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# The effects of positive and negative verbal feedback on repeated force production

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ABSTRACT

Studies indicate that providing subjects with positiveaugmented feedback (PAF) enhances motor learning and performance compared to negative- (NAF), or no-feedback. However, in the majority of these studies, the performance feedback was provided relative to a peer-group (e.g., "your performance is higher/lower than the norm"). Here we examined how different, and less explored types of PF and NF, influenced repeated force production of 22 resistance-trained subjects (50%-males). On three occasions, subjects completed 12 isometric maximal voluntary contractions (MVC) with their elbow flexors, while electromyography (EMG) was collected from their biceps and triceps brachii muscles. After every second repetition, subjects received either PF (e.g., "You are looking great."), NF (e.g., "You are not trying."), or no-feedback. All measurements were normalized to pre-test MVCs and reported aspercentages. Subjects applied greater forces in the NF condition compared to the PF (4.3%, 95%CI: 2.8, 5.8) and no-feedback (7.9%, 95%CI: 6.4, 9.4) conditions. Similarly, subjects demonstrated greater biceps EMG activity in the NF compared to the PF (6.6%, 95%CI: 3.7, 9.4) and no-feedback (2.8%, 95%CI: 9.9, 15.6) conditions. We speculate that NF can lead subjects to exert greater forces bysignaling that their efforts are lacking. These results indicate that under some circumstances, NF can have practical benefits over no-feedback and even PF; however, we note that NF should be delivered with caution since it may also hinder motivation and self-efficacy over time.

## 1. Introduction

Augmented feedback (AF)refers to information provided byexternal sources,such ascoachesand devices, aiming to enhancemotor learning and performance[18,24]. AF can be used to emphasizeinformation about the outcome, quality,and patterning of themotor task [18,24].Moreover, AFcan be used toemphasizethe positive (PAF)or negative(NAF) aspects of one'sperformance relative to othersor oneself, whichin turn, altersexpectancies of future performance[7,13,16,23,29]. Two common ways in which expectancies of future performance are studied include the provision of AFafter good or bad repetitions, and false-comparative AF. The first is a strategy in which AFis provided after the best or worst repetitionsin a given trial[3,7,23]. For example, providing AFafter the three most-or least-accurategolf putts attempts out of six in total[3]. The second strategy includes providing trainees with a deliberately erroneous AFrelative to a peer group or oneself [1,13,15,20]. For example, telling trainees that their performance was 20% better or worst compared to the average result of a group[20], or to their previous attempts. Motor learning studies regularly report superior learning effects when trainees receive PAF[29], using one of the two above-mentionedapproaches, mostly in tasks that require accuracy [7,23]and balance[1,20](but see [22]as an exception).

Whereas research from the motor learning domainreport consistent effects favoring PAF, fewer studies investigated the effects of PAF and NAFon tasks that require muscularforce, power,or endurance, and those conducted report mixed results.For example, competitive boxers' punching forces remained unaffected by false-positive, negative and neutral comparative AF, that was delivered between rounds of maximal effort punches [13]. Time-trial completion times of endurance athletes were unaffected by false-positive or negative AF in which running or cyclingspeedswere shown to beslower or faster than the actualspeeds [9,27]. Conversely,recreational runners improved their running economywhen receiving false-PAFevery few minutes during a running trial, compared to a no-feedback control group[26].Physically-trained

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subjects jumped higher after receiving positive comparative AF compared to a no-feedback control group [8]. Last, recreationally-trained participants were able to endure longer durations in a continuous submaximal grip task after receiving false-positive comparative AF,relative to a negative and control AF groups [16].These discrepancies could stem from a number of reasons, including the type, timing, and frequency ofAF, the outcome measures, and subjects'training background. Given the limited number and conflicted results of studies examining positive and negative AF on tasks requiring strength and endurance, more research is warranted.

One limitation of the positive and negative AF literature is that the two most frequent ways of providing themlack ecological validity. This is because the day-to-day interactions between coaches and traineesinclude theprovision of a wide array of AF that contains more than objective feedback concerning the motor outcome, or a comparison of the outcome to apeer-group or the trainees themselves. To illustrate, a coach may be pleased with the way a trainee is performing a specific task and state “great job”. On a different day, the coach may be frustrated with the way the traineeis performing the very same task, and state “you are not trying hard enough”.To date, little research examined the effects of such feedback on performance. There is thus a need to investigate the effects of other types of PAF and NAF on motor performance that are more representative of real-life events. This is especially relevant with tasks that requiremuscular strength and endurance, because of the limited and mixed results of studies investigating them. Accordingly, in the current study we explored how providing PAF andNAF – designed to be representative of coach and trainee interactions – influenced repeated maximal force production with the elbow flexorsamong resistance trained subjects.

