7 Effortless Attention, Hypofrontality, and Perfectionism

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Autotelic experiences, popularly known as flow, are associated with enhanced or even optimal performance. They occur when one becomes so deeply engrossed in a task and pursues it with such passion that all else disappears, including any sense of the passage of time or the worry of failure. Attention and action in such an autotelic state seem to flow effortlessly, and the task, whichever it may be, is performed without strain or effort to the best of the person's ability.

In sports competition, for instance, such a performance-enhancing state of mind is, for rather obvious reasons, highly desirable. Although no lives are at stake in the literal sense, as there are, for instance, in the skilled movements of a surgeon in the operating theater, winning or losing in sports is, in contemporary society at least, not a minor matter. There can be an extraordinary monetary benefit to be had for professional athletes and their entourages, along with a whole host of other perks, such as prestige and social status, to say nothing of things like national pride. It is not surprising, then, that no effort is being spared in optimizing athletic performance on the part of the people who have a stake in it. This includes, obviously, the desire to use this somewhat peculiar alteration to mental status known as flow as a way to tap into superior performance, preferably at will.

There is, as there has to be, only one minor hitch. We don't know, you see, what makes flow come and go, so to speak. Without some decent grasp of how to induce it, preferably on command, and maintain it, preferably in those all-important critical moments, athletes cannot reliably take advantage of it on their way to glory, gold, or other rewards, to say nothing of that place in history.

There are several reasons why we don't understand the underlying mechanisms, cognitive or neural, of autotelic experiences. Even compared to other altered states of consciousness that are equally difficult to nail down in terms of neurocognitive mechanisms—meditation, hypnosis, daydreaming, or the runner's high—flow states have escaped, in more ways than one, the attention of cognitive neuroscientists. The main reason for this oversight is perhaps the fact that the phenomenon is somewhat of a paradox and remains difficult to explain according to traditional theories of attention and mental effort for the simple reason that they assume that better performance, on any task, is associated with increased conscious effort allocated to that task. Theories of attention and action, such as those by Kahneman (1973) or Sanders (1997), assume that higher task demands require more effort, both objectively, in terms of caloric consumption by the brain, and subjectively, in terms of perceived mental effort. In flow, however, the opposite appears to be the case. Here the perceived mental effort decreases, sometimes to the point of utter effortlessness, yet such seemingly automatic action is associated with superior performance. In other words, increased task demands are met not by an increase in mental effort but by a decrease. In flow states, in fact, action seems to be entirely outside of conscious awareness—the experience is often described as if it happens by itself, without any effort at all. What, then, might explain how a decrease in mental effort, especially in terms of attentional resources (according to Kahneman and Sanders), improves task performance?

This chapter starts by summarizing previous work in the cognitive neurosciences that might account for this phenomenon. To understand the neurocognitive mechanisms underlying the flow state requires that we fully appreciate the fact that the brain runs two functionally and anatomically distinct information-processing systems, the explicit and implicit systems, and that we rigorously apply the flexibility–efficiency trade-off that exists between these two systems to the computational problem of skilled motor performance. In addition, the transient hypofrontality theory is briefly outlined, which can account for the phenomenological features of autotelic experiences, such as, for instance, the merging of awareness and action, the exclusion from consciousness of distractions, the loss of the sense of time passing, and the lack of worry of possible failure. These are all higher order metacognitive processes that require, in order to be subtracted from consciousness, the downregulation of brain regions, primarily in the prefrontal cortex, that play a key role in the computation of these higher order thoughts and feelings in the first place.

Finally, this chapter ends with a specific example from the sports sciences of how our understanding and appreciation of these mechanisms can inform training strategies to improve performance. To that end, we review the evidence linking perfectionism to success in competition. This is relevant because athletes who show negative perfectionist tendencies—that is, are overly self-critical, preoccupied with mistakes, and feel that a discrepancy exists between expectation and result—often fail to perform at their best. Their frequent inability to enter a state of effortless action, especially when the stakes are high, informs our understanding, in mechanistic terms, of how personality characteristics and individual differences influence the brain processes that control the execution of a skilled movement.

I Don't Know How to Do It, but My Body Does

A key to understanding the neurocognitive underpinnings of the flow state, its phenomenology included, arises from the well-known but apparently underappreciated distinction made between the explicit and implicit information-processing systems. Briefly, the brain operates two distinct information-processing systems to acquire, represent, and implement knowledge. The explicit system is rule-based, its content can be expressed by verbal communication, and it is tied to conscious awareness. In contrast, the implicit system is skill or experience based, its content is not verbalizable and can only be conveyed through task performance, and it is inaccessible to conscious awareness (Ashby and Casale 2002; Dienes and Perner 1999; Schacter and Bruckner 1998). Research on animals, patients with brain damage, and neuroimaging studies of healthy subjects have shown that these systems can be dissociated from each other functionally and anatomically (Schacter and Bruckner 1998; Squire 1992).

