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Onward and upward: Optimizing motor performance

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ABSTRACT

In the OPTIMAL theory of motor learning (Wulf & Lewthwaite, 2016), three factors are postulated to facilitate motor performance and learning: Enhanced expectancies (EE) for performance, autonomy support (AS), and an external focus (EF) of attention. We examined whether EE, AS, and EF would have immediate performance benefits and whether implementing these factors consecutively would lead to incremental performance increases. Participants were assigned to the optimized or control groups and performed a maximal jump. After the first trial block (baseline), optimized group participants were provided different conditions on each of the following 3 blocks: (a) Positive social-comparative feedback (EE); (b) choice of figure on the ground from which to jump (AS); and (c) instructions to focus on a marker on their waist (EF). The order of conditions was counterbalanced. Control group participants performed all 4 blocks under the same (control) condition. The optimized group outperformed the control group on Blocks 2–4. Moreover, their jump height increased with each addition of another variable, whereas it did not change across blocks in the control group. Thus, EE, AS, and EF had additive or incremental benefits for performance. The findings corroborate the importance of key variables in the OPTIMAL theory for motor performance.

The OPTIMAL theory of motor learning (Wulf & Lewthwaite, 2016) identifies three factors key to the optimization of motor performance and learning. These three variables – enhanced expectancies (EE), autonomy support (AS), and external focus (EF) of attention – appear to make partially independent contributions to goal-action coupling or the fluidity with which the intended goal is translated into action (Wulf, Lewthwaite, Cardozo, & Chiviacowsky, 2017). The result of efficient goal-action coupling is enhanced motor performance as well as motor skill learning. Motivational and attentional factors help prime and align central cortical and subcortical and peripheral neuromuscular processes to the intended goal (e.g., Cole, Laurent, & Stocco, 2013; Kuhn, Keller, Ruffieux, & Taube, 2017; Lohse, Sherwood, & Healy, 2010; Manohar et al., 2015; Meadows, Gable, Lohse, & Miller, 2016; Wulf, 2013; Wulf & Lewthwaite, 2016) in part, through instruction and the intrinsic neuromodulatory influence of reward-related dopamine.

One of the myriad ways to *enhance expectancies*, that is, elevate a person's expectations for positive experiences or success, is the provision of normative feedback that suggests that performance is better-than-average in the context of comparison with others (Hutchinson, Sherman, Martinovic, & Tenenbaum, 2008; Lewthwaite & Wulf, 2010b; Stoate, Wulf, & Lewthwaite, 2012; Wulf, Chiviacowsky, & Lewthwaite, 2010). Positive feedback indicating that one was performing better relative to others was found to increase performers' perceived competence over and above that of participants who were provided with negative feedback or no social-comparative feedback (Lewthwaite & Wulf, 2010b). Likewise, the liberal defining of success criteria (Chiviacowsky, Wulf, &

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Lewthwaite, 2012; Palmer, Chiviacowsky, & Wulf, 2016; Trempe, Sabourin, & Proteau, 2012) or the use of visual illusions (Chauvel, Wulf, & Maquestiaux, 2015; Marchant, Carnegie, Wood, & Ellison, 2018; Witt, Linkenauger, & Proffitt, 2012) to suggest relative ease of task can increase confidence in personal performance capabilities. The provision of simple statements that suggest to a person that peers typically perform well at the task (Hively & El-Alayli, 2014; Wulf, Chiviacowsky, & Lewthwaite, 2012), and the mindset that performance increases progressively with practice (Jourden, Bandura, & Banfield, 1991; Wulf & Lewthwaite, 2009) are other possible strategies for enhancing performers' expectancies. Enhanced performance expectancies serve a task-readying function by directing attention to the task goal and suppressing task-irrelevant or self-related thoughts (see Wulf & Lewthwaite, 2016). Further, expectations of rewarding experiences trigger a dopaminergic response that facilitates short-term performance and longer-term learning through functional and structural connectivity (Gruber, Ritchey, Wang, Doss, & Ranganath, 2016; Lappin et al., 2009; Wise, 2004).

