Effects of normative feedback on motor learning are dependent on the frequency of knowledge of results

Abstract

Studies on normative feedback have shown superior motor learning outcomes for individuals who believe that they are performing better than others through increased self-efficacy. Nevertheless, the effects of normative feedback were never dissociated from the knowledge of results (KR) provided to the learners which potentially interacts with self-efficacy as well. Thus, we investigated whether the effects of normative feedback on motor learning, associated with self-efficacy, would be dependent on the amount of KR provided. Fifty-six participants were randomly assigned to four experimental groups in terms of KR frequency (100% and 33%) and normative feedback (positive and negative). In the acquisition phase, all groups received the average KR of their performance at the end of each block of trials (True feedback) and a fake KR based on their own performance (but said to be from a group of participants who practiced the same task) (False Feedback). The False Feedback indicated better or worse performance of the participant in comparison to the fake group, depending on their experimental group. Retention tests were performed immediately and after 24 hours from the acquisition phase. To measure self-efficacy, a questionnaire on participant's efficacy was applied before the first block, after each block of trials and before the retention tests. The results revealed superiority of positive normative feedback and 100% KR frequency, compared to negative normative feedback and 100% KR frequency in the 24h retention test. No difference was found between the groups with a frequency of 33% of KR (positive and negative). All groups increased self-efficacy during practice, but there was no difference between groups at any stage of the study. We conclude that the effects of normative feedback on motor learning are dependent on the KR frequency. However, they were not associated with self-efficacy.

Keywords: Motor skills; Motivation; Positive feedback; Self-efficacy; Social comparison.

1. Introduction

When learning to perform a motor skill, how beneficial/harmful is to know the performance of others? Over the past decades, this question has been addressed on a number of studies that revealed that social comparison, through the provision of so-called normative feedback, highly affects learning and performance in daily activities and sports (e.g., Fitzsimmons, Landers, Thomas, & Van Der Mars, 1991; McAuley, Talbot, & Martinez, 1999; Montes, Wulf, & Navalta, 2018; Simpson, Cronin, Ellison, Carnegie, & Marchant, 2020; Wulf, Lewthwaite, Cardozo, & Chiviacowsky, 2018). Specifically, gains have been found in performance and acquisition when the learner/athlete receives the information that he/she is performing better than others (positive normative feedback) compared to when the information states the opposite (negative normative feedback) or when the learner receives no normative feedback at all (Hutchinson, Sherman, Martinovic, & Tenenbaum, 2008; Lewthwaite & Wulf, 2012; Wulf & Lewthwaite, 2016). Although the panorama of studies indicates robustness of its effects in the acquisition of different motor skills (e.g., Ávila, Chiviacowsky, Wulf, & Lewthwaite, 2012; Gonçalves, Cardozo, Valentini, & Chiviacowsky, 2018; Wulf, Chiviacowsky, & Lewthwaite, 2012), few studies have addressed the posited mechanisms underlying the benefits of positive normative feedback.

One explanation has been associated with increased self-efficacy (Wulf & Lewthwaite, 2016). This construct emerged from the Social Cognitive Theory (Bandura, 1986) and is defined as the belief or judgment that a person has about his or her ability to perform specific actions (Bandura, 1977, 1994). In theory, if an individual finds himself successfully executing a certain task, he will have a growing expectation of future successful performances (Moritz, Feltz, Fahrbach, & Mack, 2000). In contrast, when individual experiences are unsuccessful, these consequently lower expectations of further success.

One way to inform the trainee about his/her personal success is through normative feedback. Indeed, studies on cognitive and motor tasks show that participants who received negative normative feedback exhibited lower levels of self-efficacy, while participants who received positive normative feedback reported higher levels of self-efficacy (e.g., Bandura & Jourden, 1991; Hutchinson, Sherman, Martinovic, & Tenenbaum, 2008; McAuley, Talbot, & Martinez, 1999; Motl, Konopack, Hu, & McAuley, 2006). Few studies examined the relation of self-efficacy with normative feedback on skill acquisition, however. Exceptions are the studies by Pascua, Wulf, & Lewthwaite (2015) and Wulf, Chiviacowsky, & Cardozo (2014) on which the provision of positive normative feedback revealed greater self-efficacy and gains in learning compared to groups that did not receive any normative feedback (but see Ong & Hodges, 2018).

