



ELSEVIER

Optimizing motivation and attention for motor performance and learning

Rebecca Lewthwaite¹ and Gabriele Wulf²

We review three lines of recent research at an intersection of motor learning and sport psychology as they relate to motor skill acquisition: enhanced expectancies, autonomy support, and external attentional focus. Findings within these lines of research have been integrated into a new theory, the OPTIMAL (Optimizing Performance through Intrinsic Motivation and Attention for Learning) theory (*i.e.*, OPTIMAL theory, Wulf and Lewthwaite, 2016), and have been applied in motor skill acquisition and performance. Implications range from more effective skill development in children and novice performers to athletes and performers in many fields, including clinical rehabilitation.

Addresses

¹ Rancho Los Amigos National Rehabilitation Center and University of Southern California, USA

² University of Nevada, Las Vegas, USA

Corresponding author: Wulf, Gabriele (gabriele.wulf@unlv.edu)

Current Opinion in Psychology 2017, 16:38–42

This review comes from a themed issue on **Sport psychology**

Edited by **Peter Beek, Vana Hutter** and **Raoul Oudejans**

<http://dx.doi.org/10.1016/j.copsyc.2017.04.005>

2352-250X/© 2017 Elsevier Ltd. All rights reserved.

Introduction

In 1986, legendary golfer Arnold Palmer made a hole-in-one during the Chrysler Cup Pro-Am in Potomac, Maryland. When he later talked about this event, he recalled a TV camera crew showing up on the same hole the next day of the tournament, asking him to hit a hole-in-one again so that they could film it. In the interview, Palmer commented on how ridiculous the suggestion was that he would be able to repeat a hole-in-one on the same hole one day later. Yet, he indeed made another hole-in-one!

Optimal performance is rare. What does it take to perform the perfect golf shot, penalty kick, or gymnastic routine? This is the goal of most athletes, and instructors, coaches, and others who strive to help athletes optimize their performance. In recent years, researchers in motor learning and performance have generated several lines of

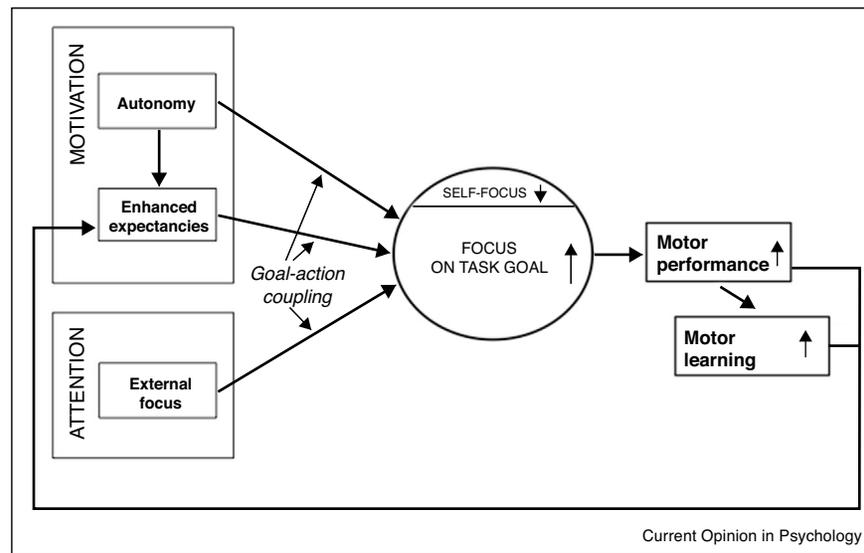
evidence that indicate important roles for motivation and attentional focus in motor performance and learning. We recently posed the OPTIMAL theory of motor learning [1•] that integrates this research (see [Figure 1](#)). OPTIMAL is an acronym for Optimizing Performance Through Intrinsic Motivation and Attention for Learning. Factors with influence include *enhanced expectancies* for performance (positive experiences or outcomes), performer *autonomy*, and an *external focus of attention*. The putative mechanisms for motivational effects include their roles in generating dopaminergic response in *temporal pairing* with skill practice. This dopaminergic response is thought to strengthen memory and learning [2] and to contribute a form of intrinsic neuromodulation to the development of efficient *goal-action coupling* via structural and functional neural connectivity [3,4•].