## 2. Methods

### *2.1. Experimental approach to the problem*

The study consisted of three testing days with twoto eight days between sessions.Subjects were told that the goal of this experiment was to investigate the reliability of the force production protocol over three sessions in an attempt to disguise its true purpose. During the first session, subjects were familiarized with the equipment and the procedure of the experiment. Then, in all conditions, subjects completed a five-minute warm-up consisting of cycling at 70 RPM at 1 kgpond on a stationary cycle ergometer (Monark Ergomedic 828E, Sweden). As part of the specific warm-up,subjects performed 12 isometric contractions with their elbow flexorswhile applying20% of their perceived maximal voluntary contraction (MVC) using a 5/10 s work to rest ratio. This was also done to familiarize or remind them of the full protocol work to rest ratio. Subjects then performed two repetitions equal to their perceived50% of MVC, andfollowing two minutes of rest, theyperformed two pre-test MVCs lasting five seconds with two minutes of rest between each attempt. If the maximum force of the twoMVCs were not within 5%, a third MVC was completed.

Then, in all conditions, subjects performed a repeated force production protocol,routinely used in our lab [11,12], consisting of 12 MVCs and a 5/10 s work to rest ratio.In all conditions,which were randomized and counterbalanced, the same female experimenter provided the “go” and “stop”verbal signals before and after each repetitions. The three conditions differed in the verbal feedback provided by the same secondfemaleexperimenter. During the no-AF, subjects were not provided with any additional verbal feedback during the protocol in addition to the“go” and “stop” signals. During the PAF and NAFconditions, subjectsreceivedthree different feedback statements that were repeated twice during the 12 MVC protocol.Following the same order indicated below, a single statement was provided after the 2nd,4th,and 6thMVCs, and then repeated in the same order again for the 8th, 10th and 12th MVCs, respectively. The feedback statements for each condition were as follows:

PAF: (1) “Great effort.” (2) “Excellent values.” (3) “Looking strong.”

NAF: (1) “You're not trying.” (2) “Low values.” (3) “You can do better.”

The feedback statements were selected for the following reasons. First, in both conditions, weusestatementsthat are easyand require a short time to state by the investigator. Second, based on the extensive collective coaching experience of the first (IH) and last (DB) authors, we attempted to use statements that are commonly used in coaching environments. Third, we attempted to contrast the PAF and NAF as much as possible. For example, “Excellent values” and “Low values”. Fourth, while we attempted to make the NAF statements as realistic as possible, we also had to consider that they may havenegative psychological effects on subjects. Thus, we decided to deliver the three statements in a particular order. We acknowledge that the first and last statements in the NAF condition may be perceived as negative but also as encouraging in specific situations. For this reason, we placed the “Low values” statement in the middle.In the context of the second statement, we presumed that the other two statements will lead one to perceive their performance in a negative manner. The experimenter emphasised providing the feedback using neutral voice and consist pitch, and practiced doing so during the pilot trials. Finally, in order to reduce the effects of various confounders, the physical location of the experimenter which provided the AF was consistent across sessions. Furthermore, only the two female researchers and the participant were allowed in the laboratory during the conditions to ensure there was no additional influence from other individuals.

### *2.2. Subjects*

A convenience sample of twenty-two subjects were recruited. Of the 22 subjects 11were females (Mean ± SD: 20.6 ± 0.8years, 167 ± 5.6 cm, 69.2 ± 10.2 kg) and 11 males (Mean ± SD: 20.3 ± 0.7 years, 181 ± 7.3 cm, 80.7 ± 7.7 kg). All subjects were experienced with resistance-training and performed two to five resistance-training sessions a week for at least six months prior to the beginning of the study. Exclusion criteria included subjects who had experienced musculotendinous or musculoskeletal injuries to the upper body in the last six months. This study was approved by the Interdisciplinary Committee on Ethics in Human Research (#20192489-HK) and was in accord with the Declaration of Helsinki. Subjectssigned the informed consent forms prior to beginning the experiment.

### *2.3. Force measurements*

Subjects were seated in a chair with their right forearm supported and elbow flexed at 90°. The supinated wrist was placed into a padded strap attached by a high-tension wire to a load cell (strain gauge: Omega Engineering Inc., LCCS 250, DonMills, Ontario, Canada) that was used to measure elbow flexion forces. Subjects were strapped around their torso to minimize extraneous movement. All force data was sampled at a rate of 2000 Hz with the peak force of each MVC used for the analysis (BioPac AcqKnowledge data acquisition and analysis system: DA 150: analog-digital converter MP100WSW, Holliston, MA).