One aspect that draws attention is that, with the exception of Zobe, Krause, & Blischke (2019) that does not discuss self-efficacy, all the studies investigating the effect of normative feedback on skill acquisition also had the provision of knowledge of results (extrinsic feedback on action outcome – KR) for all trials during practice. However, studies also point to a possible motivational property of KR that would, in principle, also affect learning (see Lewthwaite & Wulf, 2012; Thorndike, 1927)[1]. Studies have found that providing feedback after the best trials of a block leads to better retention (e.g., Chiviacowsky & Wulf, 2007; Chiviacowsky, Wulf, Wally, & Borges, 2009), with one of the explanations being greater self-efficacy (Saemi, Porter, Ghotbi-Varzaneh, Zarghami, & Maleki, 2012). In the same direction, Chiviacowsky, Wulf, & Lewthwaite (2012) manipulated learners' perception of competence by stating, differently for each group, a performance that would be considered a good trial. They found, first, that individuals seek information when they believe they had performed well and, second, that there were improvements in self-efficacy and motor learning only when learners were able to confirm their expected good performance.

1 It is worth mentioning that KR has been historically related to information guiding action changes in practice (Swinnen, 1996; Wulf & Shea, 2004). It has been shown that higher KR frequencies can be detrimental for performance given such informational role (see Marschall, Bund, & Wiemeyer, 2007; Salmoni, Schmidt, & Walter, 1984). However, more recent studies have argued that perhaps the high frequency of KR is not always detrimental to skill acquisition (e.g. Buchanan & Wang, 2012; Drews, Pacheco, Bastos, & Tani, 2020; Krause, Agethen, & Zobe, 2018; Schorer, Canal-Bruland, & Cobley, 2010). Authors (e.g. Wulf & Shea, 2002, 2004) posit that to understand the of KR in skill acquisition one must consider the interaction of KR with other factors (e.g., type and complexity of the task). Therefore, in this study, possible informational effects of low frequency of KR were not considered *a priori* since no effects were found in a previous study using the same task (Drews et al., 2020).

The fact that KR is linked to self-efficacy and normative and KR feedback were always administered in conjunction may suggest that the observed effects of positive normative feedback are dependent on the KR provided; a relation not yet examined. Some authors have pointed out that the ability to accurately determine whether you are successfully learning a motor skill is critical to developing motivation for continued practice and has an influence on how confident a person feels about his skills (Lee & Wishart, 2005; Simon & Bjork, 2001). Therefore, receiving different amounts of extrinsic information on performance – KR – would directly affect the effects of normative feedback, positive and negative. If individuals cannot monitor their performance, normative feedback would be ineffective, learners would be "at a loss to know what skills to enlist, how much effort to mobilize, how long to sustain it, and when to make corrective adjustments in their strategies" (Bandura, 1997, p. 66).

The aim of the present study, therefore, was to test the potential dependency of normative feedback on KR. We tested the effects of providing normative feedback in conjunction with different frequencies of KR on learning an anticipatory timing task. Athletes from different sports are required to perform extremely precise actions (e.g., hitting a home run in baseball – Regan, 1992) and learning how to deal with target moving at speed is, therefore, necessary. Anticipatory action performance might highly depend/relate on the accuracy of our temporal estimations/perception (Bastos, Marinovic, Rugy, & Tani, 2013; Marinovic, Reid, Plooy, Riek, & Tresilian, 2011). Four groups receiving positive/negative normative feedback and 100/33% KR frequencies performed an anticipatory timing task on two consecutive days with learning being measured through immediate and delayed retention tests. In addition, self-efficacy was measured through a questionnaire on the participant's confidence to achieve a given performance level on the task. The questionnaire was applied before and during the task acquisition, and before the learning tests.