Enhanced expectancies

Certainly, past performance accomplishments establish a foundation for a sense of confidence or self-efficacy [5] and previously positive outcomes give rise to positive expectations for future outcomes in similar circumstances. Further, confidence has been recognized as a prospective predictor of motor performance [6–8], and learning (retention and/or transfer of skill) [9–11]. A variety of means to experimentally influence a performer's perception of ability or prospective confidence have been found to affect performance and learning. Among these are the provision of normatively superior or better-than-average performance feedback [12–15], evidence of the performer's own best performance [16,17], liberal definitions of task success or descriptions of relative task ease [18,19,20•], stereotype-relevant and other priming [21,22], visual illusions [23,24], conceptions of ability as incremental [25,26], and positive affect. Clearly, not all approaches to enhancing expectancies, including deception and the provision of external rewards, are suitable for translation into practice.

Several studies of novice, experienced, and expert performers illustrate the impact of a sense of success on subsequent performance. Palmer *et al.* [19] provided non-golfers with instructions that putting to a target located within smaller or larger concentric circles would constitute 'good' golf putts. The group for whom the larger circle was identified putted more accurately in practice and in later 24-hour retention and transfer tests than did the group with the more conservative or higher standard of success. The larger-circle group experienced 22% of their trials on average as 'good' by definition,

Figure 1



Schematic of the Optimizing Performance Through Intrinsic Motivation and Attention for Learning (OPTIMAL) theory [1**]. Conditions that provide the performer with a sense of autonomy and enhance expectancies for future performance, and an external focus of attention, facilitate goal-action coupling by keeping attention directed at the task goal and reducing a detrimental self-focus. The resulting successful motor performance and ease of movement further contribute to learning and subsequent performance.

whereas the smaller-circle participants ‘saw’ success on only 7.9% of their practice-phase trials.

Stoate *et al.* [15] provided feedback to one group of experienced competitive runners while running on a treadmill at 75% of their maximal oxygen consumption that indicated they were performing more efficiently than others (*e.g.*, “You’re doing great. Your oxygen consumption is in the top 10th percentile for your age and gender”). Perceived running ease and positive affect increased, fatigue was reduced, and oxygen consumption decreased after the expectancy enhancement for that group but remained the same in a control group who did not receive this purported insight. A study by Rosenqvist and Skans [8] of professional male golfers on the European Professional Golfers’ Association tour examined performance in subsequent tournaments one week after a golfer marginally made or missed the prior tournament’s cut line. After accounting for pre-existing ability (scoring average) differences, those golfers who in effect received a boost of confidence from just making the cut outperformed those who just failed to make the cut, by approximately a quarter of a shot after two rounds in the subsequent tournament.

Autonomy

Practice conditions that support a performer’s sense of agency [27], or autonomy and self-determination [28], even in ostensibly small ways [29,30], can affect motor performance and learning [1**]. In one example of a burgeoning literature with learner control over aspects

of practice, Post *et al.* [31] provided one group of basketball novices with the opportunity to determine how many set shots to take and the spacing of those shots within 15-min practice epochs. A yoked group shot at the rate and inter-shot spacing of counterparts in the learner-controlled group. Participants in the learner-controlled group received higher form scores from blinded raters and shot more accurately during the retention test than did those in the yoked group.

