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ORIGINAL RESEARCH

Can Ability Conceptualizations Alter the Impact of Social Comparison in Motor Learning?

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We examined the interactive influence of normative feedback and conceptions of ability on the learning of a balance task. Ability conceptions were induced by instructions portraying the task as either an acquirable skill or reflecting an inherent ability. Bogus normative feedback about the "average" balance scores of others on a given trial suggested that participants' performance was either above (Better groups) or below average (Worse groups). Thus, there were four groups: Inherent-Ability Better, Inherent-Ability Worse, Acquirable-Skill Better, and Acquirable-Skill Worse. Following two days of practice, learning was assessed on Day 3 in retention and dual-task transfer tests. The Better groups demonstrated more effective learning than the Worse groups. Questionnaire results revealed differences in self-related concerns between those groups. Signature size changes suggested that participants in the Worse groups perceived negative normative feedback as a threat to the self. The findings highlight the importance of motivational influences on motor learning.

***Keywords*:** knowledge of results, balance, motivation, normative feedback, entity theory, incremental theory, automaticity, performance

Over the past several decades, social-cognitive researchers have explored the motivational pathways connecting socially influenced thoughts, affective and experiential responses, and behavior in movement contexts and other arenas of human functioning (e.g., Bandura, 1997; Deci & Ryan, 1985; Dweck & Leggett, 1988; Feltz, Short, & Sullivan, 2008; Hagger & Chatzisarantis, 2007; Martens & Landers, 1969). Some attention has been focused on relationships of social-cognitive variables such as self-efficacy to motor performance (e.g., Moritz, Feltz, Fahrbach, & Mack, 2000), but much less to the impact of motivational variables on the acquisition of new motor skills.

Traditionally, motor learning research has viewed motivation as a temporary influence on performance without lasting, or at best indirect, impacts on movement skill learning (cf. Schmidt & Lee, 2011, p. 425). Motor learning research instead has focused on various factors thought to influence information processing, memory consolidation, and retention and transfer of motor skills. Conditions of practice, such as task scheduling (e.g., Lee, 2012; Shea & Wulf, 2005), observational practice (e.g., McCullagh, Law, & Ste-Marie, 2012), or augmented information feedback (e.g., Salmoni, Schmidt, & Walter, 1984; Schmidt, 1991; Swinnen, 1996; Wulf & Shea, 2004), are assumed to influence how information is processed and affects the learning of motor skills.

While the informational aspect of these "conditions of practice" is arguably important, there has been increasing evidence from both behavioral and neuroscientific lines of research that *motivational* factors, particularly those that might be termed positive, rewarding, or reinforcing, have an important influence on motor learning as well (Lewthwaite & Wulf, 2012; Wise, 2004). Motivational factors with evidence of motor learning effects include those serving as extrinsic "rewards" as well as those of a social-cognitive and intrinsic nature. Neurophysiologic and neurocomputational research has framed learning-related motivation in terms of reward or expected reward (e.g., Abe, Schambra, Wassermann, Luckenbaugh, Schweighofer, & Cohen, 2011; Wickens, Reynolds, & Hyland, 2003), and used real or virtual money or food for good performance to influence the learning of motor tasks. The working assumption in this line of work is that reward affects the release of dopamine in the corticostriatal system which, in turn, is critical for memory consolidation and synaptic plasticity, and thus learning.

In recent behavioral research, several forms of variables with motivational significance show evidence of motor learning impact (Lewthwaite & Wulf, 2012). These variables include opportunities for self-direction (e.g., Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997), collaborative participation (e.g., Shea, Wulf, & Whitacre, 1999), information conveying incremental conceptions of ability (e.g., Jourden, Bandura, & Banfield, 1991; Wulf

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& Lewthwaite, 2009), and augmented feedback signaling success or competence (e.g., Lewthwaite & Wulf, 2010b; Trempe, Sabourin, & Proteau, 2011). Feedback is not just "neutral" information about an individual's performance, but can create positive or negative self-evaluations and affect, which in turn may influence learning (e.g., Badami, VaezMousavi, Wulf, & Namazizadeh, 2011; Badami, VaezMousavi, Wulf, & Namazizadeh, 2012; Chiviacowsky & Wulf, 2007; Chiviacowsky, Wulf, Wally, & Borges, 2009). Recent studies have demonstrated that feedback about the performance of *others* (i.e., normative feedback) affects motor skill learning (e.g., Ávila, Chiviacowsky, Wulf, & Lewthwaite, 2012; Lewthwaite & Wulf, 2010b; Wulf, Chiviacowsky, & Lewthwaite, 2010, 2012).