Following current theoretical perspectives (cf., Wulf & Lewthwaite, 2016), greater self-efficacy and gains in motor learning can be expected from the provision of positive normative feedback at a high frequency of KR. However, understanding that a way to inform the individual about his or her personal success is through the provision of KR, a lower frequency of KR provision would decrease, if not eliminate, the effect of normative feedback on learning. This would occur once that less KR translates into less information on success and would not be sufficient to affect learner's self-efficacy – for better or for worse.

2. Method

2.1 Participants

Fifty-six volunteers (13 women, average age of 23.7 ± 3.5 years) without previous experience on the task, participated in this study. An *a priori* power analysis in G*Power 3.1.9.7 showed that for a within-between interaction of medium effect size ($\eta_p^2 = 0.06$) we would need, in total, 48 individuals. The sampling was greater as extra participants were interested in participating (considering the same effect size our achieved power was of $(1 - \beta) = 0.87$. All participants reported having normal or corrected-to-normal vision and all gave written informed consent. This study is in accordance with the Declaration of Helsinki and was approved by the local Ethics Committee of the School of Physical Education and Sport—University of São Paulo (Brazil) (CAAE: 01281112.2.0000.5391).

2.2 Task and Equipment

The task (cf. Bastos, Tani, Drews, Riek, & Marinovic, 2018) was developed in GNU Octave (Eaton, Bateman, Hauberg, & Wehbring, 2015), using the toolbox Psychtoolbox (Kleiner, Brainard, & Pelli, 2007) and was performed on an Ubuntu Linux 12.04 operating system. The task goal consisted of pressing a button at the time of arrival of a moving target at a predetermined position on a monitor screen (Figure A.1). Button presses generated Transistor-Transistor Logic (TTL) pulses that were recorded using a data acquisition card (Labjack U3-HV). The target moved horizontally, from left to right, on a 22-in. computer screen (Samsung 2233RZ, 120 Hz refresh rate, 1,680 x 1,050 resolution). The target started its motion between 1.5 and 3 s (the period varied in a pseudo random fashion – with no repetitions in subsequent trials) after the beginning of the trial and took 1.4 s to arrive at the predetermined position. After moving onset (initial velocity: 28.3 degrees of visual angle per second [dva/s]), the target constantly decelerated in a ratio of 5.7 dva/s^2. Additionally, the moving target was occluded in the last 784 ms of its displacement. The purpose of the deceleration during the occlusion was to make participants dependent upon the KR, as learning to estimate time of arrival, when the target moves with a constant speed and undergoes a fixed period of occlusion, occurs quickly (Marinovic, Tresilian, de Rugy, Sidhu, & Riek, 2014).

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In order to assess the self-efficacy, a questionnaire (Bandura, 2006) was used that aims to analyze how the individual evaluates their ability to successfully perform a specific task. In the questionnaire, participants answered how confident they were on a scale of 0 ("not at all confident") to 10 ("extremely confident") to achieve on average an error less than 250, 200, 100, 80, 50, 30 and 10 ms referring to the next block of trials to be performed.

2.3 Experimental design and procedures

The experiment consisted of three phases: acquisition phase (AQ), immediate retention test (IRT) and 24h retention test (RT). Participants were randomly assigned to four experimental groups, according to KR frequency and normative feedback: 100% KR frequency plus positive normative feedback (PF100), 33% KR frequency plus positive normative feedback (PF33), 100% KR frequency plus negative normative feedback (NF100) and the 33% KR frequency plus negative normative feedback (NF33). Before the start, participants performed 3 trials in order to familiarize them with the task. During AQ, participants performed 90 trials. For the 100% KR frequency groups, after each trial the participants received KR, provided in milliseconds, with the words “after” or “before,” indicating the difference between the response (button press) and the arrival of the target to the contact line. Within a window of 1 ms, participants would receive a “zero” error KR. In turn, the 33% KR frequency groups received a KR every 3 trials.

Additionally, all groups received both average KR of their performance (True feedback) at the end of each block of 15 trials and an average KR from a fake group of participants who practiced the same task (False Feedback). False feedback for the positive normative feedback groups (PF100, PF33) consisted of the participant’s average KR plus 20% of the value indicating superior performance in relation to “other participants who practiced the task” (e.g., Lewthwaite & Wulf, 2010; Wulf et al., 2010). For negative normative feedback groups (NF100; NF33) false feedback consisted of the participant's KR minus 20% of the value indicating inferior performance to the other participants.

