KNOWLEDGE OF PERFORMANCE (KP)

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December 1, 2025

RECOMMENDED CITATION

Mohammed looti (2025). *KNOWLEDGE OF PERFORMANCE (KP)*. Encyclopedia of psychology. Retrieved from https://encyclopedia.arabpsychology.com/?p=21012

The Conceptual Framework of Knowledge of Performance (KP)

Knowledge of Performance (KP) is defined formally as the verbalized or encoded information pertaining specifically to the nature of the movement pattern employed by a learner during the execution of a motor skill. Unlike feedback focused solely on the achievement of the goal, KP directs attention inward, providing critical details about the kinematics, movement components, or coordination patterns utilized to attempt the desired aim. This intrinsic focus on the process, rather than solely the outcome, makes KP an indispensable tool in the motor learning environment, particularly when the relationship between movement quality and outcome success is complex or obscured. The fundamental role of KP is to provide the learner with an external reference point that clarifies internal sensory processes, enabling them to compare their intended action plan against the actual execution, thereby facilitating **error detection** and subsequent refinement of the motor program. KP can take various forms, including descriptive accounts, prescriptive recommendations, or even sophisticated visual aids, all designed to enhance the learner's awareness of their own physical dynamics during performance.

The utilization of KP is deeply rooted in contemporary theories of motor control, particularly those emphasizing the importance of internal modeling and **self-correction mechanisms**. When an individual attempts a new skill, their central nervous system generates a preliminary motor command, but without accurate external feedback concerning the movement's quality, the ability to refine this command is severely limited. KP acts as the bridge between the internal, often noisy, sensory signals and the external standard of optimal performance. For instance, a golf instructor might provide KP by stating, "Your lead elbow broke too early during the downswing," which is highly specific information about the movement pattern itself, independent of whether the ball reached the target. This specificity allows the learner to isolate and adjust the problematic component of the movement, which is far more efficient for long-term retention and generalization than simply knowing the outcome was unsuccessful. Therefore, KP serves not merely as corrective input but as a rich source of informational guidance that updates the learner's internal representation of the required motor skill, driving adaptive changes in the motor system.

Understanding the core definition of KP requires acknowledging that it is a subset of **augmented feedback**, meaning it is external information provided by a source other than the learner's own sensory systems (like vision, proprioception, or audition). While intrinsic feedback is generated automatically during the movement, augmented feedback like KP is delivered deliberately to supplement or clarify this intrinsic information. In situations where intrinsic feedback is misleading, absent, or difficult for the novice learner to interpret--such as in complex tasks requiring rapid coordination or when sensory receptors are compromised--KP becomes the primary driver of skill acquisition. The expert provision of KP requires the instructor or system to accurately observe, analyze, and translate complex motor actions into meaningful, actionable linguistic or visual cues that resonate with the learner's cognitive processing capacity. This transformation process is critical, as poorly formulated or overly complex KP can overwhelm the learner, leading to confusion and potential **dependence** on the external feedback source, thereby hindering the development of autonomous self-regulation skills vital for mastery.

Distinguishing KP from Knowledge of Results (KR)

A crucial distinction in motor learning literature lies between **Knowledge of Performance (KP)** and **Knowledge of Results (KR)**, although both fall under the umbrella of augmented feedback. KR focuses exclusively on the outcome of the movement relative to the environmental goal, answering the question: "Did I achieve the aim?" Examples of KR include being told the target score, the time taken, or whether a shot missed or hit the target. It provides an immediate evaluation of success or failure. Conversely, KP addresses the quality of the movement itself, answering the question: "How did I move?" This differentiation is fundamental because the two types of feedback serve different, though complementary, functions in the learning process. While KR is essential for motivational purposes and establishing a reference for success, KP is the mechanism that provides the detailed prescription for **corrective action**, linking the movement pattern directly to the resulting outcome achieved in the task environment.