Background

Normative Feedback

Social comparison has a long and continuing history of psychological examination (Chartrand & Bargh, 2002; Festinger, 1954). Studies on normative feedback, in which norms such as a peer group's (bogus) average performance scores were provided in addition to the participant's actual score have shown reduced task motivation, self-efficacy, and self-esteem in response to negative (normative) feedback (e.g., Hutchinson, Sherman, Martinovic, & Tenenbaum, 2008; Johnson, Turban, Pieper, & Ng, 1996; Lamarche, Huffman, Eliasz, Gammage, & Adkin, 2008; Nussbaum & Dweck, 2008). In contrast, if such normative comparisons are favorable for an individual, increased self-efficacy, perceptions of higher competence, enhanced effort, positive self-reactions, and task interest result. Hutchinson and colleagues, for example, found increased self-efficacy and sustained effort on a handgrip task involving continuous force production as a function of positive normative feedback compared with both negative feedback and a control condition. Furthermore, normative feedback not only has a temporary effect on motor performance but can also affect *learning*. A study by Lewthwaite and Wulf (2010b) provided evidence that normative feedback (falsely) indicating better-than-average performance can produce more effective learning of a motor task than feedback indicating below-average performance or no normative feedback (see also Ávila, Chiviacowsky, Wulf, & Lewthwaite, 2012; Wulf, Chiviacowsky, & Lewthwaite, 2010, 2012). One purpose of the current study was to examine normative feedback in potential interaction with conceptions of ability in the context of motor learning.

Conceptions of Ability

Conceptions of ability reflect how people think about the nature of certain key abilities, and whether they believe that those are attributes fixed at birth, or amenable to change with experience or practice. In various achievement-related domains, people's beliefs about the malleability (incremental theory) or stability (entity theory) of abilities—whether they are dispositional beliefs or induced through instructions—have been shown to affect their performance and learning (e.g., Dweck & Leggett, 1988; Mangels et al., 2006). In one of the few studies related to motor performance, Jourden, Bandura, and Banfield (1991) found less improvement across practice of a motor task (pursuit rotor) for participants who were led to believe that their performance reflected inherent ability compared with participants who were informed that the task represented an acquirable skill. These researchers also found more positive affective self-reactions and enhanced self-efficacy under the acquirable-skill relative to the inherent-ability condition. More recently, Wulf and Lewthwaite (2009) showed that induced ability conceptions affected the learning of a motor skill; individuals who believed that their performance on a balance task was reflective of an inherent balance ability (and control group participants) demonstrated degraded learning relative to participants who viewed the task as an acquirable skill.

Interaction of Normative Feedback and Conceptions of Ability

Normative feedback is one means by which perceptions of competence are influenced (Ávila et al., 2012; Lewthwaite & Wulf, 2010b). The effects of feedback, indicating relative success or failure and high or low ability, may have differential effects, therefore, on individuals' performance or learning, depending on their ability conceptions (e.g., Cimpian et al., 2007; Dweck & Leggett, 1988; Mangels et al., 2006). Because entity theorists are more likely to perceive negative feedback as a threat to the self, feedback indicating that they are performing below average might be expected to have a more detrimental effect for them, compared with incremental theorists. Some evidence for this comes from the study by Cimpian and colleagues who found that, in 4-year old children, subtle differences in the wording of feedback implying either a fixed drawing ability or a more malleable one, influenced the children's self-evaluation and persistence on a drawing task. Specifically, after making a mistake, children who had been given (positive) feedback connoting a stable trait had lower scores on self-evaluation and persistence measures than children who had been given (positive) feedback suggesting that drawing performance was malleable. In another study, Mangels and colleagues demonstrated how people's dispositional conceptions of ability (i.e., intelligence) can influence the learning of new information. In that study, participants were first given a general knowledge test, in which feedback about the correctness of their answer as well the correct answer was provided after each question. On a subsequent surprise retention test consisting of questions that they had not answered correctly in the first phase, entity theorists showed less improvement compared with incremental theorists. Thus, entity theorists learned less from their errors, presumably because concerns about their performance prevented them from sufficiently processing the corrective feedback.

Goals of the Current Study

In the current study, we examined whether motor skill learning would be affected differently by positive or negative normative feedback in interaction with an induced conceptualization of the task as one in which performance reflected inherent ability or acquirable skill. We used a dynamic balance task (stabilometer) and informed different groups of participants that task performance reflected people's natural capacity for balance (inherent ability condition), or that it measured balance performance and that balance was a learnable skill (acquirable skill condition). In each condition, a fabricated average score was provided in addition to performers' own scores, indicating that their performance on a given trial was either better (Better condition) or worse (Worse condition) than that of the "average" performer. Thus, we used a factorial design to examine the relative contributions of each factor, as well as possible interactive effects. After two days of practice, the relatively permanent effects of those manipulations on learning were assessed in retention and dual-task (counting backward in 3s) transfer tests on the third day. Transfer tests often present greater challenges to performers and tend to be more sensitive measures of learning than retention tests (e.g., Chiviacowsky & Wulf, 2005; Lai & Shea, 1998; Wrisberg & Wulf, 1997).