### *2.4. Electromyography (EMG(*

Surface EMG recording electrodes (Ag/AgCl;Kendall MediTrace foam electrodes, Holliston, Massachusetts,USA)were placed approximately 3 cm apart over the proximal, lateral segment of the biceps brachii (BB) and over the lateral head of the triceps brachii (TB). The BB electrodes were placed midway between the acromion process and the olecranon process. The TB electrodes were placed in the same position (mid-belly). The position of the electrodes was marked with indelible ink to ensure accurate replacement for subsequent tests. The electrodes were placed in a similar fashion to our previous studies and according to common guidelines[11,12]. Thorough skin preparation for all electrodes included shaving, removal of dead epithelial cells with an abrasive pad, and cleansing with an isopropyl alcohol swab. AllEMG signals were collected over a 1 second period corresponding to the peak MVC force (500 ms before and after peak force)with the Biopac dataacquisition system at a sample rate of2000 Hz (impedance = 2 MΩ, common mode rejectionratio >110 dB min (50/60 Hz), noise >5 µV).A bandpass filter (10–500 Hz) was applied prior todigital conversion.

### 2.5. Statistical analysis

To compare between the three conditions, the absolute peak values of both force and EMG in repetitions 3 to 12 MVCs completed during the fatiguing protocol were normalized to the mean value of the pre-test MVCs completed on each day (e.g., MVC number eight divided by the average of the two pre-test MVCs values completed in the NAF day, multiplied by 100). The reason the analysis started at the 3rd repetitions is that those completed prior to it were not affected by any feedback statement.

Using the normalized values, we fitted a linear random effects model for either MVC, biceps EMG or triceps EMG as numeric, dependent variables. Condition, sex, and repetition number were considered as independent variables. Condition and sex were coded as categorical variables, whereas repetition was coded as a numeric variable. Condition and repetition were both introduced into the model as fixed effects. In addition, we introduced a random intercept for each subject, and a random slope for each subject's repetition variable. The sex variable as well as the interaction terms between condition and repetition did not contribute to the explanatory power of any of the explored models (i.e., high p-values and increase in Akaike information criterionscores) and hence they were dropped from all analyses. Conservative multiple comparisons adjustment to p-values was performed to determine the differences between the three condition categories using the Bonferroni correction. Differences were considered statistically significant when the corresponding p-values were <0.05. Accordingly, 95% confidence intervals not containing the null hypothesis (e.g. the value 0) were considered showing a statistically significant effect.All models were re-run under a Bayesian Markov chain Monte Carlo (MCMC) framework with the*rstanarm* R package and the*stanlmer*function using the default parameters [19], to verify no substantial numeric errors biased the results during the approximation performed for the mixed effects model estimation. This resulted in highly similar point estimates and certainty intervals around parameters obtained in both methods. All statistical analyses were conducted using *R* (version 3.6.0, R Core Team, Vienna, Austria).For reproducibility purposes all the raw data can be found in the following linkhttp://dx.doi.org/10.17632/szwnbvch8f.1.

## 3. Results

All 22 subjects completed the study's requirements. The adjusted effects of repetitions and different conditions on the measured variables, using a mixed effects linear regression model, is presented in Table 1 and Fig. 1.The estimated differences between allthree conditions using a post-hoc analysis is presented below.

**MVC.**Under the NAF condition, MVC values were 4.3% (95% CI: 2.8, 5.8) greater than under the PAFcondition, and 7.9% (95% CI: 6.4, 9.4) greater than under the no-AFcondition. Additionally, under the PAFcondition, MVC values were 3.6% (95% CI: 2.1, 5.1) greater than under the no-AFcondition(Fig. 1A and D).

**EMG biceps.** Under the NAF condition biceps EMG valueswere 6.6% (95% CI: 3.7, 9.4) greater than under thePAF condition, and 12.8% (95% CI: 9.9, 15.6) greater than under thePAF condition. Additionally, under the PAF condition biceps EMG valueswere 6.1% (95% CI: 3.2, 8.9) greater than under theno-AF condition(Fig. 1B and E).

**EMG triceps.** Under the NAFcondition, triceps EMG values were 6.5% (95% CI: 4.5, 8.4) greater than under the PAF condition, and 6.8% (95% CI: 4.8, 8.7) greater than under the no-AF condition. However, trivial and statistically insignificant differences of −0.3% (95% CI: −1.99, 1.93) were observed between the no-AF and PAF conditions (Fig. 1C and F).