The functional separation of KP and KR is particularly evident in early stages of learning or when skills involve complex coordination. A learner might receive positive KR (e.g., hitting the target) but realize through KP that the movement pattern used was highly inefficient, unsustainable, or potentially injurious. In such cases, the KP acts as a crucial warning signal, prioritizing long-term **motor program optimization** over short-term success. For instance, a high jumper might clear the bar (positive KR), but the coach provides KP indicating that the approach run lacked the necessary acceleration curve. Without this KP, the learner would wrongly reinforce an inefficient motor pattern. Therefore, KR validates the success of the goal, whereas KP validates the efficiency and correctness of the underlying motor plan. Effective instruction often involves integrating both types of feedback, ensuring the learner understands not only what happened but why it happened in terms of underlying biomechanical and dynamic movement characteristics.

The informational content of KP is inherently richer and more descriptive than KR. KR is typically binary or scalar (e.g., success/failure, distance error), while KP delves into the **spatiotemporal characteristics** of the movement. Consider a rehabilitation context where a patient is relearning gait. KR might be whether they walked ten meters without falling. KP, however, would be the therapist stating, "You need to increase your knee flexion during the swing phase," or providing a video replay showing insufficient hip extension. This detailed kinematic information is essential for rebuilding functional movement patterns based on anatomical constraints and biomechanical efficiency. While KR is often easier to provide (as it is intrinsic to the task environment), KP requires specialized observation skills, technological assistance (like motion capture or **biofeedback** devices), and the ability to articulate complex movement concepts in an accessible manner, highlighting its advanced role in shaping the specific details of the motor control system.

Modes and Types of Knowledge of Performance Delivery

The delivery of **Knowledge of Performance (KP)** can be categorized based on the sensory channel utilized and the complexity of the information provided. The primary modes include verbal, visual, and biofeedback, each offering unique advantages depending on the learner's stage of skill acquisition and the nature of the task. **Verbal KP**, the most traditional form, involves the instructor translating observations into spoken descriptions or prescriptive commands, such as "Keep your head steady" or "Rotate your hips earlier." While highly flexible and customizable, verbal KP relies heavily on the instructor's ability to select and time the most critical information, avoiding cognitive overload, especially for complex, rapid movements where verbal processing time is limited and the movement is highly transient.

Visual KP involves presenting the learner with graphical or video representations of their movement. This mode capitalizes on the human capacity for visual learning and comparison, often utilizing split-screen video replay to contrast the learner's execution against a model performance or previous attempts. Visual feedback is particularly effective for tasks where **spatial orientation** and coordination are paramount, as it bypasses the need for the instructor to verbally encode complex spatial relationships. For instance, a gymnast can instantaneously identify deviations in limb alignment when viewing a slow-motion replay. However, visual KP requires careful direction; simply viewing the movement without explicit cues (known as attentional focusing strategies) about which specific errors to observe can be overwhelming or ineffective, reinforcing the need for the instructor to guide the learner's visual attention toward the most relevant kinematic markers, such as joint angles or body segments.

A highly sophisticated form of KP delivery is **Biofeedback**, which utilizes specialized instrumentation to provide real-time, objective data about physiological or biomechanical processes that are typically not consciously perceived by the learner. Examples include electromyography (EMG) feedback showing muscle activation levels, force plates displaying ground reaction forces, or kinematic sensors measuring joint angles. Biofeedback is exceptionally powerful because it provides immediate, quantifiable data directly related to the movement pattern, thereby reducing ambiguity. This modality is frequently employed in specialized contexts, such as clinical rehabilitation (e.g., using pressure sensors to correct weight distribution) or elite sports training where subtle adjustments to internal processes are necessary for maximizing efficiency. The key benefit of biofeedback KP is its objectivity and immediacy, allowing the learner to develop a direct internal mapping between sensory input and the desired motor output, accelerating the calibration of the internal reference system without relying on subjective interpretation.

The Functional Roles and Mechanisms of KP in Motor Learning

Knowledge of Performance fulfills several critical functional roles within the motor learning process, primarily acting as an informational guide, a motivational enhancer, and a reinforcement mechanism. As an informational guide, KP aids in the formation of a robust **motor schema**, which is the rule or relationship linking movement parameters (like force or timing) to movement outcomes. By providing detailed information about **how** the movement was executed, KP allows the learner to refine the parameters used in the motor program on subsequent attempts, effectively updating their internal model of the skill. This refinement process is essential for achieving both accuracy and consistency, as the learner uses the KP to narrow the gap between the intended action and the perceived action, thus developing stronger error detection capabilities necessary for autonomous performance and generalization across varied conditions.