To examine how learners' ability conceptions and normative feedback affected their motivation, task-, and self-evaluations, we administered a customized questionnaire at the end of each day. We also used changes in signature size—an indirect, unobtrusive measure of implicit self-esteem compensation (Rudman, Dohn, & Fairchild, 2007)—to assess reactions to experimental conditions. Following the technique of Zweigenhaft (1977; Zweigenhaft & Marlowe, 1973), Rudman and colleagues used differences in signature size from a baseline condition to a situation following some degree of peer rejection to unobtrusively assess college students' implicit reactions to social threat. Intraindividual enhancements in signature size (i.e., the area formed by a rectangle surrounding the length and height of an individual's signature) were found to be associated with the degree of threat experienced, with larger signature sizes associated with greater preceding threat. Further, the implicit measure of signature size change was inversely related to the degree of anxiety explicitly reported (Rudman et al., 2007).

Social comparisons yielding unfavorable results (i.e., negative normative feedback) produce negative reactions such as upset, disappointment, or frustration, and might also impact individuals' self-esteem (Nussbaum & Dweck, 2008; Tesser, 2000), perhaps particularly when it relates to performance reflecting an inherent ability (Nussbaum & Dweck, 2008). As a consequence, one would expect self-related concerns, nervousness, etc. to be heightened, signatures to be larger (i.e., implicit self-esteem compensation), and motor learning to be degraded in the Worse groups, perhaps especially the Inherent-Ability Worse group (Cimpian et al., 2007; Dweck & Leggett, 1988; Mangels et al., 2006; Nussbaum & Dweck, 2008). Alternatively, positive feedback—independent of whether it is interpreted as reflecting one's learning success or superior ability—could have a facilitatory effect on learning in the Better groups, perhaps particularly in combination with an incremental view of ability (i.e., Acquirable-Skill Better group). Jourden and colleagues found more positive self-reactions in an acquirable-skill group relative to an inherent-ability group practicing a motor task, but their study did not cross conceptions of ability with a condition that experimentally varied success and failure, nor did it involve a retention test of learning, particularly one that would include a 24-hr memory consolidation interval (Trempe et al., 2011). In an experiment examining the interactive effects of an induced theory of intelligence with positive and negative normative feedback on a speed-reading task, Nussbaum and Dweck (Experiment 3) found an explicit measure of state self-esteem to be affected by feedback valence, but not by theory of intelligence. That study focused on investigating strategic social-comparison-related (defensive) choices that might follow negative feedback, thus no responses other than that related to higher state self-esteem following positive feedback are available to inform the current study (Nussbaum & Dweck).

Following earlier work in which motor learning was positively affected separately by positive normative feedback (Lewthwaite & Wulf, 2010b) and an incremental conception of ability (Wulf & Lewthwaite, 2009), we hypothesized main effects of these variables on retention and transfer tests of learning. Furthermore, we expected positive but not negative normative feedback, and incremental but not entity conditions, to enhance learning. We tentatively predicted that positive normative feedback effects on learning would be heightened by an incremental belief regarding balance ability. We expected that cognitive, affective, and signature size responses to negative normative feedback and entity inductions would be found, reflecting threat-related impacts of these variables. However, if recent work suggesting the primacy of positive experiences for motor learning is supported, these negative impacts would not negatively affect motor learning.

Method

Participants

Fifty-six undergraduate students (36 females, 20 males) with a mean age of 22.3 years (standard deviation: 2.25) participated in this experiment. Informed consent was obtained from all participants. Participants had no prior experience with the experimental task, and they were not aware of our specific purpose in the study. The study was approved by the university's institutional review board. Participants were debriefed regarding the ability-related manipulation and bogus nature of the normative feedback following their participation in the experiment.

Apparatus and Task

Participants were asked to balance on a stabilometer ("stability platform"; Lafayette Instrument, Lafayette, IN) and to try to keep the balance platform in a horizontal position for as long as possible during each 90-s trial. The stabilometer consists of a 65 × 105-cm wooden platform, with the maximum possible deviation of the platform to either side being 26 degrees. DataLab 2000 Software (Lafayette Instrument, Lafayette, IN) was used for data acquisition and provision of feedback in terms of error scores (root-mean-square error; RMSE).

Procedure

All participants were informed that the task was to keep the platform in the horizontal position, or as close to horizontal as possible, during each 90-s trial. They were also informed that, after each trial, they would be given a score that represented their own average deviation of the platform from the horizontal (in degrees), as well as the average performance score on the respective trial produced by participants in previous experiments.

Participants were randomly assigned to one of four groups: Inherent-Ability Better, Inherent-Ability Worse, Acquirable-Skill Better, and Acquirable-Skill Worse groups. Instructions were designed to induce different conceptions of ability. Specifically, before the beginning of practice, participants in the two Inherent-Ability conditions read the following statements: "The balance platform (stabilometer) measures people's basic natural capacity for balance. You will be asked to perform several trials on each of three days. The scores you will be given after each trial, as well as how easy it is to improve, will reflect your inherent balance ability." Participants in the two Acquirable-Skill groups were provided with the following information: "The balance platform (stabilometer) measures people's balance performance. Like many other skills, balance is a learnable skill. At the beginning, it is common to have relatively large platform excursions. You will be asked to perform several trials on each of three days. The scores you will be given after each trial, as well as your improvement across trials, will reflect your learning and your 'getting the hang of it'." Thus, the instructions were designed to induce ability conceptions that corresponded to either an entity theory or an incremental theory, respectively.

