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Feedback

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Feedback, or response-produced feedback, consists of all the information an individual receives as a result of a practice trial of a motor skill, classically divided into two parts—*intrinsic* and *extrinsic.* Intrinsic feedback is all of the information one receives *naturally*, such as vision, audition, and proprioception. Extrinsic feedback is information provided over and above intrinsic feedback, often by a teacher, coach, or experimenter. In the laboratory, tasks or procedures are used such that the learner typically cannot detect how well one has met the task goal, and then extrinsic feedback is manipulated to access its effects on learning. Using this method, *augmented feedback* has been considered a key variable in the learning process, without which learning does not occur at all. It operates to guide the learner to the correct movement pattern. The learner uses this information to correct errors on subsequent trials, until the desired skill level is achieved. Researchers distinguish between two types of augmented feedback: (1) *knowledge of results* (KR), provided after a trial about the movement outcome in relation to its goal, and (2) *knowledge of performance* (KP), provided during or after the movement about the nature of the movement pattern. Even though KR and KP may, on occasion, have somewhat different functions in the learning process, both seem to follow the same principles in the way they affect skill learning. Therefore, here we refer to them both as *feedback*.

Research related to the role of feedback in the learning of motor skills has a relatively long history dating from the early 1900s. The view of the role feedback plays in the learning process has changed throughout this time and continues to change. The following sections describe how our understanding of the functions of feedback has developed from the early views (1900–1970) to the second phase (1980–2000) and current research (2000–present).

Early Views: 1900–1970

Toward the beginning of the previous century, psychologists saw feedback as having primarily a reinforcing role. In particular, Edward Thorndike's law of effect stated that actions tended to be repeated if they had pleasant or rewarding consequences and avoided if they were followed by unpleasant or punishing effects; thereby, it provided an account of feedback's role in learning. Much of this early research was guided by animal (occasionally human) research showing, for example, that feedback delays and feedback frequency had negative and positive effects on animal learning, respectively. Starting in about the 1950s, researchers such as Edward A. and Ina M. Bilodeau focused more on the informational role of feedback. Feedback was considered vital for continued improvement with practice, and learning often did not seem to occur without it. Practice without feedback was thought to allow performance to drift away from the goal movement pattern and to weaken the memory representation of the movement. This view is also reflected in Jack A. Adams's (1971) closed-loop theory and Richard A. Schmidt's (1975) schema theory of motor learning. In both theories, the memory representation of a skill (perceptual trace in Adams' theory; recall and recognition schemata in Schmidt's theory) was thought to develop as a function of practice and feedback. That is, the greater the number of trials with feedback a person had performed, the stronger memory representations were assumed to be, and the better the person's ability both to perform and to detect and correct errors without augmented feedback. According to this view, feedback would be most effective if it was provided frequently and **[p. 288 ↓]** immediately. In the 1980s, these ideas began to be questioned.

Second Phase: 1980–2000

The second major phase of feedback research was initiated and inspired by an influential review of the feedback literature by Alan W. Salmoni, Richard A. Schmidt, and Charles B. Walter in 1984. It became clear that many of the earlier studies had shortcomings, most notably a lack of retention or transfer tests to assess the more permanent, or learning, effects of different feedback manipulations (e.g., temporal delays, frequencies, precision). Inferring learning from the performance of different groups during the practice phase—that is, under the influence of different feedback conditions—became unacceptable. Instead, it was argued, the use of delayed tests under common conditions was crucial to assessing stable learning effects of various experimental variables including augmented feedback. Importantly, Salmoni et al. provided a new conceptual framework for feedback, which was formalized as the *guidance hypothesis.* The term referred to the role of feedback in guiding the performer to the correct movement pattern during the learning process. Aside from this positive function of feedback, several potentially negative effects of frequent feedback were proposed as well. In particular, it was hypothesized that the learner, with very frequent feedback, could become dependent on the augmented feedback, thereby neglecting the processing of intrinsic feedback, which would be necessary for the development of intrinsic error detection and correction mechanisms. Frequent feedback was also assumed to result in excessive variability in performance, as it would prompt learners to constantly correct even small (perhaps acceptable) errors (so-called maladaptive short-term corrections) that perhaps reflected inherent variability in the motor system. The result would be the development of a less stable movement representation. The guidance hypothesis therefore suggested a positive influence of frequent, immediate, or precise feedback during practice while it was present, but it could have a detrimental impact on learning if it were overdone.

