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Normative Feedback Effects on Learning a Timing Task

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This study investigated the influence of normative feedback on learning a sequential timing task. In addition to feedback about their performance per trial, two groups of participants received bogus normative feedback about a peer group's average block-to-block improvement after each block of 10 trials. Scores indicated either greater (better group) or less (worse group) than the average improvement, respectively. On the transfer test 1 day later, which required producing novel absolute movement times, the better group demonstrated more effective learning than the worse group. These findings add to the mounting evidence that motivational factors affect motor skill learning.

Key words: knowledge of results, motivation, motor learning, social comparison

Studies examining the function of feedback (knowledge of results, knowledge of performance) for motor learning have a long history (e.g., Bilodeau & Bilodeau, 1958; Bilodeau, Bilodeau, & Shumsky, 1959; Thorndike, 1914, 1932; for reviews, see Salmoni, Schmidt, & Walter, 1984; Schmidt, 1991; Swinnen, 1996; Wulf & Shea, 2004). Feedback is thought to have several roles in the learning process, including informational and motivational functions (e.g., Schmidt & Lee, 2005, pp. 396–398). Most research on feedback has focused on its informational role (e.g., on how performers use augmented feedback to correct errors, how feedback delay or error estimation influences learning, or how various types of extrinsic feedback affect intrinsic feedback processing). In contrast, motor learning researchers have somewhat neglected the motivational aspects of feedback, perhaps because motivation is often assumed to exert only temporary effects on performance or to have, at best, indirect effects on learning through increased practice (e.g., Schmidt & Lee, 2005, p. 397). Conversely, social-cognitive researchers who study motivational issues in physical activity, have generally focused on achievement-related cognitions and behaviors and have not addressed the impacts of motivation on motor learning (for an exception, see Jourden, Bandura, and Banfield, 1991, who examined motor performance as a function of ability conceptions).

A few findings, however, suggested the motivational function of feedback may exert more than indirect effects on learning, and that the extent to which feedback produces a positive or negative motivational state in the learner directly affects learning. Research examining the effects of learner-controlled practice conditions, including when to obtain feedback, has demonstrated superior learning for participants with choice over practice circumstances relative to individuals in yoked conditions (for a review, see Wulf, 2007). One choice learners seemed inclined to make was requesting feedback after relatively successful, rather than less successful, trials (e.g., Chiviacowsky & Wulf, 2002, 2005). In addition, studies have shown that providing learners with feedback after "good" trials, compared to "poor" trials, resulted in more effective learning (Chiviacowsky & Wulf, 2007; Chiviacowsky, Wulf, Wally, & Borges, 2009). Thus, feedback emphasizing successful performance, while ignoring less successful attempts, appears to benefit learning presumably because of its positive motivational effects. Findings such as these indicate that performance feedback is not just processed as "neutral" information—without any affective implica-

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tions—to minimize errors. Rather, augmented feedback appears to influence motivational processes that, in turn, affect learning.

Feedback involving comparisons with others, or social comparison—whether evidenced through direct competition or the provision of information about one's own relative performance—can affect learners' motivation, performance, and learning. Studies on normative feedback, in which a learner gains information about his/her score in addition to a peer group's (false) performance, have demonstrated differential effects on task motivation and self-evaluation in response to "positive" versus "negative" normative feedback (e.g., Hutchinson, Sherman, Martinovic, & Tenenbaum, 2008; Johnson, Turban, Pieper, & Ng, 1996; Lamarche, Huffman, Eliasz, Gammage, & Adkin, 2008; Zell & Alicke, 2008). Studies also found effects of normative feedback or social comparison on motor performance (e.g., Hutchinson et al., 2008; Triplett, 1898). Hutchinson and colleagues (2008), for example, showed that feedback indicating above-average performance increased self-efficacy and task enjoyment (or reduced task aversion) on a hand-grip isometric force production task, with concomitant impacts on performance reflected in increased exertion tolerance and sustained effort, relative to feedback indicating below-average performance. Social comparison information (i.e., normative feedback) not only affects performance while it is provided but can also have more permanent effects on motor learning, as reflected in retention and transfer test performance in classic learning paradigms. In a recent study, learning a balance task was enhanced by positive relative to negative normative feedback, as demonstrated on a no-feedback retention test (Lewthwaite & Wulf, 2010). Thus, although veridical information about their performance indicated to learners they were improving—presumably providing some evidence of "success"—favorable or unfavorable social comparison information affected not only the level of their improvement during practice but also the degree to which task skill was retained and generalizable.