Each trial started with the left side of the platform on the ground. At a start signal, the participant attempted to move the platform toward the horizontal, and data collection began. At the end of each trial, the experimenter informed the participant of his or her score (RMSE). In addition, the experimenter (calculated and) provided the "average" error score, which was 20% higher or lower than each individual's actual score, for the two Better or Worse groups, respectively. All participants completed two days of practice, each consisting of seven 90-s trials with veridical and normative feedback. Before the beginning of practice on Day 1, and again at the beginning of Day 2, participants were asked to read the instructional statements provided above. On Day 3, all participants performed a retention test, which also consisted of seven trials. However, no instructions or (veridical or normative) feedback were provided. After the retention test, participants completed a transfer test, consisting of one stabilometer trial during which they were asked to count backward in threes aloud from a random two-digit number that was provided by the experimenter.

To assess if, and how, induced ability conceptions and normative feedback influenced participants' motivation, participants completed a customized questionnaire at the end of each day. (The two questionnaires were identical, except that questions related to feedback, for example, were excluded on Day 3 on which no feedback was provided.) Aside from a manipulation check ("Relative to other people, how skilled are you on the stabilometer/balance task?"), the questionnaire included various task-, feedback-, and self-related items (see Table 1). Task-related questions were aimed at assessing participants' motivation to learn the task, how much they enjoyed practicing it, and how much they were looking forward to the next session. Items related to normative feedback addressed its subjective usefulness and its motivational effects. Various self-related questions were incorporated to determine participants' self-reported satisfaction with their performance, degree of nervousness before and after receiving feedback, thoughts and concerns about their performance and ability, thoughts about body position, as well as confidence in future successful performance. For most items on the questionnaire, participants were asked to circle a number that best reflected how they felt at the present time. The numbers ranged from 1 ("not at all") to 10 ("very"). Participants responded to a single question asking for their preference for receiving feedback regarding others' scores with a "yes" or "no" answer.

Finally, at the end of each of the three days, participants were asked to sign a sheet, which stated that they completed testing for that day, and which was purported to be for extra-credit purposes. The line on which they were to sign was placed in a way that it did not limit the size of a (normal) signature.

Data Analysis

For each 90-s trial, the average deviation of the platform from the horizontal (RMSE) was calculated. RMSE was analyzed in 2 (ability conception) × 2 (normative feedback) × 2 (days) × 7 (trials) analysis of variance (ANOVA) with repeated measures on the last two factors for the practice phase, and in a 2 (ability conception) × 2 (normative feedback) × 7 (trials) repeated-measures ANOVA for the retention test. The transfer test data were analyzed in a 2 (ability conception) × 2 (normative feedback) ANOVA.

Questionnaire responses were analyzed in separate 2 (ability conception) × 2 (normative feedback) ANOVAs for Day 1 and Day 3. Signature size was measured by determining the maximum height and length (in mm) of each signature on each day, and then calculating the signature area (in mm^2; cf. Zweigenhaft, 1977). The percentage of the signature area, relative to the signature area on the consent form (100%), was then determined and analyzed in a 2 (ability conception) × 2 (normative feedback) × 3 (day) ANOVA with repeated measures on the last factor.

Results

Balance Performance

The four groups showed similar performance scores (RMSEs) at the beginning of practice, and all reduced their deviations from the horizontal position across both days of practice (see Figure 1). The main effects of both day, $F(1, 52) = 343.77$, $p < .001$, $\eta_p^2 = .87$, and trial, $F(6, 312) = 165.70$, $p < .001$, $\eta_p^2 = .76$, were significant. Furthermore, the interaction of day and trial was significant, $F(6, 312) = 33.51$, $p < .001$, $\eta_p^2 = .39$, indicating generally greater reductions in error in Day 1 as compared with Day 2 of practice. The two Better groups showed greater improvement across trials than the two Worse groups, particularly on the first day, as well as overall more effective balance performance on both days. The main effect of normative feedback was significant, $F(1, 52) = 4.85$, $p < .05$, $\eta_p^2 = .09$, as was the interaction of normative feedback, days, and trials, $F(6, 312) = 2.24$, $p < .05$, $\eta_p^2 = .04$. In addition, while the Better and Worse groups in the Inherent-ability condition performed relatively similarly, the Better group in the Acquirable-skill condition showed greater improvement across trials than did the corresponding Worse group, as indicated by a significant Normative Feedback × Ability Conception × Trial interaction, $F(6, 312) = 3.14$, $p < .01$, $\eta_p^2 = .06$. The main effect of ability conception, $F(1, 52) < 1$, and the interaction of normative feedback and ability conception, $F(1, 52) = 1.58$, $p > .05$, $\eta_p^2 = .03$, were not significant.

On the retention test without feedback, all groups showed reductions in RMSE across trials, $F(6, 312) = 5.41$, $p < .05$, $\eta_p^2 = .09$. The two Better groups had overall lower error scores than the two Worse groups. The main effect of normative feedback was significant, $F(1, 52) = 3.92$, $p = .05$, $\eta_p^2 = .07$. In addition, the interaction of normative feedback and trial was significant, $F(6, 312) = 2.28$, $p < .05$, $\eta_p^2 = .04$, although post hoc tests did not identify the exact source of the interaction. The main effect of ability conception and the interaction of both factors were not significant, $F(1, 52) < 1$.

