined this issue in the comparison of movement and gaze behaviors of soccer goalkeepers in typical video simulation and in situ research designs. Significant differences in participant behavior were observed between task constraints that required verbal or simulated movements compared with the in situ (representative) interceptive action condition during a penalty kick. Such findings have major implications for experimental design in research in sport (Araújo & Davids, 2009; Araújo & Kirlik, 2008; Dicks et al., 2008; van der Kamp et al., 2008). Current perceptual–motor behavior research is beginning to extend this line of study to address parallel concerns in the design of task constraints in sport development and training programs (e.g., the use of ball projection machines in practice), where the removal of key information sources from the performance environment has been observed to significantly affect the timing and control of interceptive actions (Pinder, Renshaw, & Davids, 2009; Shim et al., 2005). Critically, the traditional (mis)conceptualization of ecological validity may not allow for the implications of representative task design to be fully appreciated beyond the generalization of experimental settings to performance. Just as sport psychologists must be aware of the interacting constraints of the specific experimental settings and the limitations of applying empirical findings beyond these settings, coaches and pedagogues need to fully understand the constraints of the sport in question, and consider how the design of practice tasks and interventions may allow for the maintenance of coupled perception and action processes that reflect the functional behavior of athletes in specific performance contexts. This distinction highlights the need for the adoption of the concept of representative design. In the next section we propose a new term that theoretically captures how sport scientists and pedagogues might use these insights to ensure that practice and training task constraints are representative of the context toward which they are intended to generalize: the performance setting.

"Representative Learning Design"

Recent work in physical education, sport pedagogy, and coaching science has demonstrated how principles of ecological psychology and dynamical systems theory can underpin interventions and practice in a nonlinear pedagogy (Chow et al., 2006, 2007; Renshaw, Chow, Davids, & Hammond, 2010; Renshaw, Davids, Shuttleworth, & Chow, 2010). Nonlinear pedagogy is predicated on the conceptualization of the performer/learner in sport as a complex neurobiological system exemplifying a nonlinear dynamical system in nature. Theoretical and empirical advances have provided a sound rationale for a nonlinear dynamics explanation of how processes of perception, cognition, decision making, and action underpin intentional movement behaviors in dynamic environments (e.g., Turvey & Shaw, 1999; van Orden, Holden, & Turvey, 2003). This perspective proposes that the most relevant information for decision making and regulating action in performance environments is emergent during performer–environment interactions (see Araújo et al., 2006; van Orden et al., 2003) Nonlinear pedagogy proposes that athletes, considered as neurobiological systems, exhibit purposive adaptive behaviors from the spontaneous patterns of interactions between system components. An important feature of complex neurobiological systems is the emergent relationship that develops between perception (information) and action (movement) as such systems coordinate their actions with respect to the environment. This position was summarized by Gibson's (1979, p. 223) view that "we must perceive in order to move, but we must also move in order to perceive."

Nonlinear pedagogy is predicated on the mutual interdependence between perception and action in neurobiology, and it has been suggested that these processes should not be allowed to function separately in learning design (e.g., Araújo et al., 2006). Gibson's (1979) insights reveal why practice tasks in sport need to be carefully structured and managed to maintain relationships between key sources of information and action for learners and performers during practice. Different sources of perceptual information present different affordances for performers to execute specific actions in sport, and for this reason care should be taken in designing learning environments. Nonlinear pedagogy emphasizes the manipulation of key task constraints (particularly informational constraints on action) during learning to allow functional movement behaviors to emerge in specific sports and physical activities. These manipulations require skillful construction by pedagogists according to the theoretical principles of representative learning design.

In the practice of coaches, sports scientists, and physical educators, experimental design equates to the design of practice and training environments. As in experiments, the constraints of training and practice need to adequately replicate the performance environment so that they allow learners to detect affordances for action and couple actions to key information sources within those specific settings. This critical requirement was highlighted in a recent study examining the effectiveness of training drills to replicate the lower limb coordination patterns in the sport of triple jumping (Wilson, Simpson, Van Emmerik, & Hamill, 2008). Findings indicated that coaches should focus on dynamic, rather than static, training drills that more closely replicate the coordination patterns representative of competitive triple jumping performance. Similar issues with static task constraints have been highlighted in the design of performance analysis tests to assess skilled movement (e.g., Ali et al., 2007; Huijgen, Elferink-Gemser, Post, & Visscher, 2010) or decision-making behaviors (e.g., Nevill, Balmer, & Williams, 2002; Ripoll, Kerlizin, Stein, & Reine, 1995). Static tests lack functionality and do not successfully represent the constraints of performance environments. For example, Ali et al. (2007) attempted to overcome recognized limitations of previous "closed" soccer skills tests, claiming to have "enhanced ecological validity" by designing tests for the assessment of ball passing that required players to pass soccer balls to specific targets on benches arranged in a square in a gymnasium. The shooting skills tests required targeting specific goal areas when faced with a static plywood goalkeeper in a "set" position. Furthermore, the consequences of not adequately representing the key variables in that performance environment can be directly applied to sport psychology research. Abouzekri and Karageorghis (2010) adopted this passing test in the assessment of a precompetition state anxiety intervention on performance timing and accuracy. This example highlights how our understanding of different aspects of sports performance may be limited by lack of representative design in experimental protocols. However, there do exist some clear examples of observing the importance of representative design in some research studies, although perhaps not articulated explicitly. For example, reflecting on recent studies of visual attention of orienteers (e.g., Eccles, Walsh, & Ingledew, 2006), representative design was attained due to the selected experimental task constraints replicating those of the performance environment (Davids, 2008).