Wulf and Lewthwaite (2009, 2010) hypothesized that information indicating below average performance triggers thoughts about the *self*, a mechanism they termed the "self-invoking trigger." Feedback indicating poor performance compared to others' presumably activates self-regulatory processes to manage thoughts and affective responses (Carver & Scheier, 1978; Schmader, Johns, & Forbes, 2008). Efforts to manage self-related thoughts and emotions may be so demanding that available attentional resources are exceeded and performance suffers. In contrast, self-related concerns and ensuing activities to suppress them might be unnecessary when one purportedly performs well (i.e., above average). In fact, positive affect resulting from such knowledge may have an energizing or reinforcing effect that facilitates learning (Kühn et al., 2008).

Given the ubiquity of (formal or informal) social comparison information available in settings in which motor skills are performed or learned (e.g., physical education, music, physical therapy), we deemed it important to further investigate the impact of normative feedback. Specifically, we wanted to examine the generalizability of normative feedback effects to a different type of task. In previous studies, continuous tasks of relatively long durations, such as balancing (60-s trials, Lamarche et al., 2008; 90-s trials, Lewthwaite & Wulf, 2010) or a sustained handgrip (approximately 2–3 min, Hutchinson et al., 2008), were used. The trial durations may have promoted self-related processing during performance that interfered with learning. In the present study, we used a short-duration, sequential-timing task. Fast, preprogrammed movement sequences such as these should reduce the potential for interference from self-regulatory activity during task execution and might, therefore, be less susceptible to the effects of normative feedback. Alternatively, negative feedback may hamper the processing of relevant feedback (Mangels, Butterfield, Lamb, Good, & Dweck, 2006) and lead to impaired learning relative to positive normative feedback even in short-duration tasks.

Another difference relative to previous studies was that normative feedback in the present study referred to a peer group's *improvement* from one trial block to the next, rather than to absolute performance scores. Improvement scores are somewhat more ambiguous than absolute performance scores or errors. For example, a smaller-than-average improvement could be interpreted as suggesting that one's average performance may already be better than average, and, therefore, relative improvements from block to block would be expected to be smaller. Furthermore, in contrast to previous studies (e.g., Hutchinson et al., 2008; Lewthwaite & Wulf, 2010), participants did not receive their (improvement) scores but only normative (improvement) scores. Thus, any comparisons with the "norm" had to be based on participants' estimations of improvement (which, in turn, were based on the feedback they got after each trial). Previous studies have shown that learners become relatively proficient at estimating their errors on the type of task used in the present study (e.g., Chiviacowsky & Wulf, 2002; Chiviacowsky, Wulf, Laroque de Medeiros, & Kaefer, 2008). The greater uncertainty with interpreting the normative feedback might be to potentially reduce the effects of (positive vs. negative) normative feedback. Yet, if there were group differences despite these "disadvantages," they would underscore the potency of social-comparison feedback.

Participants in the present study were asked to press six keys in a specified order, with specified intervals between key presses. After every trial, they got veridical feedback about the actual movement times. In addition, after every tenth trial, they received normative feedback—bogus feedback about other participants' average improvement.