Numerous studies examining various feedback manipulations provided support for the guidance idea. These studies typically used feedback manipulations that in some way attempted to reduce the detrimental effects of frequent feedback by encouraging learners to attend to and utilize their intrinsic feedback. For example, reducing the relative frequency of feedback (reduced percentage of trials after which feedback is provided) was found to enhance learning compared with feedback after every trial (100% feedback). Also, summary or average feedback (feedback for individual trials or as an average, respectively, presented only after a set of trials has been completed) have been shown to be more beneficial for learning than feedback after every trial. Furthermore, bandwidth feedback (feedback provided only when errors exceed a certain predetermined bandwidth) appears to reduce movement variability and enhance learning. Finally, delaying feedback, even by a few seconds, and asking learners to estimate their errors prior to receiving feedback have been demonstrated to yield more effective learning outcomes than providing feedback immediately after the completion of the movement, or concurrently with the execution of a movement.

The guidance hypothesis had an important impact on motor learning research. It has contributed to a better understanding of how feedback influences performance and learning. Yet, even though there has been considerable support for the guidance hypothesis, this support comes primarily from studies using relatively simple laboratory tasks or involving situations in which learners were deprived of intrinsic outcome information and therefore had to rely on the augmented feedback provided by the experimenter. In recent years, it has become clear that the guidance view does not provide a comprehensive description of the various functions of feedback in the process of (complex) motor skill learning. One important factor that influences the effectiveness of feedback, and that qualifies the influence of the feedback frequency, is the attentional focus induced by it. Furthermore, there is converging evidence that feedback has not only an informational role, but that its motivational influence on learning is more important than previously thought.

Current Research: 2000–Present

Feedback and Focus of Attention

Studies have consistently shown that feedback or preperformance instructions promoting an external focus of attention—whereby attention is directed to the movement effect on the environment (e.g., the motion of implement, trajectory of **[p. 289 ↓]** a ball)—enhances learning compared with those instructions inducing an internal focus by directing one's attention to one's body movements. That is, a simple change in the wording of feedback can elicit an external or internal focus and produce markedly different learning results. For example, references to the movement of a golf club have been shown to be more effective than those related to the performer's arm movements. External focus advantages for learning have been found for many different types of motor skills, different age groups, and levels of expertise.

Feedback that directs performers' attention to their own body movements causes them to use a more conscious mode of control, which constrains the motor system and interferes with automatic control processes (the *constrained-action hypothesis*). In contrast, by adopting an external focus on the intended movement effect, performers use a more automatic type of control that makes use of unconscious, fast, and reflexive processes. Studies have shown associations of external attentional foci and various measures of automaticity—including reduced attentional demands, reduced premovement times (more efficient motor planning), high-frequency (reflexive) movement adjustments, and reduced muscular activity. The result of adopting an external focus is typically enhanced motor performance and learning, as seen in increased movement effectiveness and efficiency.

Not only does feedback promoting an external focus of attention lead to more effective learning than feedback referring to body movements, but the previously found benefits of a reduced relative to a high-feedback frequency have been found to be reversed. That is, despite the informational content being the same, feedback inducing an external focus is most effective when it is provided frequently (e.g., 100%), whereas feedback inducing an internal focus is least effective when it is given frequently. The interaction of feedback frequency and attentional focus, as well as the overall benefits of external relative to internal focus feedback, cannot be explained by extant conceptualizations of feedback (e.g., guidance hypothesis).

One possibility is that at least some of the learning benefits of reduced feedback frequencies found in previous studies were not primarily due to learners' becoming dependent on frequent augmented feedback. Rather, the detrimental effects of frequent feedback may have been because of constant internal focus reminders, with those (negative) effects being attenuated under reduced feedback conditions. The interactive effects of feedback frequency and attentional focus would be consistent with the concept that experiencing less of a detrimental influence (limited use of an impairing thought such as an internal focus of attention) is good, as more of a good thing (frequent reminders to maintain a beneficial external focus) is good.

