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Temporal-Comparative Feedback Affects Motor Learning

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In this experiment, we investigated the motivational effects of feedback on motor learning observing the impact of temporal-comparison feedback on the learning of a coincident timing task. Two groups of participants, a positive (PTC) and a negative temporal-comparison group (NTC), received veridical feedback about their accuracy scores after every other practice trial (50%). In addition, after each block of 10 trials, the PTC group was given bogus feedback suggesting that their average performance was better than it was in the previous block, while the NTC group received bogus feedback suggesting that their average performance was worse than it was in the previous block. A retention test was performed one day after the practice phase, without feedback, to observe learning effects. In addition, after the practice phase and before the retention test, all participants filled out questionnaires to report their self-efficacy levels. The results demonstrate that temporal-comparison feedback affects the learning of motor skills. Participants of the PTC group showed greater timing accuracy and reported higher self-efficacy levels than the NTC group on the retention test. The findings further support the important motivational role of feedback for motor learning.

Keywords: self-evaluation, motivation, competence, self-efficacy, knowledge of results

Feedback has long been considered one of the most powerful variables affecting learning. In general, it is conceptualized as information provided by an agent (e.g., teacher, peer, coach) related to aspects of one's performance or understanding (Hattie & Timperley, 2007). In the motor behavior area, numerous experiments in the past 30 years have examined the role feedback is thought to play during the acquisition of motor skills. Common to these experiments was the main concern with the feedback informational function (for reviews, see Salmoni, Schmidt, & Walter, 1984; Schmidt, 1991; Swinnen, 1996; Wulf & Shea, 2004).

However, recent experiments have provided converging evidence that behind its informational properties, feedback presents an important motivational function for motor learning, especially connected to learners' perceptions of competence. For instance, the results of Chiviacowsky and Wulf (2002) showed the learners'

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preferences for receiving feedback after good instead of after poor trials. Following this finding, other experiments demonstrated that, indeed, providing learners with feedback after trials with relatively small errors can positively affect learning and intrinsic motivation, as opposed to feedback after trials with larger errors (Badami, VaezMousavi, Wulf, & Namazizadeh, 2012; Chiviacowsky & Wulf, 2007; Chiviacowsky, Wulf, Wally, & Borges, 2009; Saemi, Wulf, Varzaneh, & Zarghami, 2011). Together, these experiments essentially indicate that feedback information is critically linked to learners' perceptions of competence, an important source of human motivation (Deci & Ryan, 2000, 2008). Perceived self-efficacy, defined as an individual's belief in his or her competence to perform a given task (Bandura, 1977), has been shown to act as a predictor of motor performance and learning (e.g., Chiviacowsky, 2014; Moritz, Feltz, Fahrbach, & Mack, 2000).

The effects of manipulating individuals' perceptions of competence through feedback on the learning of motor skills were also observed in more recent experiments using social-comparative feedback, a kind of feedback involving competence evaluation through the comparison of outcomes of an individual with those, actual or false, of others. Lewthwaite and Wulf (2010) first observed in the motor learning area that positive, relative to negative or no social-comparative feedback, enhanced adults' learning of a balance task. Similar results were found in subsequent motor learning experiments, in which participants learned a sequential timing task (Wulf, Chiviacowsky, & Lewthwaite, 2010), and also while learning a throwing task (Pascua, Wulf & Lewthwaite, 2015; Wulf, Chiviacowsky, & Cardozo, 2014). The beneficial effects of this kind of comparison feedback on motor learning were also observed in experiments involving other populations, including older adults (Wulf, Chiviacowsky, & Lewthwaite, 2012), and children (Ávila, Chiviacowsky, Wulf, & Lewthwaite, 2012).