The explicit system is a sophisticated system that represents knowledge in a higher order format; that is, it represents additional information about the information, such as the fact that it contains the information it contains. This permits the information to be broadcast to a global work space, making it usable for other parts of the system. The complexity involved in organizing information in propositional and abstract terms is beyond any single brain structure's computational ability. Thus, the explicit system depends on several brain structures, each specialized in performing a particular step of information processing. Grossly oversimplified, the prefrontal cortex handles working memory, the hippocampus helps in the consolidation of that information, and permanent storage occurs in a plethora of cortical networks.

The implicit system is a more primitive and evolutionarily ancient system that does not form higher order representations. As a consequence, the explicit system, or any other functional system in the brain, does not know about knowledge imprinted in the implicit system, making it unavailable for representation in working memory and, thus, consciousness. For implicit knowledge to reach consciousness, it must first be explicated, which cannot proceed, due to its concrete-operational organization, through a bottom–up process. We must perform or execute implicit knowledge, which allows the explicit system to observe it and extract its essential components. Because the implicit system precludes metarepresentations, it is not burdened by the computational complexity that comes with higher order thought, and a single brain structure, such as the basal ganglia or cerebellum, can handle all information-processing steps (Dietrich 2004a). This makes knowledge execution in the system highly efficient and fast, albeit only to its specific application. Smooth sensorimotor integration leading to purposeful motion must occur in real time, and this is the domain of the implicit system, responding to environmental stimuli in a rapid and accurate manner (Dietrich 2004a).

This efficiency of implicit knowledge is paramount to motor skills because purposeful movement must occur in real time. As an example, consider the lightening-fast escape maneuvers of a squirrel. Lacking an overall strategy or plan, the squirrel gets to safety entirely by relying on moment-to-moment adjustments. Such smooth feedback-driven sensorimotor integration can produce extremely complex movement patterns that can serve an overall and/or higher goal (safety) yet require no more than the reaction to immediately preceding input. This is not unlike an outfielder trying to catch a fly ball. Starting with only a vague idea as to the ball's ultimate location, the player progressively approximates that location by continuously adjusting his or her movements based on updates of the ball's trajectory and speed as it approaches (McLeod et al. 2001). Because these are fluid situations occurring in real time, they require, first and foremost, efficiency. A system is most efficient if it represents knowledge in a fully implicit manner—that is, it codes the application of the knowledge within the procedure and refrains from buffering any other property of the information in a higher order representation. On the flip side, this setup is the reason why motor behavior must progress stepwise from immediately preceding input. The lack of metarepresentation precludes the system from calculating hypothetical future scenarios that would enable it to anticipate several steps in advance.

Framed in computational terms, it becomes clear why such metarepresentation is unattainable for movement. Even for squirrels, the number of possible next moves is so astronomically high that future projections would quickly multiply to infinity. Such a nonlinear calculation is unpredictable, rendering the calculation of hypothetical future scenarios useless. Accordingly, the combinatorial complexity of skilled movement, coupled with the real-time speed requirement of its production, make it impossible to micromanage such a system explicitly. However, the explicit system can exert influence by steering events toward a strange attractor. For instance, a tennis match is a dynamic system with two moving targets. Although moment-to-moment events are completely unpredictable, the explicit system might settle to one or more strange attractors, such as the opponent's weak backhand. The explicit system can guide motor output toward such a strange attractor as long as the attractor is of a complexity that does not challenge the capacity limit of working memory.

This flexibility–efficiency trade-off between the explicit and implicit systems is critical in understanding the control of skilled movement. The explicit system has evolved to increase cognitive flexibility but is limited, exactly because of its ability to deal with computational complexity, to tasks that must be solved outside real time and that can be broken up into chunks of complexity that do not exceed the capacity limit of working memory. Since this is not the case for skilled movement, the implicit system must handle real-time movements, which it does on a moment-by-moment basis (Dietrich 2004a). This is especially so for complex patterns that have been automated through hours of repetition. The more a motor skill is practiced and becomes habitual, a learning effect often known by the unfortunate misnomer muscle memory, the more the details of its execution come under the control of the implicit system in the basal ganglia, supplementary motor cortex, and lower brain centers in the brain stem (Jenkins et al. 1994).