Right after AQ, participants performed IRT with 20 trials, without KR and normative feedback. The same test was performed after 24 hours (RT). In addition, before the first trial of AQ and after each block of 15 trials, as well as before IRT and RT, the self-efficacy questionnaire was applied (Bandura, 2006).

2.4 Data analysis

Absolute error (AE), defined as the absolute value of the difference between the participant's response time and the arrival of the moving target in the predetermined position (in milliseconds), represented the performance measure analyzed. Additionally, self-efficacy measures were analyzed before and throughout AQ, as well as before IRT and RT.

The groups' performances were analyzed in 2 (Normative Feedback: positive versus negative) x 2 (Frequency of KR: 100% versus 33%) x 6 (blocks of 15 trials) analysis of variance (ANOVA) with repeated measures on the last factor for the AQ. For IRT and RT, each, a 2 (Normative Feedback: positive versus negative) x 2 (Frequency of KR: 100% versus 33%) x 2 (blocks of 10 trials) ANOVA was performed.

With regard to the self-efficacy questionnaire, we performed a general hierarchical linear modelling as to estimate self-efficacy change over blocks (see Drews et al., 2020). This measure has a different nature than AE as it refers to a probability and will naturally show a sigmoidal curve (an S-shape curve) that goes from not likely at all to totally likely succeeding at the given criterion of performance. Thus, we treated the likelihood as a percentage (out of ten trials as in a binomial distribution) and modelled it using the general hierarchical linear model analysis using the logit transformation of the independent measure. Also, the scale (250, 200, 100, 80, 50, 30 and 10 ms) was converted to integers from 0 to 6 as to match a scale of "task difficulty". This analysis then, treats the dependent variable varying as a sigmoid function of the independent variables. Two models were adjusted, one for acquisition blocks (questionnaires applied after each block of practice) and one for pre and post-acquisition questionnaires (before the first block of acquisition and before the RT). Both models were analyzed using an iteratively backward stepwise procedure where the model with and without the independent variable with lowest *t*-statistic were compared: if the measure increased the explanatory power (evaluated by the Bayesian Information Criterion), it was maintained in the model.

Bonferroni's Post Hoc tests were used to verify specific differences in all analyses performed. The post hoc testes were always reported with the mean ± standard error of the relevant variables. The calculation of the effect size used was the Partial Eta Squared (η_p^2). The Statistical Package for Social Sciences (SPSS 20.0) was used to perform the statistical procedures and adopted an alpha level of significance of 5%.

3. Results

3.1 Acquisition phase

Figure A.2 shows the performance of the four groups through the acquisition. The ANOVA on AE during the acquisition trials revealed a significant effect for blocks (F [3.75, 195.00] = 5.32, p = .001, η_p^2 = 0.09). However, there was no interaction between blocks and normative feedback (F [3.75, 195.00] = 1.25, p = .292, η_p^2 = 0.02), blocks and KR frequency (F [3.75, 195.00] = 0.61, p = 0.65, η_p^2 = 0.01), and blocks, normative feedback and KR frequency (F [3.75, 195.00] = 1.67, p = .162, η_p^2 = 0.03). Bonferroni post hoc tests shows that the AE on the first block (153.12 ± 10.76 ms) was significantly higher than the third (126.09 ± 8.30 ms), fourth (116.97 ± 5.49 ms), fifth (120.87 ± 5.48 ms) and sixth blocks AE (118.24 ± 8.92 ms).

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In addition, there was no difference between normative feedback groups (F [1, 52] = 0.31, p = .580, η_p^2 = 0.01), and KR frequency groups (F [1, 52] = 2.28, p = .137, η_p^2 = 0.04). No interaction between normative feedback and KR frequency groups was verified (F [1, 52] = 2,60, p = .113, η_p^2 = 0.05).