Furthermore, KP serves a powerful **reinforcement function**, especially when delivered immediately following a successful or partially successful movement attempt. When KP confirms that the learner used the correct movement strategy, even if the outcome was not perfect, it selectively strengthens the neural pathways associated with that motor pattern. This positive reinforcement is crucial for stabilizing the newly acquired skill and mitigating the natural variability inherent in early learning stages. Conversely, when KP highlights an error, it functions as a corrective mechanism, prompting the learner to adjust the underlying motor command before the next execution. The effectiveness of KP in this role is contingent upon its specificity; vague feedback such as "Do better" lacks the necessary information content to drive meaningful motor program modification, whereas precise KP provides the necessary constraints and detailed information for effective mental rehearsal and refined action planning.

Beyond cognitive and motor refinement, KP also plays a significant role in **attentional focusing**. The instructor uses KP to direct the learner's attention to the most relevant features of the movement, which can be internal (e.g., focusing on the feeling of muscle contraction) or external (e.g., focusing on the trajectory of the implement). Research consistently suggests that KP is most effective when it encourages an **external focus of attention**, leading to more automated and efficient movement execution. For example, telling a basketball player, "Focus on where the ball hits the rim," (external focus) is often more effective than telling them, "Focus on flexing your wrist fully," (internal focus). By strategically framing the KP, the instructor can manipulate the learner's cognitive resources, preventing conscious over-control of the movement, which often results in suboptimal performance, commonly referred to as choking or paralysis by analysis, thereby promoting natural movement fluency.

Optimizing the Timing and Frequency of Knowledge of Performance

The effectiveness of **Knowledge of Performance (KP)** is heavily dependent on the scheduling parameters--specifically, when the feedback is provided (timing) and how often it is provided (frequency). Historically, the conventional wisdom suggested that more frequent and immediate feedback was superior for performance during practice. However, extensive research in motor learning has demonstrated that high frequency and immediate KP can lead to a phenomenon known as the **guidance hypothesis**, where the learner becomes excessively dependent on the external input. This dependence prevents the learner from developing their own error detection mechanisms, leading to excellent performance during practice but poor retention and transfer when the KP is withdrawn. Therefore, optimizing KP delivery often involves strategies designed to reduce dependency and promote the development of autonomous self-regulation skills necessary for long-term mastery.

Regarding frequency, modern best practices recommend adopting **reduced frequency schedules**, such as faded feedback, bandwidth feedback, or summary feedback. **Faded feedback** involves providing KP frequently early in practice when the learner needs the most guidance, and then systematically reducing the frequency as skill improves, encouraging reliance on intrinsic feedback. **Bandwidth feedback** is delivered only when the learner's performance error falls outside a predetermined acceptable range (the bandwidth), which has the dual benefit of reducing feedback frequency and reinforcing successful attempts by withholding unnecessary correction. **Summary KP** involves delaying feedback until after a block of trials is completed, requiring the learner to recall and evaluate their intrinsic feedback across multiple attempts before receiving the consolidated, external analysis, thereby strengthening memory consolidation and self-assessment skills essential for independent learning.

The timing of KP delivery, particularly the interval between the movement completion and the provision of feedback (the feedback delay interval) and the interval between feedback and the next trial (the post-feedback interval), is also crucial. While KP must be delivered soon enough to remain relevant to the preceding movement, allowing a brief delay (a few seconds) is often beneficial, as it gives the learner time to engage in internal error estimation and processing of their intrinsic feedback before receiving the augmented KP. This practice encourages active cognitive engagement rather than passive reception, forcing the learner to attempt to solve the movement problem internally first. The post-feedback interval must also be sufficient to allow the learner to mentally rehearse the movement modification suggested by the KP before attempting the next trial. Manipulating these temporal parameters strategically ensures that KP serves as a catalyst for genuine learning and retention, rather than simply a temporary performance enhancer that masks deficiencies in the underlying motor program.