Because a highly practiced skill is still performed by a conscious person, it is possible for the explicit system to partake in the skill's moment-to-moment execution. To stay with the example of tennis, this occurs when a player buffers any part of the game—consciously reflecting on the strokes, for instance—in a higher order representation and allows such analysis to guide movements. However, due to the explicit system's inefficiency and capacity limit, it should be obvious that any amount of transfer of the actual motor execution from implicit to explicit control gravely affects its quality. Indeed, it has been proposed that the degree of implicitness of motor competence is positively related to the quality of the performance (Dietrich 2004a).

Let's take a concrete example to illustrate the deleterious effect of such a transfer. A movement can be executed by the explicit system and/or the implicit system, but an explicit-predominant movement proceeds from a mental representation that is, for all we know, different in kind from one that is implicit predominant. Transferring the control of the motion from implicit to explicit has rather profound consequences for its speed and efficiency. Take Roger Federer's tennis serve, for instance, which, during competition, is entirely driven by his implicit system. None of the task's requirements are, presumably, explicit in consciousness as he performs the serve. To find out how much the explicit system actually knows about how to do a tennis serve, we can introduce a slight change. All we have to do is to ask Federer to perform the serve with his other arm. Now the explicit system must take over. The problem is that a tennis serve is too fast and too complicated to be executed by a mental representation that is general in nature and needs to apply its abstract knowledge, in real time no less, to a specific example. The resulting tennis serve would bear little resemblance to a world-class one, and neither would the brain activation.

In sum, the implicit system owes its efficiency and speed to the fact that it does not form costly higher order representations of its knowledge. This very feature, however, also limits its use to the specific application in which it is embedded. The explicit system owes its flexibility to exactly this abstract representational format, which is the very feature that limits its use for applications, such as skilled movements, where time is of the essence. Each system can have a representation of the task requirements, and there is, of course, a lot of anatomical cross-wiring, for various reasons, at several levels between these two systems, but their respective motor representations are still fundamentally different (Dietrich 2008), one being general, context independent (explicit), and the other specific and context dependent (implicit; Dietrich 2004a).

This allows us to look at the paradox of effortless performance from a different angle. Traditional models of attention have assumed that superior performance, in any task, is associated with increased attentional effort allocated to that task (Kahneman 1973; Sanders 1997). Experiments on experts—skilled athletes, in most cases—have shown that once a motor skill is perfected, directing attention to a motor task is detrimental to its execution (e.g., Beilock and Carr 2005; Ravizza 1977). Wulf and Lewthwaite (chapter 3, this volume) have also found that directing attention to the effect of an action increases performance, irrespective of skill level, but this is different from directing attention to the actual execution of the movement. This literature has broadly supported an inverse, instead of a linear, relationship between conscious attention to movement and performance (Fitts and Posner 1973). Indeed, recent computational models have shown that such an inverse relationship between focusing the mind on motor execution and actual motor execution is inherent in any dynamic system that operates with time-delayed feedback and is subjected to random perturbations (Milton et al., forthcoming; Insperger 2006). According to these models, optimal performance requires that an optimal amount of attention be allocated to a task, and the optimal amount of attention for an expert is, apparently, as little as possible, while the optimal amount of attention for a novice is, apparently, as much as possible.

Thus, optimal performance, by an expert, of a well-learned, real-time, sensorimotor integration task is associated with maximal implicitness of the task's execution. Put another way, effortless attention is an inherent feature of superior performance in such situations.

The computational perspective on the explicit–implicit distinction also accounts for some of the phenomenal features of the flow state. People have described these autotelic experiences, saying that action and awareness are merged, the surrounding events are excluded from consciousness, there is no worry of failure, the movements feel as if executed automatically, self-consciousness disappears, or the sense of time becomes distorted. These are all examples of metacognitive processes that require explicit, higher order processing. In other words, they are *about* the motor task. If any of these processes were activated and allowed to feed into the computation of the actual motor plan, the performance level would suffer due to the inherent loss of efficiency of applying general knowledge to a specific movement.

The flow experience, then, precipitates that those metacognitive processes are downregulated. This, as we will see in a later section, is easier for some people than for others. Given that the explicit system which computes such higher order thought is subserved by prefrontal regions, flow experiences must occur during a state of transient hypofrontality that can bring about the inhibition of the explicit system

(Dietrich 2003, 2004b, 2006). To see how this might take place, a brief, general overview of the transient hypofrontality theory (THT) might be helpful.