The two Better groups again demonstrated more effective balance performance in transfer than did the two Worse groups. The main effect of normative feedback was significant, $F(1, 52) = 4.63$, $p < .001$, $\eta_p^2 = .08$. The main effect of ability conception and its interaction with normative feedback were not significant, $Fs(1, 52) < 1$.

Motivation

The questionnaire results are shown in Table 1. The manipulation check indicated that the provision of normative feedback was effective: Participants in the two Better groups indicated they were more skilled on this balance task than most people, while participants in the two Worse groups assumed the opposite. The main effect of normative feedback was significant for both questionnaire

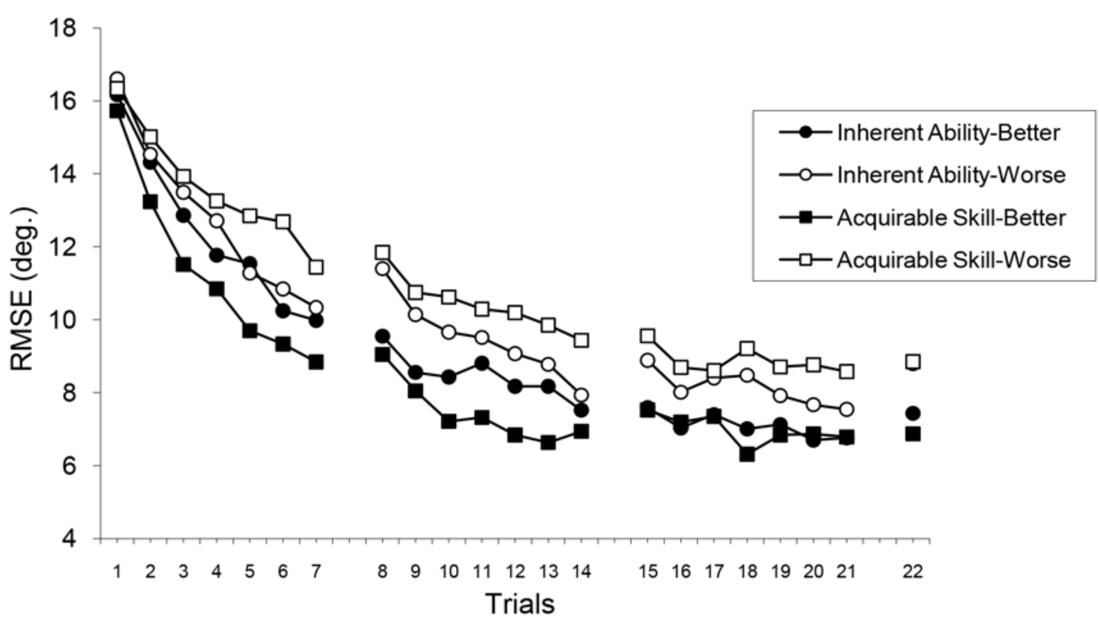

Figure 1 — Platform deviations (RMSE) from the horizontal position for the Inherent-Ability Better, Inherent-Ability Worse, Acquirable-Skill Better, and Acquirable-Skill Worse groups during two days of practice, and on the retention and dual-task transfer tests on Day 3.

Table 1 Mean Ratings on Motivational Questions Completed Following the First Day of Practice and the Retention and Transfer Tests (Day 3)

	Inherent-Ability Better	Inherent-Ability Worse	Acquirable-Skill Better	Acquirable-Skill Worse
Questions	Day 1, Day 3	Day 1, Day 3	Day 1, Day 3	Day 1, Day 3
Normative balance ability (manipulation check)				
Relative to other people, how skilled are you on the stabilometer/balance task?	6.6, 7.6	4.4, 5.5	8.0, 8.3	5.1, 5.9
Task-related responses				
How motivated were you to learn this task?	7.6, 8.7	7.4, 8.7	8.6, 8.4	8.6, 8.4
How much did you enjoy practicing this task?	8.3, 7.7	7.3, 8.0	8.0, 8.1	7.7, 8.5
Feedback-related responses				
Did you find the feedback (your score relative to other people's average score) useful?	7.9	7.5	8.0	7.5
Did you find the feedback (your score relative to other people's average score) motivating?	7.9	8.8	8.9	7.4
Self-related responses				
How satisfied are you with your performance on the balance platform?	6.3, 8.1	5.1, 7.3	7.8, 8.4	5.4, 7.0
How did you feel after receiving feedback on your trials today?	7.9	6.0	8.1	6.3
How nervous were you while you were waiting for the feedback?	2.8	4.8	2.0	3.6
How nervous were you before the start of each trial?	4.4, 3.1	5.3, 2.2	3.7, 3.1	3.0, 1.6
How nervous were you while you were balancing on the platform?	4.2, 3.6	5.9, 3.4	3.3, 2.9	3.8, 2.9
How much did your mind turn to thoughts about your balance performance while on the balance platform today?	8.2, 8.1	8.0, 7.8	7.2, 6.5	7.6, 6.4
How much did your thoughts concern your body position (for example, your feet, knees, hips, head) while balancing today?	8.6, 8.8	8.9, 8.4	8.2, 6.4	8.9, 7.6
How much did your thoughts concern your ability on this task while on the balance platform today?	7.6, 8.2	8.1, 7.8	7.1, 6.6	8.1, 7.2