Lewthwaite *et al.* [29] demonstrated that choices incidental to the task, such as choice of golf ball color in a golf putting task, could produce learning differences from yoked counterparts not given these opportunities. These findings parallel effects of a wide variety of task-relevant and not-so-relevant choices on learning, as well as other autonomy-supportive conditions including respect for learner opinions [29, Experiment 2] and instructor language antithetical to authoritarian control [32] (see Wulf and Lewthwaite [1**] for further examples).

Does the autonomy-support effect seen in novice motor learners hold for more expert performers? Although few studies have examined this issue in elite performers to date, Halperin *et al.* [33*] showed that giving athletes choice can have immediately beneficial effects on motor performance. A world-champion kickboxer ([33*], Study 1) and amateur kickboxers with national-level competitive experience ([33*], Study 2) performed under counterbalanced conditions marked by choice over the order of type of punch to be thrown or experimenter-determined

order. When they had a choice, punching velocities and impact forces were higher, compared with the control condition with a prescribed order of punches.

External focus of attention

A clear focus on the task goal is essential for optimal performance and learning. Evidence has amassed for the advantages of concentrating on or adopting an *external focus* of attention on the intended movement effect (e.g., motion of an implement, striking a target, exerting force against an object) relative to an *internal focus* on body movements (for reviews see Wulf [34**] and Wulf and Lewthwaite [1**]). Since the publication of the first study demonstrating the advantages of an external focus for motor learning [35], many studies have followed. In that original paper, learning was found to be enhanced when participants were instructed to focus on the pressure exerted on the wheels of a ski simulator (external focus) (Experiment 1) or the markers attached to a balance platform (Experiment 2) as opposed to their feet (internal focus). In fact, in these and subsequent studies, a one- or two-word difference in the instructions ('your hand' versus 'the club') had differential effects on learning—despite similar informational content. Instructions that direct attention *away from one's body or self* and *to the intended movement effect* have consistently been found to have a beneficial effect on motor performance and learning. The stronger benefits found for performers with more distal rather than proximal targets (e.g., on the more distant flag rather than the golf ball) for an external focus are consistent with shifting attention away from one's own body [36]. The use of analogies may serve the same purpose by directing attention externally to the production of a given image, rather than to body movements [37].

An external focus often has immediate beneficial effects on performance, as well as retention and transfer. Enhanced performance or learning with an external focus has been found for movement *effectiveness* (e.g., accuracy in hitting a target [36], producing force [38] maintaining a balanced position) and *efficiency* (e.g., reduced muscular activity, movement kinetics [38], oxygen consumption [39]) [1**,34**]. Thus, an external focus of attention effectively speeds the learning process so that a higher skill level is achieved sooner [40].

Mechanisms for motivation and attentional focus effects

Enhanced expectancies, autonomy support, and an external attentional focus are thought to optimize skill acquisition and performance through effects on learning and memory, as well as brain structural and functional connectivity. Rewarding circumstances that enhance expectations for future performance success can potentiate even more success, improvement, and learning. Expectancies can operate through cognitive, attentional,

behavioral, and neuromodulatory (dopaminergic) means to affect subsequent performance, fulfilling performance-affecting task-readying and priming roles, as well as memory-enhancing ones [2,41]. Self-efficacy can influence goals and goal-setting [42], self-regulatory activity [25,43], and effort expenditure [12,44]. Expectancies can affect attention priming and prioritization, heightening attention to task-relevant cues and suppressing it for less relevant ones [45,46]. Anticipatory neural processes including cortical excitation and inhibition and reduced reaction times can facilitate motor performance [47,48]. The presence of dopamine from the expectation of rewarding experiences or outcomes, in conjunction with task practice, further acts to 'stamp in' [2,41] memories and build the structural and functional connections that underlie skilled performance [3,4*].

Autonomy-supportive conditions share an anticipatory sense of agency or control [5,27] with other means of enhancing expectancies, often producing higher self-efficacy along with intrinsic motivation and performance and learning effects [1**,11,32,49]. Like self-efficacy effects [43], potential consequences of autonomy support include facilitation of performance through enhanced processing of task errors and greater self-regulatory responsiveness [50].