Transient Hypofrontality

The THT proposes a common neural mechanism for altered states of consciousness. The theory is explicitly based on functional neuroanatomy and views consciousness as composed of various attributes, such as self-reflection, attention, memory, perception, and arousal, which are ordered in a functional hierarchy with the frontal lobe necessary for the top attributes. Although this implies a holistic view in which the entire brain contributes to consciousness, it is evident that not all neural structures contribute equally to conscious experience. This layering concept localizes the most sophisticated levels of consciousness in the zenithal higher order structure: the prefrontal cortex. From such considerations, the THT of altered states of consciousness can be formulated, which attempts to unify all altered states into a single theoretical framework (Dietrich 2003, 2007).

Because the prefrontal cortex is the neural substrate of the topmost layers, any change to conscious experience should affect, first and foremost, this structure, followed by a progressive shutdown of brain areas that contribute more basic cognitive functions. Put another way, the highest layers of consciousness are most susceptible to change when brain activity changes. It follows from this "onion-peeling" principle, as we might call it, that higher cognitive processes such as working memory, sustained and directed attention, and temporal integration are compromised first when an alteration to mental status occurs. All altered states share phenomenological characteristics whose proper functions are regulated by the prefrontal cortex, such as time distortions, disinhibition from social norms, or a change in focused attention. This suggests that the neural mechanism common to all altered states is the transient downregulation of functional networks in the prefrontal cortex.

The reduction of specific contents of conscious experience is known as phenomenological subtraction. The deeper an altered state becomes, induced by the progressive downregulation of prefrontal regions, the more of those subtractions occur and people experience an ever greater departure from their normal phenomenology. In altered states that are characterized by severe prefrontal hypoactivity—various drug states such as those induced by LSD or PCP, for instance—this change results in an extraordinarily bizarre phenomenology—hallucinations and delusions, most prominently. In altered states that are characterized by less prefrontal hypoactivity, such as long-distance running, meditation, or hypnosis, the modification to consciousness is much more subtle. In any event, the idea is that an individual simply functions on the highest layer of phenomenological consciousness that remains fully operational.

A consequence of the THT is that full-fledged consciousness is the result of a fully operational brain. Thus, and despite popular belief to the contrary, default consciousness is the highest possible manifestation of consciousness, and all altered states represent, by virtue of being an alteration to a fully functional brain, a reduction in consciousness. Altered states of consciousness that are often presumed to be "higher" forms of consciousness, such as, for instance, transcendental meditation or the experiences reported after taking "mind-expanding" drugs, are therefore really "lower" states of consciousness, as they, functionally speaking, all reduce cognitive processes—attention, working memory, temporal integration, and so forth—that are associated with the highest forms of consciousness. This view is also in contrast to the theories of, for instance, William James (1890) and Charles Tart (1972), who maintained that normal consciousness is not qualitatively different from any other state of consciousness. It is difficult to imagine how "higher consciousness," whatever that might be, would look in terms of brain activity or feel in terms of phenomenology, but shouldn't it entail an enhancement of mental abilities ascribed to the prefrontal cortex rather than, as is the case in the above examples, their subtraction?

If all altered states share this common neural mechanism, why, then, does each feel unique? To anyone who frequents them, the experience of, say, hypnosis is unmistakably distinct from that of dreaming or meditation. How can we reconcile this with the proposal that prefrontal downregulation is the underlying cause for all altered states? A clue may be found in the induction procedure. There are several ways by which a change in mental status is achieved. We can use a variety of behavioral methods; for instance, we can take advantage of our ability to control executive attention, a method we use to enter the states of daydreaming, hypnosis, or meditation. This is also the route by which flow occurs—by a change in attentional focus. Alternatively, we can use our ability to engage in prolonged, rhythmic motion, such as running or dancing, to get into a trance state. One altered state, dreaming, we enter entirely involuntarily through a circadian rhythm controlled by the brain stem. And then there is the direct manipulation of neurotransmitter systems by taking psychoactive substances. It is almost certainly the case that these different techniques alter brain function in different ways, but the overall effect should, given the similarities in phenomenological subtractions, be the same. That is, according to the THT, mental functions computed at the level of the prefrontal cortex that comprise the top layers of consciousness are altered first, followed by a progressive downregulation of mental functions lower in the hierarchy. What accounts for the distinct experience of each state is that each induction method targets different sets of prefrontal networks which remove quite specific mental faculties from the conscious experience (Dietrich 2007).