Note. Responses for each question could range from 1 = "not at all" to 10 = "very."

administrations on Day 1, $F(1, 50) = 18.80$, $p < .001$, $\eta_p^2 = .27$, and Day 3, $F(1, 51) = 15.44$, $p < .001$, $\eta_p^2 = .23$. Questions pertaining to the task did not yield significant main or interaction effects. However, the two Acquirable-Skill groups tended to have higher ratings, compared with the Inherent-Ability groups, during practice (Day 1) with respect to how motivated they were to learn the task, $F(1, 51) = 3.70$, $p = .06$, $\eta_p^2 = .07$. There were no significant effects with regard to the feedback-related responses (i.e., in terms of how useful or motivating the normative feedback was perceived to be). However, the self-related questions yielded a number of interesting effects. When feedback was provided (Day 1), the Better groups reported that they were more satisfied with their performance, $F(1, 51) = 7.65$, $p < .01$, $\eta_p^2 = .13$ (they also tended to be more satisfied on Day 3, $F(1, 51) = 3.17$, $p = .08$), felt better after receiving feedback, $F(1, 51) = 12.97$, $p < .001$, $\eta_p^2 = .20$, and were less nervous while waiting for feedback, $F(1, 51) = 7.30$, $p < .01$, $\eta_p^2 = .13$, than their Worse counterparts. The instructions given to influence participants' ability conceptions resulted in the Inherent-Ability groups being more nervous before the start of a trial, $F(1, 51) = 4.09$, $p < .05$, $\eta_p^2 = .07$, as well as while balancing on Day 1, $F(1, 51) = 6.00$, $p < .05$, $\eta_p^2 = .11$. The Inherent-Ability groups also reported having more thoughts about their performance, $F(1, 51) = 7.35$, $p < .01$, $\eta_p^2 = .13$, their body position while balancing, $F(1, 51) = 7.50$, $p < .01$, $\eta_p^2 = .13$, as well as their ability, $F(1, 51) = 3.94$, $p = .05$, $\eta_p^2 = .07$, than the Acquirable-Skill groups on Day 3.

Thus, participants who believed that their performance was above average, as opposed to below average, were more satisfied with their performance, felt better after receiving feedback, and were less nervous while waiting for feedback. Induced inherent-ability relative to acquirable-skill conceptions increased learners' degree of nervousness before and while balancing (on Day 1), and thoughts about their performance and ability, as well as the degree to which they focused on their body movements (on Day 3).

Signature Size

The signature area, relative to the consent form signature (baseline), is shown in Figure 2. At the end of each of the two practice days, the signature areas in the two Worse groups (average across both groups and days: 122.2%) was increased relative to baseline (100%), whereas the two Better groups (average: 102.6%) were similar to baseline. The main effect of normative feedback was significant, $F(1, 52) = 5.46$, $p < .05$, $\eta_p^2 = .10$. In addition, there was an interaction of conception of ability and day during the practice phase, $F(1, 52) = 4.51$, $p < .05$, $\eta_p^2 = .08$. On Day 1, the Inherent-Ability groups (122.1%) demonstrated larger increases in the signature area than the Acquirable-Skill groups (107.8%), but this difference was diminished (and tended to be reversed) on Day 2 (106.6 versus 113.2%, respectively). Post hoc tests were not able to identify the source of the interaction. When instructions and feedback were removed on Day 3, the main effects of conception of ability, $F(1, 52) < 1$, and normative feedback, $F(1, 52) = 1.22$, $p > .05$, $\eta_p^2 = .02$, or Conception of Ability × Normative Feedback interaction, $F(1, 52) = 1.68$, $p > .05$, $\eta_p^2 = .03$, were not significant.

Discussion

Both normative feedback (Hutchinson et al., 2008; Lewthwaite & Wulf, 2010a; Wulf et al., 2010) and beliefs about the malleability or stability of abilities have been shown to independently affect performance and learn-