While social-comparative feedback has been demonstrated to affect motor learning in different kinds of tasks and populations, the comparison of outcomes of the same individual, also called temporal-comparison, has not received attention from researchers in the learning area. However, temporal-comparison can also be considered an important source of information for competence evaluation (Brown & Middendorf, 1996; Butler, 1998; Miller, 1977; Wilson & Ross, 2000; Zell & Alicke, 2009). Specifically, temporal self-comparison involves the opinions and abilities of an individual that can constitute a self-description of that individual at different points in time, acting to fulfill people self-evaluation goals (Albert, 1977). In the experiment of Zell and Alicke (2009), temporal-comparison was manipulated by informing participants that the number of items correctly identified on each of the 50-item social sensitivity tests used either gradually improved or declined over time. The authors also observed that social and temporal comparison can independently influence individuals' evaluations of their own skills when jointly provided. Interestingly, in the research of Wilson and Ross (2000), participants were shown to report at least as many temporal comparisons as social comparisons, mainly favoring temporal-comparison information when seeking to improve over time and social comparison when they wished to perform an accurate self-evaluation.

Therefore, the purpose of this experiment was to investigate if temporal-comparison feedback provided to participants about whether their performance was improving or declining over time would affect the learning of motor skills. To our knowledge, the effects of this variable, if any, on the performance and learning of motor skills have not yet been explored. Temporal-comparison information is considered important for competence evaluation (Brown & Middendorf, 1996; Butler, 1998; Zell & Alicke, 2009), and perceived competence has been shown to affect motor performance (Moritz et al., 2000) as well as learning (Chiviacowsky & Harter, 2015; Wulf, Chiviacowsky, & Cardozo, 2014; Stevens, Anderson, O'Dwyer, & Williams, 2012). Thus, it can be anticipated that participants provided with feedback on improvement across blocks of practice may show enhanced learning compared with participants informed of diminished performance. Such findings support the important motivational role of feedback in motor learning. In the present experiment, two groups of young adults were asked to practice a task involving anticipatory coincident timing. While both groups received veridical feedback after every other trial (50%) regarding accuracy, the positive and negative temporal comparison groups received bogus feedback suggesting that their average performance in a determined block of trials was above or below, respectively, the average performance in their previous block. A self-efficacy questionnaire was also used to determine the influence, if any, of temporal-comparison feedback on participant's perceptions of competence. One day after the practice phase a retention test without feedback was performed to examine learning effects as a function of temporal comparison. As temporal comparison can be considered a potential important source of information for competence evaluation (e.g., Wilson & Ross, 2000; Zell & Alicke, 2009), and considering the human psychological need for competence (Deci & Ryan, 2000, 2008), it was expected that both groups would improve performance, decreasing absolute and variable errors with practice. However, the positive temporal-comparison group was expected to report increased perceptions of competence and demonstrate higher learning of the motor task than the negative temporal-comparison feedback group.

Method

Participants

Twenty university students (16 males, 4 females), with a mean age of 21.6 years (*SD* = 1.98) participated in the experiment. All participants gave their informed consent, and the university's institutional review board approved the experiment. In addition, participants had no prior experience with the experimental task and were not aware of the purpose of the experiment.

Apparatus and Task

An apparatus, consisting of a 228 cm track with 48 light-emitting diodes (LEDs) on its surface (Bassin anticipation timer, Model 35575, Lafayette Instruments, Lafayette, IN, Figure 1) was used to measure temporal accuracy. The task involved anticipatory coincident timing and the sequential illumination of the LEDs was scheduled to create a temporal perception of a luminous red light moving down the runway. The (perceived) running light moved at a constant speed of 20 mph. To increase the difficulty of the task, a barrier was placed on the top of the trackway, so that the 15 lights before the last one (target light) were obscured. Participants were asked to press a handheld switch coincidently with the illumination of the last light (target), with the thumb of the preferred hand. To do that, they had to anticipate the illumination of the target light, performing the task from a seated position, while facing the apparatus. The initiation of the trials was indicated through a yellow warning light, which was defined to illuminate for a variable period of time (2–5 s). The absolute difference between the target light illumination and the pressing of the switch was used to measure temporal accuracy (absolute error, or AE).