Given the focus of this chapter on the experience of effortless action, especially in skilled motor performance during sports competition, we need to explore further the induction method that alters consciousness by using bodily motion, as it appears that this method changes overall brain function in a unique way. Complex locomotion, especially that involving large muscle groups, is an extremely demanding task in *computational* terms—that is, to be clear, for the brain, not the body. Movement has never been understood, certainly not in cognitive psychology, as a biocomputation of the highest order. And, if one continues to think, as is customary in many fields, that motor control is a minor part of the brain's daily chores, it will be difficult to understand the consequences of movement for all regions of the brain, including—or especially—those not directly involved in moving the body.

Thus, to help you along and make you more familiar with the seemingly counter-intuitive realities of a computational perspective, we provide you with a few intriguing facts designed, primarily, to help you with conceivability. These will then be followed by some of the empirical evidence showing that the simple act of, say, running activates vast areas of the brain and thus requires the redistribution of much of the brain's metabolic resources. For starters, consider artificial intelligence, a field in which motion is readily recognized as a huge computational problem. Human artificers have managed to make machines that beat you in chess in eight-and-a-half moves with half of their transistors unplugged; yet they can't make a robot that walks nicely on two feet, let alone one that does a slam dunk. It certainly isn't because they can't make the movable equipment—arms, legs, joints, and so on (the main problem seems to be balance—Kuo et al. 2005). The reason is that sensorimotor integration, in real time, requires an astronomical amount of number crunching. Even for the simple act of walking, the brain must control umpteen millions of muscle fibers to precise specification, with every twitch affecting the strength of the contraction of the next. This is computationally, and thus metabolically, very costly, even when the movement is controlled mostly by lower brain centers. Programming an analogous movement into a robot is a real headache and has yet to be done successfully (Kuo et al. 2005).

Next, consider the brain's motor system. By simply listing the number of structures devoted to movement, you can get an appreciation of the complexity of moving the body around: primary motor cortex, secondary motor cortices (i.e. premotor and the supplementary motor area or SMA), basal ganglia, the motor thalamus, cerebellum, red nucleus, substantia nigra, the massive pathway systems, and the motor neurons all along the spinal cord, among rather many others. This represents not just an enormous amount of brain volume but also a very high number, in percentage terms, of neurons. Why, for instance, does the cerebellum have more neurons than any other structure in the brain, including *the entire cerebral cortex*?! What do you think all these neurons do? They do the brunt of the work of fine motor coordination, the very thing for which brute computational power is so critically needed. And then, let's not forget, movement occurs through space, so any motor activity must integrate sensory processes, and soon we are at yet another, nearly equally long list of brain structures that must be activated in order to process the relevant perceptual information during exercise. However, we haven't yet finished because there are also those nuclei mediating autonomic regulation such as, for instance, in the hypothalamus, the reticular formation, and many nuclei in the medulla. At this point, all the person is doing with all this massive brain activation, I remind you, is simply moving!

Let's try a third, slightly more sensitive intriguing fact. The male human brain is about 150 grams heavier than the female one. It is universally understood that this is due to the male's higher body mass. However, let's stop for a moment and think about what this really means. The male brain has, on average, 8% to 10% more brain mass only so that he can throw around what amounts to no more than a few more kilos of body mass. It is hard to believe that moving around a few more kilos of muscle and bone requires so much additional brain mass, especially in percentage terms, given that we are animals who are already copiously equipped with neuronal goo. But it does.

Finally, also keep in mind that the human motor system is more highly evolved than that of other animals. Animals with much smaller brains can produce very complex movements, movements we find extraordinary, but what they cannot do is learn motor acts for which they are counterprepared, let alone to such a state of perfection the way humans can. Just think of our ability to swim butterfly, pole vault, or play the violin, all actions we are not evolved to perform. Try teaching these to a chimp.

Such crutches for the imagination are not, of course, sound evidence as far as neuroscience goes; we simply offer them here to help you start thinking of motion in terms of its neural costs. We must understand movement as a computational issue that requires vast amounts of resources *for the brain*, even if the movement is well automated and thus driven mostly by the implicit system and/or lower brain centers.

All this is underscored by the evidence. Several techniques such as ^{133}Xe washout, radioactive microsphere, and autoradiography, as well as EEG, single photon emission computed tomography (SPECT), near infrared spectroscopy (NIRS), and positron-emission tomography (PET), have been used to measure brain activity during exercise. Converging evidence from these studies indicates that exercise is associated with profound regional changes in motor, sensory, and autonomic regions of the brain (Holschneider et al. 2003; Sokoloff 1991; Vissing et al. 1996). Physical exercise, then, requires massive neural activation in a large number of neural structures across the entire brain. It follows that prolonged movement, especially involving the entire body, requires the *sustained* activation of a large amount of neural tissue (Dietrich 2006).