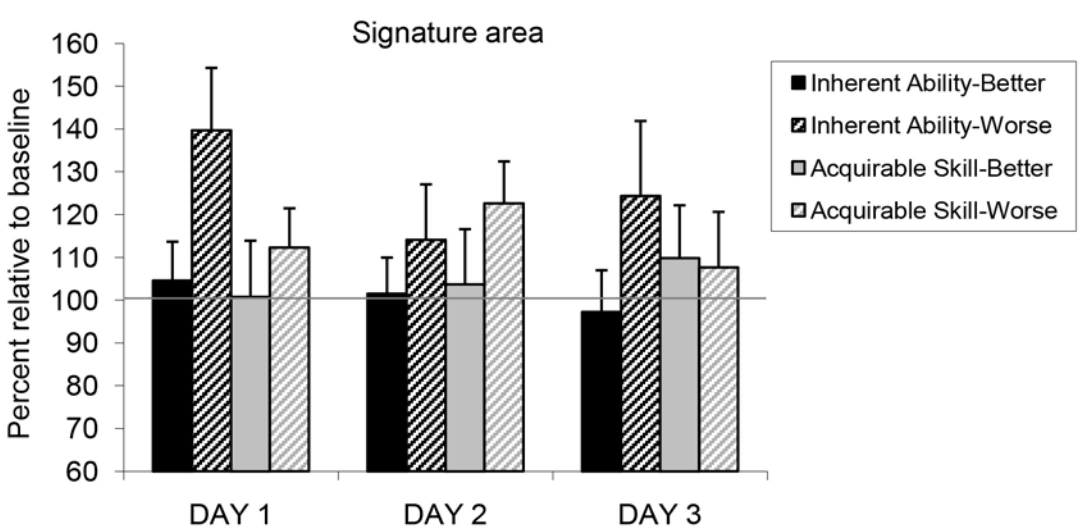

Figure 2 — Changes in signature size, relative to baseline signature, at the end of each day for the Inherent-Ability Better, Inherent-Ability Worse, Acquirable-Skill Better, and Acquirable-Skill Worse groups.

ing (e.g., Dweck & Leggett, 1988; Jourden et al., 1991; Mangels et al., 2006; Wulf & Lewthwaite, 2009). We examined the influence of normative feedback on motor skill learning as a function of learners' conceptions of ability. Feedback suggesting poor performance would be expected to produce some negative reactions such as disappointment even in those individuals with an incremental (acquirable-skill) conception of ability (e.g., Nussbaum & Dweck, 2008). According to one hypothesis, feedback indicating relatively poor performance would be expected to have a particularly detrimental effect if the performer interpreted it as a reflection of low inherent ability (Cimpian et al., 2007; Dweck & Leggett, 1988; Mangels et al., 2006; Nussbaum & Dweck, 2008). Alternatively, positive feedback whether indicating personal progress or normative success—perhaps particularly in combination with an incremental view of ability—could have an energizing effect that leads to further learning.

During the practice phase, when normative feedback was present, the two Better groups demonstrated greater improvement than did the two Worse groups, with the Acquirable-Skill Better group showing the most effective performance throughout the practice phase. The acquirable-skill conception induction may have provided additional positive motivational contribution to performance engagement, as it was accompanied by error score reduction over trials, indicating the promised progress with practice. It may also have buffered participants against future feedback that could be negative or positive, or provided "psychological distance" from the implications of negative feedback should it occur. In this study, however, while acquirable-skill inductions produced differences in acquisition-phase performance and self-related responses, they did not add to learning outcomes. Believing that skill changes with practice and is not due to an inherent ability may dampen the self-related affect that would accompany positive feedback. The fact that the induced ability conceptions did not affect learning is unexpected both in terms of prior conception of ability work in motor learning (Jourden et al., 1991; Wulf & Lewthwaite, 2009) and relative to generally positive roles assigned to acquirable-skill conceptions. If acquirable-skill conditions defuse affect, and positive affect is helpful for learning, incremental ability conceptions may not contribute as strongly to initial learning as affect-inducing influences such as positive normative feedback. This finding deserves further study.

Importantly, both Better groups demonstrated more effective learning, compared with the respective Worse groups, as evidenced by both retention and transfer test performance. The effect of normative feedback appeared to be somewhat larger on the transfer test than on the retention test. Requiring participants to count backward in 3s while balancing 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 (see below), task-related processing would be expected to suffer more (i.e., in the Worse groups) compared with the absence of that need (i.e., in the Better groups).

The questionnaire results provide some insights into how normative feedback may have influenced learning. First, participants in both Better groups rated their skill level as significantly higher than did participants in the Worse groups (see Table 1), indicating that the feedback manipulation was effective. Learners who received feedback indicating that they were performing above average were more satisfied with their performance, felt better after receiving feedback, and reported significantly less nervousness while waiting for the feedback than their Worse group counterparts. Thus, the conviction of performing better than average apparently created a positive state of mind and/or fewer self-related concerns that resulted in more effective balance performance and learning than the belief that one's performance was below average. In a previous study (Lewthwaite & Wulf, 2010b), positive normative feedback also led to enhanced performance and learning relative to a control condition without normative feedback—suggesting that positive information provides a boost to learning rather than negative information degrading it.

While the normative feedback affected mainly learners' responses to the feedback and satisfaction with their performance, the information influencing participants' conceptions of ability had differential effects on ability-related thoughts. Specifically, participants in the Inherent-Ability conditions reported being more nervous while balancing and having more thoughts concerning their ability as well as their performance than those in the Acquirable-Skill groups. In addition, they reported more body-position related thoughts. Thus, inherent-ability instructions may have indirectly promoted an internal focus of attention (Wulf, 2007a), which generally impairs motor performance and learning (for a review, see Lohse, Wulf, & Lewthwaite, 2012; Wulf, 2012). Yet, despite affecting these potentially detrimental mediators of learning, the influence of ability conceptions on learning was less potent than that of normative feedback as operationalized in this study. It is possible that two inductions of instruction (regarding conceptions of ability) could not outweigh provision of normative feedback after every acquisition-phase trial in terms of learning, although they were sufficient to affect motivational states and performance in acquisition when present.