Procedure

All participants, after completing the consent form, were randomly assigned to the positive (PTC) and negative (NTC) self-comparison feedback groups, with an equal number of males and females participants in each, and introduced to the task. They were informed that they should press a handheld switch using the thumb of the preferred hand coincidently with the illumination of the target light, and that it would correspond to a 0 ms error. The participants were informed that feedback would consist of the number of milliseconds during which the switch was being pressed after or before the illumination of the target light (e.g., -25 ms) and that it would be provided after every other trial (50%). They were additionally informed that at the end of the second, third, and fourth blocks of 10 trials, they would receive a general feedback informing about their average performance in relation to their previous block. Participants of the positive temporal-comparison group received false feedback suggesting that their performance was 10, 15, and 20% better (respectively after the second, third, and fourth blocks of trials) than in the previous block, while the negative temporal-comparison group received false feedback suggesting that their performance was 10, 15 and, 20% worse than in the previous block (also respectively after the second, third, and fourth blocks of trials). Results were recorded using digital display equipment (Figure 1), and participants verbally received veridical and temporal-comparison feedback from the experimenter.

Figure 1 — The Bassin anticipation timer apparatus (Model 35575, from Lafayette Instruments, Lafayette, IN) and the experimental setup.

The practice phase consisted of 40 trials and the retention test was performed 1 day later, consisting of 10 trials without feedback with an interval of approximately 10 seconds between each trial. Participants of both groups completed a self-efficacy questionnaire immediately after the end of the practice phase and before the retention test. Self-efficacy, as a measure of perceived capability, should be measured against different raising levels of task demands, representing gradations of challenges to successful performance (Bandura, 2006). In this way, in this six-item questionnaire, participants were asked to rate how confident they were that their errors would be, on average, smaller than 60, 50, 40, 30, 20, and 10 ms, respectively, the next day (after practice), or in the next trials (before retention) on a scale from 1 ("not at all") to 10 ("very"). Internal consistency of the items was measured using Cronbach's Alpha. After the end of the retention test, participants of both groups were debriefed regarding the temporal-comparison feedback received.

Data Analysis

Absolute error (AE) and variable error (VE) were averaged across blocks of 10 trials. Practice data were analyzed in a 2 (groups) × 4 (blocks) analyses of variance (ANOVA) with repeated measures on the last factor. A one-way ANOVA was used for the retention test data. The results of the self-efficacy questions, regarding the six different task-difficulty levels, were averaged and analyzed in a one-way ANOVA. A linear regression analysis was also conducted to determine whether self-efficacy (after practice and before retention) were predictors of performance on the retention test. We used partial eta-squared values to indicate effect sizes for significant results (η_p^2) and the Alpha was set at 0.05 for all analysis.

Results

Temporal Accuracy

Participants of both groups reduced their AEs (see Figure 2, left) during the practice phase. The main effect of block was significant, $F(3, 54) = 12.50$, $p < .001$, $\eta_p^2 = .41$. The main effect of group, $F(1, 18) < 1$, and the group × block interaction, $F(3, 54) < 1$, were not significant. The groups also reduced variability (VE) across practice (Figure 3, left). The main effect of block was significant, $F(3, 54) = 10.03$, $p < .001$, $\eta_p^2 = .36$, while the main effect of group, $F(1, 18) < 1$, as well as the group × block interaction, $F(3, 54) < 1$, were not significant.

As can be observed in Figure 2 (right), on the no-feedback retention test, participants of the PTC feedback group outperformed participants of the NTC feedback group. The main effect of group was significant for AE, $F(1, 18) = 7.93$, $p < .05$, $\eta_p^2 = .30$. VE was also smaller in the PTC group compared with the NTC group (see Figure 3, right). The main effect of group was also significant for VE, $F(1, 18) = 7.27$, $p < .05$, $\eta_p^2 = .28$.