Empirical findings related to an external attentional focus strongly point to movement effectiveness and movement efficiency benefits indicative of increased automaticity of movement. An external focus may play a dual role in producing these effects, including: (a) directing attention to the task goal and (b) preventing disruptive body/self-related (internal) attentional diversions from the task goal. Thus, the external focus is an important contributor to goal-action coupling, potentially through a role in functional connectivity [51*]. Further, by consistently producing more successful performance outcomes and ease of movement (*i.e.*, personal performance accomplishments [5]), an external attentional focus contributes to enhanced expectancies for performance [9,11] and goal-action coupling through a confidence pathway (see Figure 1). Importantly, previous research [9,11] suggests that enhanced expectancy, autonomy support, and external focus factors can provide complementary or additive value in the optimization of performance and learning.

Concluding remarks

In marked contrast to only a decade ago, motivational and attentional focus effects on motor performance and learning are now hard to ignore. The myriad operationalizations of motivational and attentional focus variables (see Ref. [1**]) already seed practical applications for a variety of performers and learners, from elite athletes to individuals seeking to recover from neurological and other conditions. Many research opportunities exist to examine optimizing mechanisms for early, as well as superior and

extraordinary, movement, utilizing multiple levels of analysis and methodologies. The possibility that intrinsic neuromodulatory effects, such as those that may occur when motivation and attention are temporally paired with motor practice, can be utilized in lieu of, or in conjunction with, other forms of neuromodulation deserves further attention. To connect the substantial behavioral evidence of motivational and attentional focus influences on complex motor performance and learning to their putative effects on memory and neural underpinnings of goal-action coupling represents a significant challenge going forward. Future research will benefit from continued development and deployment of multiple methods to capture the scope, timing, and precision of potentially widespread brain activations and deactivations that support very diverse task performance [52,53].

Conflict of interest statement

Nothing declared.

References and recommended reading

Papers of particular interest, published within the period of review, have been highlighted as:

- of special interest
- of outstanding interest

1. Wulf G, Lewthwaite R: **Optimizing performance through intrinsic motivation and attention for learning: the OPTIMAL theory of motor learning.** *Psychon. Bull. Rev.* 2016, **23**:1382-1414.
- In this paper, Wulf and Lewthwaite [1] provide review of behavioral evidence from three general lines of inquiry (enhanced expectancies, autonomy support, and an external focus of attention) on motor performance and learning. A theoretical framework addresses the putative relationship of these rewarding factors to dopaminergic response, which when temporally paired with task practice, both primes good performance and builds structural and functional brain connectivity consistent with effective and efficient goal-action coupling.
2. Wise RA: **Dopamine, learning and motivation.** *Nat. Rev. Neurosci.* 2004, **5**:1-12.
3. Milton J, Solodkin A, Hlutić P, Small SL: **The mind of expert motor performance is cool and focused.** *Neuroimage* 2007, **35**:804-813.
4. Kim W, Chang Y, Kim J, Seo J, Ryu K, Lee E, Woo M, Janelle CM: **An fMRI study of differences in brain activity among elite, expert, and novice archers at the moment of optimal aiming.** *Cogn. Behav. Neurol.* 2014, **27**:173-182.
- In a representative study of cross-sectional approaches to neural correlates of successful athletic performance, Kim *et al.* [4] had elite, expert, and novice archers perform a simulated archery aiming task (button push) in an MRI scanner. Neural activation patterns were different between the three types of performers, with the elite group demonstrating a more localized neural response in their pre-shot routine compared with the activations of both other groups, also different from each other.
5. Bandura A: **Self-efficacy: toward a unifying theory of behavioral change.** *Psychol. Rev.* 1977, **84**:191-215.
6. Feltz DL, Chow DM, Hepler TJ: **Path analysis of self-efficacy and diving performance revisited.** *J. Sport Exerc. Psychol.* 2008, **30**:401-411.
7. Moritz SE, Feltz DL, Fährbach K, Mack D: **The relation of self-efficacy measures to sport performance: a meta-analytic review.** *Res. Q. Exerc. Sport* 2000, **71**:280-294.
8. Rosenqvist O, Skans ON: **Confidence enhanced performance?—the causal effects of success on future performance in professional golf tournaments.** *J. Econ. Behav. Organ.* 2015, **117**:281-295.
9. Pascua LAM, Wulf G, Lewthwaite R: **Additive benefits of external focus and enhanced performance expectancy for motor learning.** *J. Sports Sci.* 2015, **33**:58-66.
10. Stevens D, Anderson DI, O'Dwyer NJ, Williams AM: **Does self-efficacy mediate transfer effects in the learning of easy and difficult motor skills?** *Conscious. Cogn.* 2012, **21**:1122-1128.
11. Wulf G, Chiviawosky S, Cardozo P: **Additive benefits of autonomy support and enhanced expectancies for motor learning.** *Hum. Mov. Sci.* 2014, **37**:12-20.
12. Hutchinson JC, Sherman T, Martinovic N, Tenenbaum G: **The effect of manipulated self-efficacy on perceived and sustained effort.** *J. Appl. Sport Psychol.* 2008, **20**:457-472.
13. Lewthwaite R, Wulf G: **Social-comparative feedback affects motor skill learning.** *Q. J. Exp. Psychol.* 2010, **63**:738-749.