Changes in participants' signature size provided additional evidence that normative feedback had differential effects on self-related reactions, in particular participants' self-esteem. Participants in the Worse conditions showed an increase in signature size, relative to baseline (consent form signature), while positive normative feedback resulted in no change. This finding is consistent with those of Rudman et al. (2007), in which a (bogus) peer rejection—a situation that posed a high threat to the self—resulted in a significant increase in participants' signature size. The authors provided evidence that this effect was a reflection of *implicit self-esteem compensation*, that is, a defensive, self-enhancing reaction to the threat. Individuals, whose self-worth was at stake, appeared to—presumably spontaneously and unconsciously—reduce the resultant anxiety by amplifying their self-esteem. The manifestation of this compensation was the increase in the size of their signature. In the same study (Rudman et al., 2007), participants in a low-threat situation (i.e., accepted by a peer) or in a control condition did not exhibit changes in signature size. Similarly, in the current study, providing learners with information indicating that they were performing below average presumably created a threat to their ego that resulted in implicit self-esteem compensation. This is demonstrated by the inflation of the sizes of their signatures during the practice (when normative feedback was present), while the groups receiving "above-average" feedback did not show a change in signature size. When feedback was removed on Day 3, signature sizes no longer differed among groups. While implicit self-esteem compensation is at times convergent and at other times divergent with explicit self-esteem alterations, we did not directly assess explicit or self-reported self-esteem, although in our study participants perceived their relative balance ability in accord with their normative feedback grouping.

Experimental studies of motor learning have been largely left to investigations from a cognitive, information-processing perspective in recent decades, in which various conditions of practice including augmented feedback and scheduling have been thought to function via informational contributions (e.g., Schmidt & Lee, 2011). The findings of the current study, as well as other recent experiments (e.g., Abe et al., 2011; Chiviacowsky & Wulf, 2007; Lewthwaite & Wulf, 2010b; Trempe, Sabourin, & Proteau, 2012; Wulf et al., 2012), however, demonstrate that motivational variables affect not only transient motor performance, but retainable motor learning as well. They may alert us to the possibility that there may be several mechanisms for motor learning. One mechanism may be relevant to the immediate neural potentiation of (motor) learning (a "moment of learning" mechanism), activated in the initial learning context and related to memory consolidation. Such influence may be related to the confluence of motor-related inputs, sensorimotor responses, and motivation-related dopamine systems in neuroplasticity and the corticostriatal pathway (e.g., Wickens, Reynolds, & Hyland, 2003). Within this system, many types of motivational variables, both extrinsic and intrinsic in nature, from monetary and food rewards to complex social-cognitive influences can function as rewards or anticipated rewards to serve as stimulants to dopamine system influences on learning. The second mechanism may involve longer-term behavioral pathways in which intrinsically oriented social-cognitive variables related to mindset and ability conceptions, expectancies, affective experience, goal orientations, goal-setting, effort, and attention facilitate continued engagement in practice. These pathways may create conditions in which learners "remain in the game" and invest in processing that leads to continued learning and sustained achievements.

Integrative research is called for that combines methods and perspectives on motor learning as investigated under diverse scientific traditions, including sophisticated psychological and neuroscientific approaches. Further research is needed to examine both implicit as well as explicit motivational effects on motor learning, and the motor output itself over time (Lewthwaite & Wulf, 2010a). Beneficial effects of positive motivational manipulations on motor learning have thus far been found for a variety of motor tasks including balance tasks, sequential timing tasks, throwing, golf putting, and visuomotor (force-field) adaptation tasks (Avila et al., 2012; Badami et al., 2012; Lewthwaite & Wulf, 2012; Trempe et al., 2012). Whether future research will identify particular types of movement tasks for which other motivational states are more beneficial for learning as has been found in some cognitive learning situations (e.g., Grimm, Markman, Maddox, & Baldwin, 2008) is an empirical question. We also note that normative feedback is but one form of influence on perceptions of competence or success and failure. We used it here experimentally because of its ubiquitous and powerful effect (e.g., Chartrand & Bargh, 2002) on human responses.

The first potential (moment of learning) mechanism described above might indicate that greater attention in applied contexts needs to be given to the creation of positive experience and stronger celebrations of initial attempts at learning to ensure optimal learning in its early stages. Our findings did not differentiate learning impacts of alternate conceptions of ability relative to feedback signifying relative success, however, other cognitive and affective impacts of incremental and entity inductions were seen. Thus, improvements, effort, and persistence might be appropriate targets for (internal or external) recognition, the former for their behavioral and longer-term impacts, and the "celebratory" or positive motivational state for its increasingly apparent role in enhancement of learning.

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