Autonomy support, or conditions that are supportive of individuals' need for control or autonomy in their actions, are important for motivation, performance, and learning (e.g., Cordova & Lepper, 1996; Deci & Ryan, 2008; Tafarodi, Milne, & Smith, 1999). In the motor learning literature, many studies have demonstrated that learning is enhanced when learners have the opportunity to make decisions about aspects of practice conditions, including the delivery of feedback, skill demonstrations, or amount of practice (e.g., Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997; Post, Fairbrother, & Barros, 2011; Wulf, Raupach, & Pfeiffer, 2005; for a recent review, see Wulf & Lewthwaite, 2016). There is also increasing evidence that providing even small or incidental choices that do not have direct task relevance can be sufficient to enhance motor performance or learning. Examples include choosing the golf ball color for a golf putting task (Lewthwaite, Chiviacowsky, Drews, & Wulf, 2015), selecting the particular order of different types of punches in kickboxing (Halperin, Williams, Martin, & Chapman, 2016), and picking the color of a mat to be placed under a target (Wulf et al., 2017). A meta-analysis of research studies on choice effects found that incidental choices can be particularly motivating (Patall, Cooper, & Robinson, 2008). Opportunities for choice enhance expectations for positive outcomes and often result in higher self-efficacy and intrinsic motivation compared with controlling conditions (Hooyman, Wulf, & Lewthwaite, 2014; Lemos, Wulf, Lewthwaite, & Chiviacowsky, 2017; Murayama, Izuma, Aoki, & Matsumoto, 2016). They allow performers to maintain their attentional focus on the task goal, without the need to engage in self-regulatory activity, and suppress negative emotional reactions resulting from controlling environments (e.g., Reeve & Tseng, 2011).

Finally, the importance of maintaining a clear *external focus* on the task goal has been demonstrated in numerous studies. An instructed external focus of attention on the intended movement effect (e.g., implement trajectory, hitting the target, exerting force against the ground) typically results in more effective and efficient performance or learning than an internal focus on body movements (for a review, see Wulf, 2013). Since the pioneering study by Wulf, Höß, and Prinz (1998) showing that adopting an external focus resulted in more effective balance learning than the use of an internal focus or no specific focus instruction, numerous studies have corroborated this effect. Immediate performance advantages or learning benefits have been found to increase accuracy in hitting a target (e.g., Bell & Hardy, 2009; Lohse et al., 2010), enhance movement kinematics (e.g., An, Wulf, & Kim, 2013; Christina & Alpenfels, 2014), increase maximum force production (e.g., Halperin et al., 2016; Wulf & Dufek, 2009), or reduce oxygen consumption (e.g., Schücker, Hagemann, Strauss, & Völker, 2009). An external focus is an important contributor to goal-action coupling. It is assumed to facilitate functional connectivity (Kuhn et al., 2017) by maintaining attention on the task goal and preventing a detrimental internal or self-related focus. Furthermore, by producing effective performance it might also contribute to enhanced expectancies for future performance (e.g., Pascua, Wulf, & Lewthwaite, 2015; Wulf, Chiviacowsky, & Cardozo, 2014).

Numerous experiments have shown that providing information to performers that enhanced their expectancies for future performance, supporting their need for autonomy, or prompting them to focus attention externally on intended movement effects enhanced performance or learning of a variety of motor tasks (for reviews, see Lewthwaite & Wulf, 2017; Wulf & Lewthwaite, 2016). Furthermore, practice conditions that included combinations of two factors – EE and AS (Wulf et al., 2014), EE and EF (Marchant et al., 2018; Pascua et al., 2015), or AS and EF (Abdollahipour, Palomo Nieto, Psotta, & Wulf, 2017; Wulf, Chiviacowsky, & Drews, 2015) – have been found to result in additional benefits relative to the presence of only one of these factors, or none, for the learning of a throwing task. That is, EE, AS, and EF seemed to have additive learning benefits. Recently, Wulf and colleagues (2017) demonstrated that combining all three factors in acquisition enhanced learning to an even greater extent than combinations of two factors. Thus, there is preliminary evidence that the learning of tasks requiring movement accuracy can be optimized by combining the three key factors in the OPTIMAL theory (Wulf & Lewthwaite, 2016). The syncing of research and methodologies to allow study of complex movement behavior with underlying neuroscience mechanisms, though advancing, is still in its infancy. However, the need is ongoing and often critical to inform instructional, coaching, and therapeutic practice in effective means to acquire skill and support high levels of performance. One relevant question concerns ways in which to invoke the factors in the OPTIMAL theory to optimally influence performance and learning. To date, no study has investigated the effects of implementing all three motivational and attentional factors in close succession in a single experimental session. It is unclear, therefore, whether the consecutive rather than combinatorial application of the three key variables of the OPTIMAL theory would have beneficial effects on the *performance* of motor skills.

Thus, the purpose of the present study was to follow up on previous findings by examining whether EE, AS, and EF would also have immediate benefits for motor performance. Importantly, we asked whether implementing all three factors consecutively, rather than simultaneously, would lead to further increases in performance. The sequential application of these three factors in successive blocks of trials provided the opportunity to glimpse behaviorally the potential sustainability of the temporal pairing of dopamine with skill execution in motor performance (Lewthwaite & Wulf, 2017). The task we chose was a countermovement jump as it requires effective whole-body coordination for maximal jump height, involving a multijoint explosive movement. Jump height is maximized by the optimal coordination of joint activation timings of the shoulders, hips, knees, and ankles (Nuzzo, McBride, Cormie, & McCaulley, 2008). We hypothesized that providing participants with either positive feedback (EE), a choice (AS), or an external focus