Yet during exercise, global blood flow to the brain, along with global cerebral metabolism and uptake of oxygen, remains constant (Ide and Secher 2000; Sokoloff 1992) or increases slightly (Secher et al. 2008). Thus, contrary to expectation, there is no evidence to suggest that the brain is the recipient of significant additional resources to offset the seemingly enormous metabolic demands that physical activity appears to require. So what, then, are the consequences for the brain of such a computationally demanding task without getting any, or only little, additional fuel?

The central idea behind the THT is that the brain, in order to drive the bodily motion, is forced to make profound changes to the way it allocates its metabolic resources. This follows from the facts that the brain has a finite energy supply and that movement is an extremely demanding task in *computational* terms. In other words, as the brain sustains, during exercise, the massive and widespread neural activation that runs motor units, assimilates sensory inputs, and coordinates autonomic regulation, it must take metabolic resources, given their limited availability, away from neural structures whose functions are not critically needed at the time, which are, according to the THT, areas of the prefrontal cortex and, perhaps, limbic system (Dietrich 2003, 2004a, 2006). This is supported by several lines of evidence in animals and humans using a multitude of techniques, such as EEG, event-related potentials, SPECT, PET, NIRS, radioactive microsphere, single-cell recording, autoradiography as well as several cognitive studies (Dietrich 2006, Dietrich and Sparling 2004, Tashiro et al. 2001).

The THT, then, simply proposes the following. When the brain is under strain, it starts to reserve its limited metabolic resources for operations that are critically needed at the time, which results, necessarily, in the downregulation of neural structures whose computations are not critical for the task at hand. As the strain continues, the brain is forced to go ever deeper into safe mode, and the THT simply suggests that this decline progresses from brain areas supporting the highest cognitive functions, down the functional hierarchy, one phenomenological subtraction at a time, to brain areas supporting the most basic ones. Thus, the prefrontal cortex, being the most zenithal higher order structure, is the first region whose computations are no longer supported sufficiently to reach muscles or consciousness. Prolonged physical exercise is simply one example of a general neural mechanism that accounts for the phenomenology of all altered states of consciousness, as, indeed, the experience of timelessness, living in the here and now, reduced awareness of one's surroundings, and diminished analytical or attentional capacities—all subtle modifications of mental functions that are typically ascribed to the prefrontal cortex—is consistent with a state of frontal hypofunction (Dietrich 2003). In most conditions or techniques producing alterations to mental function, prefrontal hypoactivity is all that is necessary, hence the name of the theory. However, if the strain continues, and, to stay with exercise, the person keeps on moving, say, running the 135-mile Badwater Ultramarathon, he or she is, sooner or later, reduced—in an onion-peeling principle of sorts—to his or her most basic mental capabilities.

This means, to come back to the topic of effortless attention and action, that sustained physical motion of the kind we see in many sports is particularly good at engendering flow states. The metabolic stress the brain is under during prolonged bodily motion causes a cascading ripple effect throughout the brain that facilitates—necessitates, actually—the inhibition of mental processes in the explicit system, which are, to repeat, supported primarily by computations in the prefrontal cortex. This eliminates metacognitive processes about the task more readily than when the exclusion of the same processes from phenomenal consciousness must be achieved purely by the muscle of focused attention, as is the case, for instance, in golf, meditation, or playing a musical instrument (see Dietrich 2003). In other words, a powerful physiological mechanism helps the person keep distractions out, which makes the task readily controlled by the implicit system, as it should be anyway for optimal execution. It is perhaps this additional mechanism that explains why autotelic experiences seem to be reported nowhere as frequently as in the arena of sports and exercise.

Perfectionism

A well-learned task is performed best if it is controlled maximally by the implicit system. As explained above, any interference by the explicit system in the actual execution of the task is detrimental to quality. Such interference can take many forms. While some people must guard against letting their explicit knowledge of the actual movement infringe on the action, others seem to be having more problems with avoiding buffering in working memory factors completely extraneous to the movement, such as worry about failure, and letting these considerations enter the motor plan execution. It is the latter kind of problem that interests us next.

Perfectionism is the disposition to regard anything short of perfection as unacceptable. Individuals possessing high levels of this trait strive for flawlessness and set excessively high standards for performance. This is accompanied by a pronounced tendency to be overly critical in evaluating their own behavior (Flett and Hewitt 2002; Frost et al. 1990). How perfectionism affects performance is highly debated in the sports sciences (Hall 2006). While some researchers have identified perfectionism as a positive trait that makes Olympic champions (Gould et al. 2002), others see perfectionism as a maladaptive trait that undermines, rather than helps, athletic performance (Flett and Hewitt 2005; Hall 2006).