3.2 Retention tests

Figure A.3 shows the performance of the four groups in the IRT and RT blocks. In the IRT performance, ANOVA found no significant effects for blocks (F [1, 52] = 2.98, p = .091, η_p^2 = 0.05). Also, there was no interaction between blocks and normative feedback (F [1, 52] = 0.43, p = .515, η_p^2 = 0.01), blocks and KR frequency (F [1, 52] =

2.54, $p = .117$, $\eta_p^2 = 0.05$), and blocks, normative feedback and KR frequency (F [1, 52] $= 0.95$, $p = .334$, $\eta_p^2 = 0.02$).

In addition, there was no difference between normative feedback groups (F [1, 52] $= 0.13$, $p = .722$, $\eta_p^2 < 0.01$), KR frequency groups (F [1, 52] $= 0.11$, $p = .743$, $\eta_p^2 < 0.01$). No interaction between normative feedback and KR frequency groups was verified (F [1, 52] $= 0.65$, $p = .426$, $\eta_p^2 = 0.01$).

In the RT performance, ANOVA found no significant effects for blocks (F [1, 52] $= 0.49$, $p = .477$, $\eta_p^2 = 0.01$). There was no interaction between blocks and normative feedback (F [1, 52] $= 0.06$, $p = .804$, $\eta_p^2 < 0.01$), blocks and KR frequency (F [1, 52] $= 1.02$, $p = .317$, $\eta_p^2 = 0.02$), and blocks, normative feedback and KR frequency (F [1, 52] $= 1.24$, $p = .271$, $\eta_p^2 = 0.02$).

In the analysis for groups, there was no difference between normative feedback groups (F [1, 52] $= 1.07$, $p = .306$, $\eta_p^2 = 0.02$), and KR frequency groups (F [1, 52] $= 0.09$, $p = .762$, $\eta_p^2 < 0.01$). In turn, there was an interaction between normative feedback and KR frequency groups (F [1, 52] $= 5.38$, $p = .024$, $\eta_p^2 = 0.09$). The Bonferroni's post hoc tests revealed that PF100 (125.22 ± 19.42 ms) showed lower AE than NF100 (190.31 ± 19.42 ms) ($p = 0.022$).

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3.3 Self-efficacy

Figure A.4 shows the changes in the self-efficacy curve as a function of blocks in pre and post-acquisition questionnaires. Table A.1 shows the results of both adjusted models. For both acquisition and pre-post models, the resultant model maintained only block and scale (and their interaction) as independent variables. It shows that all groups increased, equally, their self-efficacy over time. Also, all groups improved the differentiation of performances that they would be more or less likely to achieve as the curve became more "S-like" after practice.

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4. Discussion

The aim of the present study was to examine the relation between normative feedback and the frequency of KR on learning an anticipatory timing task. Specifically, the investigation verified whether the effects of normative feedback, associated with self-efficacy, would be dependent on the amount of KR provided. Even taking into account the growing number of studies analyzing motivational factors in motor learning in recent years (Wulf & Lewthwaite, 2016), this seems to be the first study to verify the relation between normative feedback and KR. We hypothesized that greater self-efficacy and gains in motor learning would occur as a function of normative feedback; an effect dependent on KR frequency. We found that gains in motor learning occurred, indeed, as a function of normative feedback and KR frequency. Nevertheless, self-efficacy change was independent of all manipulations. The results, thus, partially confirmed the hypothesis of the study.

Over the past two decades, studies have been building a body of evidence for motor learning gains in different motor skills when providing positive normative feedback and 100% KR frequency during practice (e.g., Lewthwaite &Wulf, 2010; Wulf, Chiviacowsky, & Lewthwaite, 2010; Wulf, Lewthwaite, & Hooyman, 2013). Thus, greater learning was expected from the provision of positive normative feedback and 100% KR frequency, which was confirmed by its superiority in the 24h retention test compared to the group with negative normative feedback and 100% KR frequency.

One of the explanatory hypotheses for the superiority of positive normative feedback in motor learning is its relation to self-efficacy (Wulf et al., 2014; Wulf & Lewthwaite, 2016). Since provision of additional information can point either below or above average performances, it will regulate the feeling of effectiveness in performing the task (e.g., Bandura & Jourden, 1991; Jourden, Bandura, & Banfield, 1991; Themanson, Pontifex, Hillman, & McAuley, 2011) with consequences on performers' nervousness and concerns about their performance (Wulf et al., 2012). Thus, normative feedback would associate with facilitation of learning outcomes and automaticity (e.g., Lewthwaite & Wulf, 2010; Pascua et al., 2015).