In sport psychology and performance analysis, there is a need for greater awareness of (a) the concept of Brunswik's (1956) representative experimental design and (b) the requirement for these methodological principles to be adopted in all kinds of practice, training and learning environments (e.g., Renshaw, Davids, et al., 2010). To facilitate this process, the term *representative learning design* could be adopted by sport psychologists and pedagogues to ensure functionality and action fidelity in interventions, as well as coaching, training, and learning. To attain representative learning design, practitioners should design dynamic interventions that consider interacting constraints on movement behaviors, adequately sample informational variables from the specific performance environments, and ensure the functional coupling between perception and action processes. Functionality (achievement and attainment in a Brunswikian sense) would ensure that (a) the degree of success of a performer's actions are controlled for, and compared between contexts, and (b) performers were able to achieve specific goals by basing actions in learning contexts (movement responses, decision making) on comparable information to that existing in the performance environment. For example, in team ball sports, the use of context-specific performance settings (e.g., game test situations; Memmert & Roth, 2007) and games-based approaches (Chow et al., 2007; Renshaw, 2010) are becoming a prominent feature of both research and practice design.

Empirically, to examine the degree of association between behavior in an experimental task with that of the performance setting to which it is intended to generalize, the importance of Stoffregen et al.'s (2003) concept of action fidelity (Araújo et al., 2007) needs to be recognized. In the use of flight simulations, Stoffregen et al. (2003, p. 120) described action fidelity as the "fidelity of performance," and proposed that fidelity exists when there is a transfer of performance from the simulator to the simulated system. In this respect, practice, training, and learning tasks could be viewed as simulations of the performance environment that need to be high in action fidelity (in much the same way that video designs in experimental settings are simulations of the performance context that is the subject of generalization). The degree of action fidelity can be measured by analyzing task performance in detail. For example, measures of task performance in sport, such as time taken to complete a task and observed kinematic (coordination) data during performance, would provide satisfactory means to assess action fidelity of simulated training, practice, and learning environments (Araújo et al., 2007). The purpose of action fidelity is to examine whether a performer's responses (e.g., actions or decisions) remain the same in two or more contexts, for example, when attempting to sample a sports performance environment within an experimental setting. Pinder et al. (2009) illustrated this idea by analyzing the movement responses of cricket batters when responding in representative performance tasks of batting against a "live" bowler, and a ball projection machine, which are ubiquitous in experimental and learning environments in sport. In essence, the ball machine in practice is used to simulate aspects of the performance environment in many ball sports. Significant differences in spatiotemporal responses of the batting action were observed by Pinder et al. (2009), primarily due to the removal of key perceptual information sources and a delay in movement initiation times under the ball machine task constraints. Critically, the removal of perceptual information from the environment (specifically pre–ball release kinematic information of the bowler's actions) was observed to limit a cricket batter's ability to use information to support actions (e.g., the creation and refinement of information–movement couplings; see Jacobs & Michaels, 2002). Fundamentally, this line of research demonstrates that practice or experimental tasks that do not consider the representative design of the performance context may not (a) allow for the correct diagnosis of the critical aspects of performance required to be trained or enhanced and (b) allow for the development of intervention or training tasks that achieve these goals.

Summary

Brunswik's (1956) methodological concept of representative design, after more than half a century of being largely overlooked or confused in the behavioral sciences, has continued to be implemented by some experimentalists. Here, we have described how Brunswik's principles of experimental design can be applied to the design of interventions, practice, and training tasks in sport. We proposed a new term, *representative learning design,* which may help sport psychologists, performance analysts, and pedagogues describe a theoretical framework for interpreting the functionality and action fidelity of practice tasks and learning environments.

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