Factors Influencing the Efficacy of KP Feedback

The overall efficacy of **Knowledge of Performance (KP)** is mediated by a complex interplay of learner characteristics, task demands, and environmental factors. Crucially, the learner's **stage of**

learning significantly dictates the type and amount of KP that will be most beneficial. Novice learners, operating in the cognitive stage, often require more frequent, descriptive KP focused on gross errors and major movement components to establish a foundational motor program. Conversely, advanced learners, in the autonomous stage, benefit more from precise, quantitative KP (often biofeedback or kinematic data) focused on subtle refinements in efficiency or consistency, as their fundamental motor program is already stable. Providing highly detailed KP to a beginner can lead to **information overload** and detrimental cognitive interference, underscoring the necessity of tailoring feedback complexity to the learner's current level of expertise and processing capacity.

Task complexity is another major factor influencing KP effectiveness. For simple, repetitive tasks, KR might suffice, as the link between the movement and the result is straightforward. However, for complex skills involving multiple simultaneous coordination requirements (e.g., performing a triple jump or executing a surgical procedure), KP becomes essential because the movement pattern is intricate and intrinsic feedback may be insufficient or confusing. Moreover, the nature of the task environment--whether it is **open** (unpredictable, requiring constant adaptation) or **closed** (stable, predictable)--influences the required focus of the KP. In open skills, KP must often address the learner's ability to adapt the movement pattern to changing environmental constraints, emphasizing variability and flexibility in execution rather than strict adherence to a single optimal, rigid pattern, which is characteristic of closed skill performance.

Finally, the recipient's motivation, attentional capacity, and interpretation skills heavily modulate how KP is internalized and utilized. If a learner lacks motivation or perceives the KP as overly critical or irrelevant, the potential for learning diminishes significantly. Instructors must ensure that KP is delivered in a constructive, supportive manner, often utilizing strategies like the sandwich approach (positive statement, corrective KP, positive encouragement). Furthermore, the learner's ability to understand the technical language used in the KP is critical; technical biomechanical terminology must be translated into accessible, actionable metaphors or analogies that resonate with the individual's cognitive framework. The most effective KP is not merely accurate, but is also personalized, timely, and focused on the elements the learner is currently capable of changing, linking the external information directly to the learner's internal goal state and perceived competence.

Practical Applications and Future Directions of KP Research

The practical applications of **Knowledge of Performance (KP)** span diverse fields, including physical education, elite athletic training, physical rehabilitation, and the acquisition of complex vocational skills (e.g., surgery, piloting, manufacturing). In sports, KP delivered via video analysis systems allows athletes and coaches to pinpoint subtle technical flaws that differentiate elite performance from sub-elite, enabling highly targeted interventions. In clinical settings, KP, often delivered through real-time **biofeedback systems**, is instrumental in helping patients regain motor function by providing objective metrics on muscle activation or weight bearing, allowing for precise recalibration of neurological pathways following injury or stroke. The goal in all these contexts is consistent: to accelerate the formation of efficient, adaptable, and robust motor programs by providing high-quality, actionable information about the movement execution itself, leading to sustained functional improvement.

Current research is heavily focused on leveraging technological advancements, particularly in **wearable sensors** and **virtual reality (VR) environments**, to enhance KP delivery. Wearable inertial measurement units (IMUs) can provide highly accurate, quantitative kinematic data immediately upon movement completion, transforming complex data into simple, digestible visual feedback accessible outside of a laboratory setting. VR environments offer the unique advantage of allowing instructors to manipulate the sensory context, providing highly customized KP within ecologically valid, yet safe and repeatable, practice environments. These technologies promise to overcome traditional limitations of verbal KP, such as subjectivity and cognitive delay, making feedback provision more scalable, precise, and immediate across various learning domains, including those where physical risk is high, such as aviation simulation.

Future directions in KP research are increasingly concerned with understanding the neurological underpinnings of feedback processing and optimizing the transition from external KP dependence to autonomous self-correction. Research is exploring how different types of KP (e.g., prescriptive vs. descriptive) affect brain plasticity and motor memory consolidation, aiming to identify optimal feedback strategies tailored not just to the stage of learning but to individual cognitive profiles. A key challenge remains the development of robust algorithms that can automatically generate personalized, high-quality KP in real-time without instructor intervention, effectively creating **intelligent tutoring systems** for motor skill acquisition. Ultimately, continued refinement of KP delivery methods seeks to maximize retention and transfer, ensuring that skills learned in practice are robust and adaptable when performed under novel or high-pressure conditions in the real world, solidifying the role of KP as a crucial informational resource.