The results of the present study, however, did not reveal any difference between the groups in self-efficacy at any stage of the study. This challenges the explanation that the gains in motor learning from positive normative feedback would be a consequence of increased self-efficacy (Pascua et al., 2015; Wulf & Lewthwaite, 2016). In fact, all groups increased self-efficacy along the blocks of trials of practice. A possible explanation for these results may be related to the learners' perception of success.

Self-efficacy, according to Bandura (1977, 1994), can be developed from different sources of information, such as social persuasion in the form of verbal judgments (e.g., normative feedback) and mastery experiences (e.g., KR) – considered the most effective reference to the experiences of the individual. The increase in self-efficacy and the consequent equality between groups can be a consequence of how individuals confirmed their performance, "good" or "bad", based on a criterion about their own "skill" (their performance change) in the task (Chiviacowsky et al., 2012).

Another explanation could come from how normative feedback was provided in this study. The normative feedback was a relative measure of the individual's own performance – specifically, minus or plus 20% of his/her performance. Considering that all groups increased performance, their AE decreased and, also, their absolute distance to the group. In this case, for the negative normative feedback groups, although they were "worse" compared to the fake group, their difference was absolutely decreasing over time to this fake group – which could be a source of increased expected efficacy. To exemplify, imagine an individual in the negative normative feedback group. At first, his/her performance was 200 ms; the fake group would show a performance of 160 ms – an absolute difference of 40 ms. After two blocks of practice, he/she improved to values around 100 ms; the fake group would show a performance of 80 ms – an absolute difference of 20 ms only. The individual could face the situation considering that he/she, even though is still worse than the group, got closer to it. The opposite occurred for the positive normative feedback groups. Although they were always better than the fake group, their "superiority" over the fake group was decreasing as they improved in the task. In this sense, the positive groups received information that was not *as positive* as it could be, and the negative groups received information that was not *as negative*. This might have levelled the increase in self-efficacy for all groups.

Other studies that analyzed self-efficacy based on the provision of normative feedback all used relative normative feedback but their results diverged. Pascua et al. (2015) and Wulf et al. (2014) found greater self-efficacy when providing positive normative feedbacks in learning to throw balls at a target. Ong & Hodges (2018, Experiment 2), on the other hand, found no difference in self-efficacy in learning a balancing task. These results could challenge our interpretation. However, in these studies, the positive normative feedback group was compared to a group without normative feedback (a control group). Note that their results showed increased self-efficacy for the positive normative group (which we also showed) and no changes of the control group. Thus, we cannot verify our interpretation; it deserves attention in future studies.

The second hypothesis of the study was that with a lower frequency of KR, individuals would show decreased, if not null, gains in motor learning. This would be a result of decreased changes in self-efficacy, since a way of informing the individual about his personal success is supply of KR. This hypothesis was confirmed since the PF100 group was superior to the NF100 and the 33% KR groups (both PF33 and NF33) were "in-between" (i.e., better than NF100 and worse than PF100 – in terms of their mean performance). This result indicates that the effects of normative feedback are dependent on the frequency of KR. However, the explanation for this effect associated with greater self-efficacy has not been confirmed. To reiterate, we found independence between motor learning gains and self-efficacy increase.

How can normative feedback drive motor learning gains independent of self-efficacy? It is possible that the provision of positive normative feedback plus a high frequency of KR (PF100) has favored the consolidation of memory from the perception of success achieved. That is, by making individuals believe that their performance was above the group mean, individuals considered their KR as a positive reinforcement (i.e., a reward). Note that the group that showed best retention (PF100) was reinforced by the KR in a high frequency, which did not happen with the groups of 33% KR. This favored the results in the 24h retention test. Indeed, the literature points out that rewards would have effects on consolidation of the short-term to long-term memory, allowing individuals to *maintain* their performance (Abe, Schambra, Wassermann, Luckenbaugh, Schweighofer, & Cohen, 2011; Trempe, Sabourin, & Proteau 2012). In line with these studies, differences would only be observed in the delayed retention test as one night of sleep is required for consolidation to occur.