It has been suggested that the mere mention of body parts like fingers, arms, or feet—within internal focus feedback or instructions—might provoke a focus on the *self* and ensuing self-regulatory activity. Efforts to manage self-related thoughts and emotions may be so demanding that available attentional capacity is exceeded and performance suffers. In contrast, when feedback promotes an external focus, a focus on the self is reduced. The mechanisms underlying the beneficial effects of feedback inducing an external focus may not be dissimilar to those responsible for the learning advantages seen when feedback is given about successful trials, or when it suggests above-average performance relative to a peer group. These types of feedback are discussed next.

Feedback After Successful Trials

Until recently, most researchers were concerned with the *informational function* of feedback, that is, its role in providing information about an individual's performance relative to the task goal. Similarly, practitioners often see performance feedback from this perspective. For instance, a coach might identify deviations from the optimal technique in an athlete's movement patterns and suggest corrections. While such feedback plays an important role in any learning process, a somewhat underappreciated aspect of feedback has been its influence on the performer's motivational state. Recent findings demonstrate that positive (or negative) feedback affects motor learning via its motivational influence.

Providing learners with feedback after good trials, as opposed to poor trials, has consistently been shown to result in more effective learning. In several studies, feedback about task performance (i.e., accuracy of throwing an object at a target) was provided after each of several blocks of practice trials. However, it was provided on only half of those trials. Unbeknownst to the learners, they were given feedback either about their most effective trials or about their least accurate trials. **[p. 290 ↓]** Participants receiving feedback after their best trials demonstrated more effective learning on a retention test. Thus, feedback emphasizing successful performance, while ignoring less successful attempts, benefited learning. This effect has been linked to participants' enhanced intrinsic motivation. Learners often appear to have a relatively good feel for how they perform, and instructor feedback indicating errors may not only be superfluous, but it can also irritate learners or heighten concerns about the self that may hamper learning (see below).

Social-Comparative Feedback

Effects of *normative feedback*—which involves norms such as a peer group's actual or false average performance or improvement scores that are provided in addition to the learner's own scores—have been examined in a related line of research. Normative information is a potent basis for evaluating one's own performance. Favorable comparisons with others typically result in perceptions of competence, increased self-efficacy, and motivation, while negative comparisons have the opposite effect. Importantly, normative feedback also has differential effects on motor learning, with learning being enhanced by positive relative to negative or no normative feedback. In other studies, bogus feedback about a peer group's average block-to-block improvement resulted in enhanced learning if it conveyed to the learner that one's own improvement was greater than average, compared to less than average. Thus, favorable social-comparative feedback affects the degree to which task skill is retained.

Positive normative feedback not only leads to improved outcome scores but also produces qualitative differences in participants' control of movements, such as greater automaticity in movement control. It is interesting that positive feedback benefits learning compared with both control conditions without comparison information and negative normative feedback conditions, which have similar effects. This suggests that the latter conditions may trigger thoughts about the self (similar to feedback inducing an internal focus), and ensuing self-regulatory activities in attempts to manage thoughts and affective responses, which hamper learning of the primary task. In contrast, when one is purportedly performing well (above average), such self-related concerns and activities to suppress them might be unnecessary—with the consequence that learning is enhanced.

For ethical reasons, providing false feedback in practical settings would not seem to be appropriate. However, the findings suggest feedback that implies one is an effective performer, or the provision of positive, competence-affirming feedback is critical for learning. While many practitioners may intuitively provide such feedback, others may be more focused on correcting errors—with unintended consequences for motivation and learning.

Conclusion

The view of how feedback functions in the process of motor skill learning has changed over the past few decades. It is now clear that the role of feedback goes far beyond providing reinforcement or guidance to the goal movement. There is mounting evidence for the motivational role of feedback—which not only has an indirect effect by increasing the amount of practice—but a *direct* impact on motor learning. The learning of motor skills not only involves the fine-tuning of motor programs and movement parameters but requires effective self-regulation of cognitive and affective processes, as well as attentional focus demands. A more integrated perspective on motivational and informational aspects of feedback in motor learning research will benefit future theoretical conceptualizations—and should also yield practical motor skill learning insights, as neutral task information is not easily found in the natural social contexts in which movement skills are learned.

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See also

- Attentional Focus

Further Readings

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