In normative feedback research (e.g., Hutchinson et al., 2008; Johnson et al., 1996), false feedback about relative performance rather than veridical normative feedback is typically used to ensure an equal level of positive and negative feedback. For one group (better), normative feedback consisted of the peer group's reduction in overall error on that block compared to the previous 10-trial block and was 20% less than the participant's own error reduction. For another group (worse), the average normative improvement scores were 20% greater than the participant's own improvement. To assess learning as a function of normative feedback, we used a retention test without feedback (i.e., giving participants neither veridical personal performance scores nor normative improvement information) on the same task participants practiced during acquisition. In addition, they performed a transfer test involving a novel task version (i.e., novel absolute movement times, but the same relative times). Transfer tests have often been found to be more sensitive measures of learning than retention tests. The additional information-processing requirements when selecting novel movement parameters (e.g., Chiviacowsky & Wulf, 2002; Lai & Shea, 1998; Wulf & Lee, 1993), for example, can reveal learning differences that may not be evident on less demanding (retention) tests. Particularly in the present case, we surmised that transfer tasks may tax individuals' information-processing capacity to a degree that self-regulatory activity—necessary to manage thoughts and affective responses due to previous "negative" performance feedback—may not be accommodated through available "excess" attentional capacity, as perhaps it would be in retention. Therefore, we expected to see larger group difference on the transfer compared to the retention test.

Method

Participants

Twenty-eight university students (12 women, and 16 men) with a mean age of 20.8 years (*SD* = 3.53) took part in this experiment. All participants provided informed consent. None had prior experience with the experimental task nor were they aware of the specific study purpose. The university's institutional review board approved the study. Following the experiment, participants were debriefed regarding the bogus nature of the normative feedback.

Apparatus and Task

A computer, color monitor, and keyboard were placed on a standard table. Participants sat on a chair and kept their arm unsupported while executing the task. The task required them to use the index finger of their right hand to sequentially depress six keys (5, 1, 6, 8, 3, and 7) on the numeric keypad portion of the keyboard. Their goal was to be as accurate as possible with regard to the absolute goal movement times (MTs) for each of the five movement segments (between keys). The goal MTs were 240, 480, 360, 240, and 480 ms (total MT: 1,800 ms) for the practice and retention phases. In the transfer phase, the goal segment times were 360, 720, 540, 360, and 720 ms (total MT: 2,700 ms). Thus, the relative MTs for all phases of the experiment were 13.3, 26.6, 20.0, 13.3, and 26.6%.

Procedure

A graphic representation was used to explain the task to the participants. They were told they would get feedback after each trial, which would consist of the goal and actual segment MTs as well as the goal and actual overall MTs (i.e., sum of segment MTs). Participants were also told that after each block of 10 trials they would receive an average improvement score (i.e., deviation from goal overall MT on the second-to-last block minus that on the last block) produced by participants in previous experiments. For two groups of participants randomly assigned to the better and worse groups (8 men and 6 women each), the average (bogus) improvement scores were different. However, after each block, the experimenter gave better group participants an improvement score 20% less than their own improvement score and provided worse group participants with a score 20% larger than their own improvement score. When a participant's average error was greater than on the previous block, the normative feedback score was calculated the same way but portrayed as improvement rather than performance deterioration to avoid participant awareness of the bogus feedback.

All participants performed 80 trials during the practice phase, with veridical feedback after each trial, and (false) normative average feedback after every 10 trials. Participants were also informed they would have to perform the task without feedback the next day. One day after the practice phase, all participants performed a retention test consisting of 10 trials on the practice task version (240, 480, 360, 240, and 480 ms). Subsequently, they performed 10 transfer trials on the novel task version with the same relative timing but a longer absolute duration (360, 720, 540, 360, and 720 ms). They had no feedback in either retention or transfer test phases.

Data Analysis

As an error measure that includes errors in both relative and absolute timing, overall timing error was calculated as follows: for each trial, the sum of the absolute differences between goal MTs and actual MTs on each segment was computed (e.g., Wulf & Schmidt, 1989). Data were averaged across blocks of 10 trials. The practice data were analyzed in 2 (groups: better, worse) x 8 (blocks of

10 trials) analyses of variance (ANOVAs) with repeated measures on the last factor. The retention and transfer data were analyzed in separate one-way ANOVAs.