14. Wulf G, Chiviawosky S, Lewthwaite R: **Normative feedback effects on the learning of a timing task.** *Res. Q. Exerc. Sport* 2010, **81**:425-431.
15. Stoaite I, Wulf G, Lewthwaite R: **Enhanced expectancies improve movement efficiency in runners.** *J. Sports Sci.* 2012, **30**:815-823.
16. Clark SE, Ste-Marie DM: **The impact of self-as-a-model interventions on children's self-regulation of learning and swimming performance.** *J. Sports Sci.* 2007, **25**:577-586.
17. Chiviawosky S, Wulf G: **Feedback after good trials enhances learning.** *Res. Q. Exerc. Sport* 2007, **78**:40-47.
18. Chiviawosky S, Wulf G, Lewthwaite R: **Self-controlled learning: the importance of protecting perceptions of competence.** *Front. Psychol.* 2012, **3** <http://dx.doi.org/10.3389/fpsyg.2012.00458> Article 458.
19. Palmer K, Chiviawosky S, Wulf G: **Enhanced expectancies facilitate golf putting.** *Psychol. Sport Exerc.* 2016, **22**:229-232.
20. Trempe M, Sabourin M, Proteau L: **Success modulates consolidation of a visuomotor adaptation task.** *J. Exp. Psychol. Learn. Mem. Cogn.* 2012, **38**:52-60.
- To examine the effects of subjective success and a memory consolidation period, Trempe *et al.* [20] used a visuomotor adaptation task. The task involving moving a manipulandum with the non-dominant hand to targets with visual feedback rotated 30°. Participants provided with an easy objective (touch the cursor to any part of the target) rather than a more difficult objective (cover the target completely with the cursor) perceived that they were more successful in session one and had less error in a second session. Participants retested 24 hours after their first session with the easy objective had better performance than those tested 5 min after the first session, thus both subjective success and a memory consolidation period appeared necessary for learning.
21. Hively K, El-Alayli A: **You throw like a girl: the effect of stereotype threat on women's athletic performance and gender stereotypes.** *Psychol. Sport Exerc.* 2014, **15**:48-55.
22. Wulf G, Chiviawosky S, Lewthwaite R: **Altering mindset can enhance motor learning in older adults.** *Psychol. Aging* 2012, **27**:14-21.
23. Witt JK, Linkenauger SA, Proffitt DR: **Get me out of this slump! Visual illusions improve sports performance.** *Psychol. Sci.* 2012, **23**:397-399.
24. Chauvel G, Wulf G, Maquestiaux F: **Visual illusions can facilitate sport skill learning.** *Psychon. Bull. Rev.* 2015, **22**:717-721.
25. Jourden FJ, Bandura A, Banfield JT: **The impact of conceptions of ability on self-regulatory factors and motor skill acquisition.** *J. Sport Exerc. Psychol.* 1991, **8**:213-226.
26. Wulf G, Lewthwaite R: **Conceptions of ability affect motor learning.** *J. Mot. Behav.* 2009, **41**:461-467.
27. Chambon V, Haggard P: **Sense of control depends on fluency of action selection, not motor performance.** *Cognition* 2012, **125**:441-451.
28. Sanli EA, Patterson JT, Bray SR, Lee TD: **Understanding self-controlled motor learning protocols through self-determination theory.** *Front. Psychol.* 2013, **3** <http://dx.doi.org/10.3389/fpsyg.2012.00611> Article 611.