The weight of the evidence suggests, however, that two major dimensions of perfectionism must be differentiated (Enns and Cox 2002; Stoeber and Otto 2006). The first dimension has been described as positive-striving perfectionism (Frost et al. 1993) and captures those facets of perfectionism that relate to perfectionist strivings, such as having high personal standards, setting exact benchmarks for one's performance, and having the drive to achieve excellence. This dimension is positively correlated with indicators of good adjustment, such as positive affect, endurance, and high academic performance (Bieling et al. 2003; Frost et al. 1993; Stumpf and Parker 2000).

The other, second, dimension has been described as self-critical perfectionism (Dunkley et al. 2003) and captures those facets of perfectionism that relate to critical self-evaluations of one's performance, such as constant concern over mistakes and negative feelings when expectations do not match results. This dimension is positively correlated with indicators of maladjustment, such as depression, stress, and anxiety (Stoeber and Otto 2006).

In sport and exercise psychology, the differentiation between positive-striving perfectionism and self-critical perfectionism is crucial because the evidence supporting perfectionism as detrimental to performance (Flett and Hewitt 2005; Hall 2006) is true only for those aspects of perfectionism associated with the self-critical dimension of perfectionism. This is not necessarily the case for those aspects that are associated with the positive-striving dimension, which is linked with positive characteristics and outcomes.

One example of this is the athlete burnout syndrome. Comparing a group of junior elite tennis players with high levels of burnout with a control group on dimensions of perfectionism, Gould and colleagues (2002) found that burned-out players reported higher levels of concern over mistakes and lower personal standards than players in the control group. As concern over mistakes is a core aspect of the self-critical dimension of perfectionism and personal standards a core aspect of the positive-striving dimension, the results suggest that only self-critical perfectionism is related to athlete burnout, while positive-striving perfectionism is not.

A similar conclusion can be drawn out from the link between perfectionism and goal orientation in athletes. Two cognitive dispositions can be distinguished here: task orientation and ego orientation (Duda and Nicholls 1992). Task orientation refers to an athlete's emphasis on mastering a task and on improving ability. This makes task orientation a good predictor of athletic development. In contrast, ego orientation represents an emphasis on outperforming others and demonstrating one's ability in comparison to others. While this emphasis may, on the one hand, motivate athletes to perform at a higher level, it may also increase the fear of failure or other such negative, external factors (Elliot 1997). A strong and exclusive ego orientation must be regarded as a potential risk to competitive performance (Ommundsen 2004).

Yet another example of this interaction is the link between perfectionism and competitive anxiety (Frost and Henderson 1991; Hall et al. 1998; Koivula et al. 2002; Stoeber et al. 2007). In general, perfectionism in athletes has been associated with higher levels of competitive anxiety (Flett and Hewitt 2005; Hall 2006). Upon closer inspection, however, only two tendencies, the concern over mistakes and negative reactions to imperfection, show a consistent relationship with high competitive anxiety as well as low self-confidence in competitions. Other aspects of perfectionism do not show this pattern (Stoeber et al. 2007). For instance, personal goals and striving for perfection show an inverse relationship with competitive anxiety as well as a positive relationship with self-confidence. These findings suggest that athletes who strive for perfection without preoccupying themselves with failure or mistakes experience lower levels of anxiety and higher levels of confidence in competitions (Craft et al. 2003).

Before these data are brought into contact, in the last section, with the neurocognitive mechanism described earlier, one final example underscores the necessity to differentiate between these two dimensions of perfectionism. The research described above relied on expert athletes. However, during the acquisition of a new task, everyone is a novice, and a new task is not yet controlled by the implicit system because it has not had the exposure to the task demands to build a mental representation of the task's requirements, which can only be done by doing the task. As a consequence, extraneous factors cannot as readily mess up performance because the acquisition of a new motor task is heavily controlled by the explicit system anyway. In this situation, some positive perfectionist tendencies can be outright beneficial. For instance, Stoll and colleagues (2008) investigated how perfectionism relates to performance by measuring performance increments over a series of trials in a new basketball training task. Two aspects of the perfectionism dimension were distinguished: (1) striving for perfection, representing the positive dimension, and (2) negative reactions to imperfection, representinging the self-critical dimension. The findings showed that perfectionism is not necessarily a maladaptive characteristic that undermines sport performance. Rather, during the learning of a new task, perfectionism may enhance performance and lead to greater progress over time. This meshes well with results from other fields in which striving for perfection is associated with higher grades in students (Bieling et al. 2003; Stoeber and Rambow 2007) and better predicts results on aptitude tests (Stoeber and Kersting 2007). Again, the critical factor here seems to be that such tests, like novel tasks, are handled mostly by the explicit system, and interference by external factors, especially when they relate to positive striving and motivation, can enhance task performance, which is less likely for tasks that have been automated and thus executed implicitly.