Results

Both groups reduced their timing errors across the practice phase (see Figure 1). The main effect of block was significant, $F(7, 182) = 17.22$, $p < .001$, $\eta^2 = .59$. The main effect of group, $F(1, 26) = 1.70$, $p > .05$, and the Group x Block interaction, $F(7, 182) < 1$, did not reach significance.

On the retention test, both groups had similar absolute timing errors, $F(1, 26) < 1$. Yet, on the transfer test, requiring novel absolute times, the better group had smaller errors (760.4 ms) than the worse group (962.6 ms). The group main effect was significant, with $F(1, 26) = 4.33$, $p < .05$, $\eta^2 = .14$. Thus, under more taxing conditions, participants who received positive normative feedback during practice performed more effectively than those who had been led to believe they performed below average.

Discussion

Feedback with information about participants' performance relative to that of others (i.e., normative feedback) has been shown to influence their motivation and performance in studies using cognitive tasks, such as complex decision making (Bandura & Jourden, 1991), association tests (Ilies & Judge, 2005), and word search tasks (Johnson et al., 1996). Only recently did researchers begin to examine the effects of motivational feedback on motor skill performance and learning (e.g., Chiviacowsky et al., 2009; Chiviacowsky & Wulf, 2007; Lewthwaite & Wulf, 2010). Feedback indicating above average performance relative to feedback reporting below average performance, has been found to result in greater sustained effort in force production (Hutchinson et al., 2008) and more effective balance learning (Lewthwaite & Wulf, 2010). The results of the present study corroborate the effects of social-comparison information on motor skill learning, extending previous evidence by showing that providing learners with normative improvement scores also influenced learning. Learners who had feedback indicating they improved more than their peers performed more effectively on the sequential timing task than those who were falsely informed they had improved less than the average performer. Despite the potential complexity of transforming personal trial information into the personal improvement estimates to compare with provided normative improvement, participants apparently "did the math" and responded to the normative improvement feedback as intended, which was sufficient to produce observed learning differences between groups. Although better group participants' overall error scores were not significantly lower than those of the worse group participants during practice—when normative feedback was provided—or on the retention test, they showed significantly greater accuracy on the transfer test. That is, when the production of novel movement times without feedback was required, the better group demonstrated greater skill in generalizing from their practice phase experience.

The fact that a group difference occurred in transfer but not in retention may not be surprising for several reasons. First, the effects of normative feedback in the present study were presumably attenuated by the relative ambiguity of improvement scores compared to absolute performance scores (Lewthwaite & Wulf, 2010), or feed-

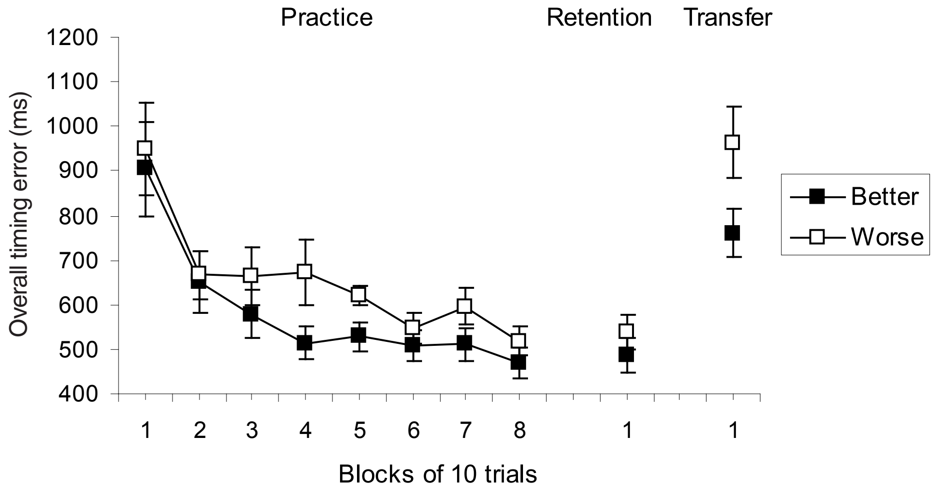

Figure 1. Errors in overall timing on blocks of 10 trials during practice, retention, and transfer for the better and worse groups (Note: error bars indicate standard errors).