Self-Efficacy

After the practice phase and before the beginning of the retention test, all participants rated how confident they were that they would be able to produce on

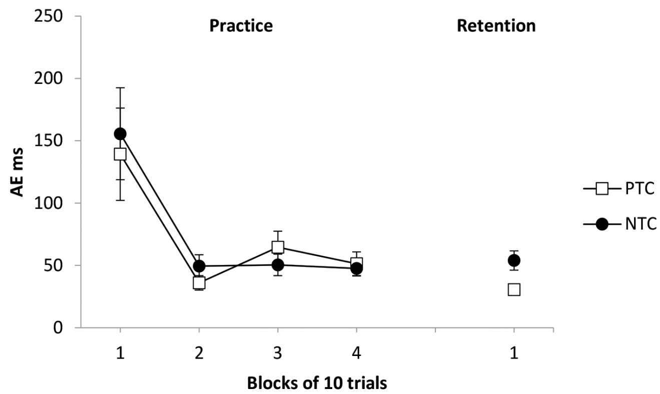

Figure 2 — Absolute error (ms) during practice and retention, for the positive and negative temporal-comparative feedback groups. Error bars indicate standard errors.

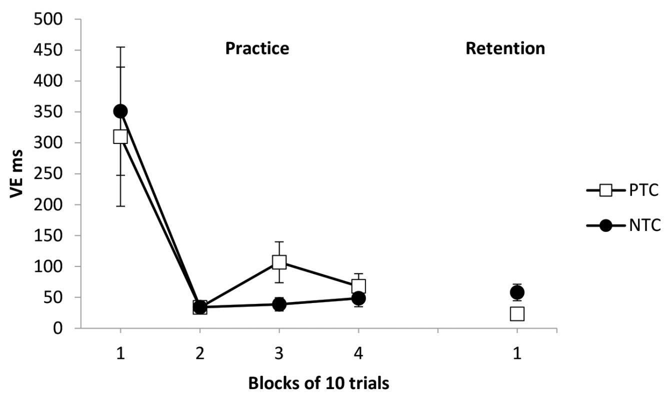

Figure 3 — Variable error (ms) during practice and retention, for the positive and negative temporal-comparative feedback groups. Error bars indicate standard errors.

the next day (after practice) or on the next trials (before retention), errors of less than 60, 50, 40, 30, 20, and 10 ms, on a scale from 1 to 10. To yield a single score of the self-efficacy ratings, the six different task-difficulty levels were averaged, separated for day. Cronbach's alpha was used to measure the internal reliability of the different levels. Alpha coefficient was .95 and .96 for the first and second days, indicating an excellent degree of internal consistency between the six scale items. The group effect was significant in day 1 (after practice), $F(1, 18) = 9.17$, $p < .01$, $\eta_p^2 = .34$, with the PTC group (7.10) showing greater self-efficacy than the NTC group (4.62); and in day 2 (before retention), $F(1, 18) = 8.78$, $p < .01$, $\eta_p^2 = .33$, with the PTC group (7.55) participants showing also greater self-efficacy than NTC group (5.10) participants (Figure 4).

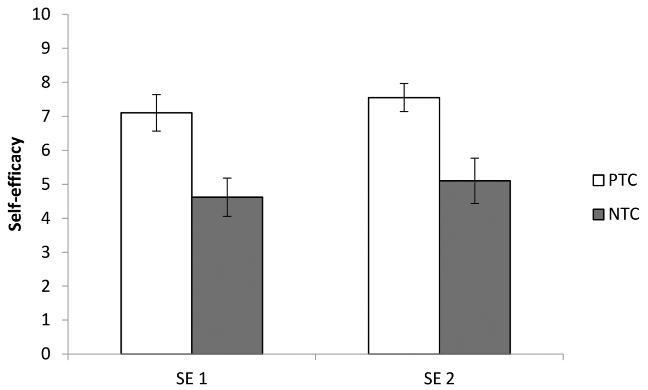

Figure 4 — Self-efficacy scores after practice (Day 1), and before retention (Day 2). Note: Error bars indicate standard errors.