29. Lewthwaite R, Chiviawosky S, Drews R, Wulf G: **Choose to move: the motivational impact of autonomy support on motor learning.** *Psychon. Bull. Rev.* 2015, **22**:1383-1388.
30. Patal EA, Cooper H, Robinson JC: **The effects of choice on intrinsic motivation and related outcomes: a meta-analysis of research findings.** *Psychol. Bull.* 2008, **134**:270-300.
31. Post PG, Fairbrother JT, Barros JA, Kulpa JD: **Self-controlled practice within a fixed time period facilitates the learning of a basketball set shot.** *J. Mot. Learn. Dev.* 2014, **2**:9-15.
32. Hooyma A, Wulf G, Lewthwaite R: **Impacts of autonomy-supportive versus controlling instructional language on motor learning.** *Hum. Mov. Sci.* 2014, **36**:190-198.
33. Halperin I, Chapman DT, Martin DT, Lewthwaite R, Wulf G:
 • **Choices enhance punching performance of competitive kickboxers.** *Psychol. Res.* 2016 <http://dx.doi.org/10.1007/s00426-016-0790-1>.
- This paper of two within-participant studies of kickboxers (a single-subject case study of a world-champion kickboxer and a follow-up study with less expert athletes) illustrates the potential for using autonomy-supportive practice conditions with more experienced performers to boost performance. This intervention involved the simple and minor choice of order of punches to be practiced. Force production, as measured by an instrumented punching integrator, and punch velocity, were greater in the choice conditions in both studies.
34. Wulf G: **Attentional focus and motor learning: a review of 15 years.** *Int. Rev. Sport Exerc. Psychol.* 2013, **6**:77-104.
 This comprehensive review article of the attentional focus literature to 2012 examined over 80 studies, finding consistent support for the performance and learning advantages of an external focus of attention in a broad range of movement tasks, participant ages, and conditions.
35. Wulf G, Höß M, Prinz W: **Instructions for motor learning: differential effects of internal versus external focus of attention.** *J. Mot. Behav.* 1998, **30**:169-179.
36. Bell JJ, Hardy J: **Effects of attentional focus on skilled performance in golf.** *J. Appl. Sport Psychol.* 2009, **21**:163-177.
37. Guss-West C, Wulf G: **Attentional focus in classical ballet: a survey of professional dancers.** *J. Dance Med. Sci.* 2016, **20**:23-29.
38. Wulf G, Dufek JS: **Increased jump height with an external focus due to enhanced lower extremity joint kinetics.** *J. Mot. Behav.* 2009, **41**:401-409.
39. Schücker L, Hagemann N, Strauss B, Völker K: **The effect of attentional focus on running economy.** *J. Sports Sci.* 2009, **27**:1241-1248.
40. Wulf G: *Attention and Motor Skill Learning.* Human Kinetics Publishers; 2007.
41. Gruber MJ, Ritchey M, Wang S-F, Doss MK, Ranganath C: **Post-learning hippocampal dynamics promote preferential retention of rewarding events.** *Neuron* 2016, **89**:1110-1120.
42. Locke EA, Latham GP: **New directions in goal-setting theory.** *Curr. Dir. Psychol. Sci.* 2006, **15**:265-268.
43. Themanson JR, Pontiflex MB, Hillman CH, McAuley E: **The relation of self-efficacy and error-related self-regulation.** *Int. J. Psychophysiol.* 2011, **80**:1-10.
44. Fiorio M, Andani ME, Marotta A, Classen J, Tinazzi M: **Placebo-induced changes in excitatory and inhibitory corticospinal circuits during motor performance.** *J. Neurosci.* 2014, **34**:3993-4005.
45. Shomstein S, Johnson J: **Shaping attention with reward: effects of reward on space- and object-based selection.** *Psychol. Sci.* 2013, **24**:2369-2378.
46. Themanson JR, Rosen PJ: **Examining the relationships between self-efficacy, task-relevant attentional control, and task performance: evidence from event-related brain potentials.** *Br. J. Psychol.* 2015, **106**:253-271.
47. Arias P, Robles-García V, Espinosa N, Corral-Bergantiños Y, Mordillo-Mateos L, Grieve K, Cudeiro J: **The effects of expectancy on corticospinal excitability: passively preparing to observe a movement.** *J. Neurophysiol.* 2014, **111**:1479-1486.
48. Meadows CC, Gable PA, Lohse KR, Miller MW: **Motivation and motor cortical activity can independently affect motor performance.** *Neuroscience* 2016, **339**:174-179.
49. Ste-Marie DM, Vertest K, Law B, Rymal AM: **Learner-controlled self-observation is advantageous for motor skill acquisition.** *Front. Psychol.* 2013, **3** <http://dx.doi.org/10.3389/fpsyg.2012.00556> Article 556.
50. Legault L, Inzlicht M: **Self-determination, self-regulation, and the brain: autonomy improves performance by enhancing neuroaffective responsiveness to self-regulation failure.** *J. Pers. Soc. Psychol.* 2013, **105**:123-138.
51. Kuhn Y-A, Keller M, Ruffieux J, Taube W: **Adopting an external focus of attention alters intracortical inhibition within the primary motor cortex.** *Acta Physiol. (Oxf.)* 2016 <http://dx.doi.org/10.1111/apha.12807>.
- This paper reports one of the first studies to examine potential brain-related differences between external, internal, and control attentional focus conditions. In a within-participant design, individuals performed an isometric force-production task with their fingers under separate attentional focus instructions. In separate sessions, subthreshold transcranial magnetic stimulation (TMS) and paired-pulse TMS were applied over the contralateral primary motor cortex while the same task was performed. The familiar performance advantage of the external focus condition was replicated in longer time to task failure. Further, the external attentional focus was accompanied by finger electromyographic (EMG) activity suppression and increased short-interval intracortical inhibition (SICI), suggesting greater neural and movement efficiency with the external focus condition. Importantly, the study demonstrates instant differential modulation within the same individuals when external and internal attentional foci are used.
52. Bernardi G, Ricciardi E, Sani L, Gaglianese A, Pappasogli A, Ceccarelli R, Franzoni F, Galetta F, Santoro G, Goebel R et al.: **How skill expertise shapes the brain functional architecture: an fMRI study of visuo-spatial and motor processing in professional racing-car and naïve drivers.** *PLoS One* 2013, **8**:e77764 <http://dx.doi.org/10.1371/journal.pone.0077764>.
53. Jongkees BJ, Colzato LS: **Spontaneous eye blink rate as predictor of dopamine-related cognitive function—a review.** *Neurosci. Biobehav. Rev.* 2016, **71**:58-82.