Conclusion

How, then, can we approach these findings in the context of the neural and cognitive explanations of effortless action? How do such personality characteristics facilitate or inhibit a state of effortless attention during sports competition? During the performance of a well-learned task, optimal performance is associated with maximal implicitness (Dietrich 2004a). It should follow from this that any interference by explicit mental processes in implicitly controlled action decreases the smoothness of the performance. This straightforward conclusion must be mitigated, however, for the simple reason that there are a whole host of other factors that also figure in the equation here, most prominently individual differences in working memory capacity (Beilock and Carr 2005) and how well the task difficulty matches the skill level. For the purpose of this chapter, however, we will pursue a different variable.

To that end, let's consider once more the characteristics that constitute autotelic experiences. The defining feature of this multifaceted phenomenon is the intrinsically rewarding experiential involvement in moment-to-moment activity that is accompanied by a positive experience quality. This main feature is responsible for further features, such as the merging of action and awareness, the altered sense of time, and the sense of control. In this state of effortless attention, the individual is completely absorbed in the activity itself and is no longer aware of being separate from the action. Although the person feels fully in control, things seem to flow as if fully automatic.

Some flow characteristics directly influence performance because they are inherently performance enhancing. For example, high concentration and a sense of control have often been cited as facilitators of performance (Eklund 1994, 1996; Williams and Krane 1997). Flow, then, is a functional state that facilitates performance directly. Indirect influences on performance have also been suggested. These involve the rewarding effects of the positive experience that accompanies flow. According to Csikszentmihalyi and colleagues (2005, 602), this positive experience is a powerful motivating force: "When individuals are fully involved in an activity, they tend to find the activity enjoyable and intrinsically rewarding." Because activities that have been rewarded are more likely to be performed again, the experience of effortlessly performing a task is likely to have a strong positive effect on motivation. As the activity is performed again, individuals find greater challenges in the task, which results in further skill development, more competence, and greater performance (Csikszentmihalyi and Larson 1987; Wong and Csikszentmihalyi 1991). In other words, the positive experience quality of flow has an indirect effect on performance by first influencing the motivation to perform the activity again, which then, in a second step, directly enhances the performance itself.

We can now attempt to disentangle a bit the effects of perfectionist tendencies on effortless action. Individuals with a negative disposition of perfectionism are extrinsically motivated, and their action is driven by a focus on outcomes and consequences (worrying about failure, ruminating, outperforming others, comparing themselves with others, experiencing competitive anxiety, having negative reactions to imperfection, being overly self-critical, etc.). Because these are factors external to the actual action, they, when activated, interfere with the quality of the execution. In other words, they are metacognitive processes that are computed in the explicit system and, as such, undermine the smoothness of a well-learned, implicitly controlled sensorimotor task.

Individuals with a positive disposition of perfectionism, on the other hand, are intrinsically motivated, and their action is driven by a focus not on ultimate objectives but rather on the quality of the activity itself. Because these cognitive processes concern themselves with the action per se, they cannot be regarded as metacognitive processes *about* the task. In other words, these cognitive processes are not superfluous to the motor plan; indeed, they represent the very features that characterize the flow state. As such, they do not decrease the efficiency of a skilled movement and might even have the potential, in a novel task that is not yet implicitly executed, to enhance its acquisition.

For individuals with negative perfectionist thinking patterns, the problem is compounded by the following set of circumstances. As explained above, to enter a state of flow, explicit metacognitive processes have to be inhibited. This necessitates that the prefrontal cortex, which plays a key role in their computation, be downregulated. This, however, is more difficult for individuals with perfectionist personality traits because they have, as it is, an elevated baseline activity in prefrontal regions compared to others (Damasio et al. 2000; Baxter 1990), which is, of course, the very source of their perfectionist thinking habits. In people suffering from full-blown obsessive–compulsive disorder, this hyperactivity in prefrontal regions is particularly pronounced (Baxter 1990). This excessive prefrontal activity acts like a double whammy for them. First, they have a longer way to go, so to speak, before the prefrontal cortex is sufficiently inhibited to keep thoughts extraneous to the activity from entering consciousness. Second, in those all important moments during competition, when everything is on the line, the predisposition to worry, to be anxious, and to think about the possible consequences of one's action is more readily reactivated because these are just the situations that tend to generate such thoughts in the first place.

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