Linear regression analyses, including group affiliation (dummy coded as PTC = 1, NTC = 0), were conducted to determine if self-efficacy, after the practice phase and before the retention test, could be considered a significant predictor of learning. The regression equation for self-efficacy after practice (day 1) was significant, $F(1, 18) = 3.92$, $p < .05$, $R = .31$, with $\beta = .48$, for group, and $\beta = -.12$, for self-efficacy, showing that self-efficacy levels reported immediately after the practice phase significantly predicted the retention test performance, explaining 23.5% of the variance. The regression equation for self-efficacy before retention (day 2) was also significant, $F(1, 18) = 4.26$, $p < .05$, $R = .33$, with $\beta = .43$, for group, and $\beta = -.20$, for self-efficacy, showing that self-efficacy following the results of day 1 significantly predicted the retention test performance, explaining 25.6% of the variance.

Discussion

The objective of the present experiment was to examine the impact of temporal-comparison on motor learning. Specifically, we evaluated the effects of providing (false) positive or negative temporal-comparison feedback, respectively, suggesting that participants' performance improved or deteriorated over time on self-efficacy and learning levels of an anticipation timing motor task. To our knowledge, it was still unclear if temporal comparison would have any effect in motor skill learning. Our results confirmed that feedback providing temporal-comparison information, in addition to veridical feedback, affects self-efficacy and motor learning. As expected, the group receiving feedback implying their performance was improving over blocks reported higher levels of self-efficacy and demonstrated higher learning of the task than the group provided with feedback informing their performance was deteriorating over time. Thus, participants seem to be sensible to feedback informing the degree to which their performance gets better or worse over time, with consequences on their perceptions of competence and learning.

The present results are in line with previous motor learning experiments in which participants' competence evaluation was manipulated through social-comparative feedback (e.g., Lewthwaite & Wulf, 2010; Wulf et al., 2010). In these experiments, it was observed that the provision of false information, suggesting that the learner's performance was superior to that of peers, enhanced learning compared with information suggesting that the learner's performance was inferior to that of peers. The findings also further support previous research indicating that self-efficacy acts as an important predictor of motor performance (for a review, see Moritz et al., 2000) and learning (Chiviacowsky, 2014; Chiviacowsky, Wulf, & Lewthwaite, 2012; Stevens et al., 2012). Indeed, experiments with young adults (Badami et al., 2012; Chiviacowsky & Harter, 2015; Chiviacowsky & Wulf, 2007), as well as children (Ávila et al., 2012; Saemi et al., 2011) have showed that the degree to which an individual experiences success or failures through feedback contributes to an increase or decrease in his motor learning.

The findings are also in accordance with consolidated motivational psychological views demonstrating the benefits of higher levels of perceived competence for performance, affective experiences, and well-being (Bandura, 1977, 1982, 2012; Deci & Ryan, 2000, 2008; Ryan & Deci, 2006). In fact, competence is considered a basic psychological need, along with autonomy and relatedness (Deci & Ryan, 2000), and is believed to lead to improved performance and learning in different domains (Bandura, 1993; Chiviacowsky & Harter, 2015; Feltz, Chow, & Hepler, 2008; Hutchinson, Sherman, Martinovic, & Tenenbaum, 2008; Palmer, Chiviacowsky, & Wulf, 2016). Lower levels of perceived competence, on the contrary, can cause worries about task performance, possibly hampering learning (Wulf & Lewthwaite, 2016).

The present findings suggest that temporal-comparison feedback can be considered a source of information for learners' performance evaluation able to affect motivation as well as the learning of motor skills. The results highlight the important role of feedback for motor learning, adding to the evidence showing that this practice variable cannot be considered as "neutral" information, because it carries also an important motivational function (for a review, see Lewthwaite & Wulf, 2012). While we would not suggest the use of any type of false comparative feedback (social or temporal) in real contexts of practice, the fact that the comparison of learners with their past performance across blocks of practice usually can result in improvements over time makes the provision of positive temporal comparison a useful and pertinent tool to benefit motor learning. In this way, future experiments could consider testing if there is a potential for enhancement of the learning process by recognizing good performances or improvements of individuals over time, compared with (control) groups not provided with temporal-comparison feedback. In addition, since the present experiment observed the effects of temporal comparison in young adults learning a coincident anticipation timing task, with a limited motor component involved, it would be interesting to verify the effects of this variable on the learning of more complex tasks as well as in different populations.

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