Studies have also argued that the positive reinforcement can occur independent of the motivational status of the individuals (e.g., Abe et al., 2011; Sugarawa, Tanaka, Okazaki, Watanabe, & Sadato, 2012). For instance, Sugarawa et al. (2012) manipulated praise as a way to induce the feeling of success in a motor task. They found that, *only* when the praise was directed to the learners, the individuals maintained performance in retention tests. The authors also tested performance in non-practiced tasks as to control how much praise would result in general motivation (influencing performance). No motivation effect was found, demonstrating that reward mechanisms can be elicited through other means, independent of motivation.

Therefore, motor learning (consolidation) and motivation (self-efficacy) need not be always related. Our argument is that they relate to different aspects of practice. As we argued above, all groups were improving in practice and this, possibly, led individuals to increase their self-efficacy. Given our manipulation of normative feedback (and the previously discussed issue of absolute gains relative to the fake group), all groups increased the expectancy of success (self-efficacy) equally. Thus, motivation would be related to *improvement* in performance. Nevertheless, performance increments do not refer directly to *success*. Our results show that the best retention performance was from the PF100 group. This group was the one who received information stating that they were better than the group, they were succeeding, and had this information reinforced for every trial (100% KR). Thus, consolidation would occur given what individuals experience as *success*, while motivation would increase as individuals experience *improvement.*

Note that, in the majority of studies that found association between self-efficacy and learning, both improvement and success might have cooccurred. Also, individuals, when not externally imposed, create their own success criterion – which blurs the relation even further. However, one must understand how consolidation is dependent on increased motivation as, in our study, all individuals increased self-efficacy. New studies must be performed to address the possibility presented here.

5. Conclusions

In this study, we tested whether normative feedback effects on motor learning are dependent by KR provision frequency. The results allow us to conclude that the answer is in the affirmative. However, despite the literature on the theme relating these effects to motivation, we found no effect of normative feedback and KR provision on self-efficacy. We discussed these results in terms of independent practice aspects (improvement and success) that would influence self-efficacy and learning differently. This indicates that greater attention to how KR is administered influencing these aspects in practice induce motivational and processing mechanisms. Future studies may investigate KR relation to different motivational feedbacks (e.g., normative, temporal, generic), manipulating error magnitude, difference to the norm, and even different motor skills (greater/ less need for extrinsic information; more/ less degrees of freedom involved).

Our findings may have implications for contexts involved in teaching-learning of motor skills and sports. The main suggestion is that coaches would facilitate practitioner/ athlete performance and learning by providing positive social comparison feedback in conjunction with KR in high frequency. A situation with high KR is frequent in daily practice (the athlete does observe his own outcome) but we would expect that similar outcomes would occur for tactical situations where the means for the same outcome are more ambiguous (i.e., following perfectly the trained tactics might not lead to scoring). Additionally, another implication of our study is that individuals are still motivated to perform despite external input stating that they are performing worse than the group. This seems to hold, we presume, if they are still improving. Clearly, this seems to lead to avoidance of previously tried strategies (poor retention) but might be a good intervention strategy when coaches/ teachers want to guide individuals to new solutions without demotivating them.

Figure Captions

Figure A.1 Experimental task diagram showing the direction of movement of the moving target to the fixed target, the moment when the target view is occluded, and the contact moment between the moving and fixed targets, at which the switch should be pressed by the participant.

Figure A.2 Performance (absolute error) curves during acquisition. The error bars represent the 95% confidence interval.

Figure A.3 Performance (absolute error) in the two blocks of Immediate Retention Test (IRT) and 24-hour Retention Test (RT). The error bars represent the 95% confidence interval.

Figure A.4 Adjusted self-efficacy as a function of task difficulty (scale) (a) pre-acquisition trials and (b) post-acquisition trials. The gray lines are adjusted curves per individual.

Table A.1 General hierarchical linear model analysis for the change in self-efficacy as a function of acquisition blocks and pre/posttest changes.