back indicating one's performance was in the top or bottom 10th percentile of a peer group (Hutchinson et al., 2008). Second, the fact that participants did not get their own improvement score, but instead had to rely on improvement estimations, further increased the difficulty of interpreting the normative information. Third, it is not unusual for group differences to emerge on transfer tests but not on retention tests (e.g., Chiviacowsky & Wulf, 2002, 2005; Lai & Shea, 1998; Wrisberg & Wulf, 1997). Compared with retention tests in which participants performed the task(s) practiced during the acquisition phase, transfer tests often present greater challenges to performers and, therefore, tend to be more sensitive measures of learning. Requiring participants to select novel movement parameters for five segments, as in the present study, imposed additional information-processing demands. If individuals' information-processing capacity is already taxed—for instance, due to the need for self-regulatory activity to manage negative affect after feedback indicating poor performance—task-related processing would be expected to suffer more (i.e., in the worse group) compared to the absence of that need (i.e., in the better group).

A variety of factors may have contributed to the differential effects of normative feedback on learning. Social-comparison information has been shown to affect individuals' perceptions of their abilities (e.g., perceived competence, self-efficacy; Bandura & Jourden, 1991; Hutchinson et al., 2008; Kavussanu & Roberts, 1996) as well as upward or downward adjustments of goal setting (Ilies & Judge, 2005; Williams, Donovan, & Dodge, 2000). This, in turn, can affect the effort invested in learning as well as attention to task performance (Bandura, 1990, 1997; Bandura & Jourden, 1991). Furthermore, normative feedback can create positive or negative affect for the self (e.g., Bandura, 1990; 1997; Bandura & Jourden, 1991) or the task (Conroy, Elliott, & Coatsworth, 2007; Deci & Ryan, 1985), which has also been linked to goal revisions (Aarts, Custers, & Holland, 2007; Chartrand & Bargh, 2002; Ilies & Judge, 2005; Stapel & Blanton, 2004). In addition, negative affect may dampen or interfere with memory processing (Kuhlmann, Piel, & Wolf, 2005). Finally, negative affect presumably heightens the need for self-regulatory activity to suppress or substitute thoughts and negative emotions (Carver & Scheier, 1978; Schmader, Johns, & Forbes, 2008). This, in turn, requires a reallocation of attentional resources, with the likely consequence of degraded learning.

The present findings did not indicate that the influence of normative feedback depends on the type of task. We found similar effects, in transfer test performance, for the discrete, short-duration (less than 2 s) sequential timing task in the present study as previous studies demonstrated for continuous, long-duration (1–3 min) tasks requiring sustained attention and effort (e.g., Hutchinson et al., 2008; Lewthwaite & Wulf, 2010). Nonetheless, it is possible the specific mechanisms mediating those effects differed depending on the task. For example, self-regulatory efforts to suppress negative affect that interfere with motor control processes may play a larger role in longer duration movements. In contrast, processing task-related feedback may influence learning discrete tasks to a greater extent, which can be either hampered by unfavorable normative feedback (Mangels et al., 2006) or facilitated by the positive affect resulting from favorable information (Kühn et al., 2008). These issues need to be examined in future studies.

The findings of the present study add to the mounting evidence that motivational factors have transient effects on motor performance and affect motor *learning*. Motor learning not only involves the fine-tuning of motor programs and movement parameters but also requires effective handling of self- and task-related thoughts and emotions to manage energy, effort, and attention. That is, it encompasses self-regulation of cognitive and affective processes as well as attentional focus demands. This may be especially true in the almost ubiquitously social context of movement tasks in which implicit (e.g., Aarts et al., 2007; Chartrand & Bargh, 2002; Stapel & Blanton, 2004) and explicit forms of social comparison are common. A more integrated perspective on motivational and informational aspects of motor learning will benefit future research. Such a perspective might be expected to yield practical motor skill learning insights as well, as purely neutral task information is not easily found in the natural social contexts in which individuals practice and perform movement skills.

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