## 4. Discussion

We investigated how PAF, NAF and no-AF conditions influence repeated force production of the elbow flexors and EMG activity of 22 resistance trained subjects. To our knowledge, this is the first study to directly compare a more ecologically valid way of delivering PAF and NAF, and examine its effects onmaximal effort force production tasks. The main findingsare that subjects applied greater forces and demonstrated greater EMG activity under the NAF condition, compared to the two other conditions. Additionally, PAF led to greater force and EMG activity compared to no-AF condition. The superior performance in the NAF condition is interesting and somewhat surprising. This is becausestudies commonlyreport superior learning and performance effects under the PAF conditions, or no considerable differences between AF conditions.

The specific NAF we selected to delivermay have elicited anger among subjects, which in turn, led them to apply greater forces. Anger has been shown to positively influence performance in tasks requiring force and power production[21,28]. For example, when subjects were asked to imagine a moment full of angerin their lives and process it prior to performing an MVC with their knee-extension, forces were higher in the anger condition compared to happiness, and neutral-inducing thoughts [28]. A subsequent study using comparable methods observed that both anger- and happiness-inducing thoughts led to greater force production with the finger muscles, and to higher jumping performance, compared to sadness-, anxiety- and neutral-inducing thoughts [21]. We speculate that the NAF used in the present study may have elicited some degree of anger leading to increases in force production. However, since we did not directly examine the emotional states of subjects, this speculation remains to be examined.

Another possible reason accounting for the superior performance under the NAF concerns the assumed role of positive and negative emotions[4,5,6]. Carver and colleagues suggest that negative feelings are meant to signalthat the rate of progress in attaining a goal is too low, and that greater efforts should be put forth[4,5,6].In the current study, the NAF may have signaled subjects that they werenot trying hard enough, leading them to apply greater forces. In contrast, according to this perspective, positive feelings signal that one is meeting or exceeding the criterion rate of progress,and that effort can be maintained or reduced[4,5,6].The PAF may have signaled to subjects that they were doing well, and that there was no need to apply greater forces. While this perspective offers a possible explanation for the results of this study, it cannot account for the fact that PAF led to superior performance compared to no-AF. It may be that AF enhances performance compared to no-AF irrespective if it is positive or negative. These resultsarealso mostly inconsistent with the motor learning domain. Given the established differences between performance and learning [17,25],it may be that certain types of feedback – such as those provided in the present study – influence the two in a different manner. Furthermore, we did not identify sex differences in response to the feedback conditions. This result is aligned with a recent meta-analysis which examined the effects of negative feedback on motivation,and did not observe a sex effect [10].

This study has a number notable strengths and weaknesses. The fact that the feedback was verbally provided by an experimenter is more representative of many practical or actual real life situations, such as when coaches provide feedback to their trainees. However, despite efforts to provide the feedback in the most consistent way possible, voice

**Table 1.**
Model specifications and estimates. Linear mixed effects regression was used to model values of relative MVC forces (*MVC*), EMG measurements for biceps (*EMGbi*), and triceps (*EMGtr*), for each subject *j* under condition *i,* in repetition *k*. The model included a fixed ($\gamma_{10}$) and random ($u_{1j}$) slope terms for the repetition number ($rep_k$), a fixed term for condition ($cond_i$) and random intercepts ($u_{0j}$). Reference level intercept was set to the control condition ($\gamma_{00}$).

| Model | Fixed effects | estimate | 95% CI | p-value |
|---|---|---|---|---|
| $MVC_{ijk} = \beta_{0j} + \beta_{1j} rep_k + cond_i$ | Condition negative | 7.97 | 6.47, 9.48 | < 0.001 |
| $\beta_{0j} = \gamma_{00} + u_{0j}$ | Condition positive | 3.63 | 2.13, 5.14 | < 0.001 |
| $\beta_{1j} = \gamma_{10} + u_{1j}$ | Repetition slope | − 1.13 | − 1.45, − 0.81 | < 0.001 |
| $EMGbi_{ikj} = \beta_{0j} + \beta_{1j} rep_k + cond_i$ | Condition negative | 12.80 | 9.92, 15.7 | < 0.001 |
| $\beta_{0j} = \gamma_{00} + u_{0j}$ | Condition positive | 6.18 | 3.3, 9.01 | < 0.001 |
| $\beta_{1j} = \gamma_{10} + u_{1j}$ | Repetition slope | − 1.32 | − 1.8, − 0.83 | < 0.001 |
| $EMGtr_{ijk} = \beta_{0j} + \beta_{1j} rep_k + cond_i$ | Condition negative | 6.88 | 4.87, 8.88 | < 0.001 |
| $\beta_{0j} = \gamma_{00} + u_{0j}$ | Condition positive | 0.38 | − 1.62, 2.38 | 0.71 |
| $\beta_{1j} = \gamma_{10} + u_{1j}$ | Repetition slope | − 0.74 | − 1.08, − 0.39 | < 0.001 |

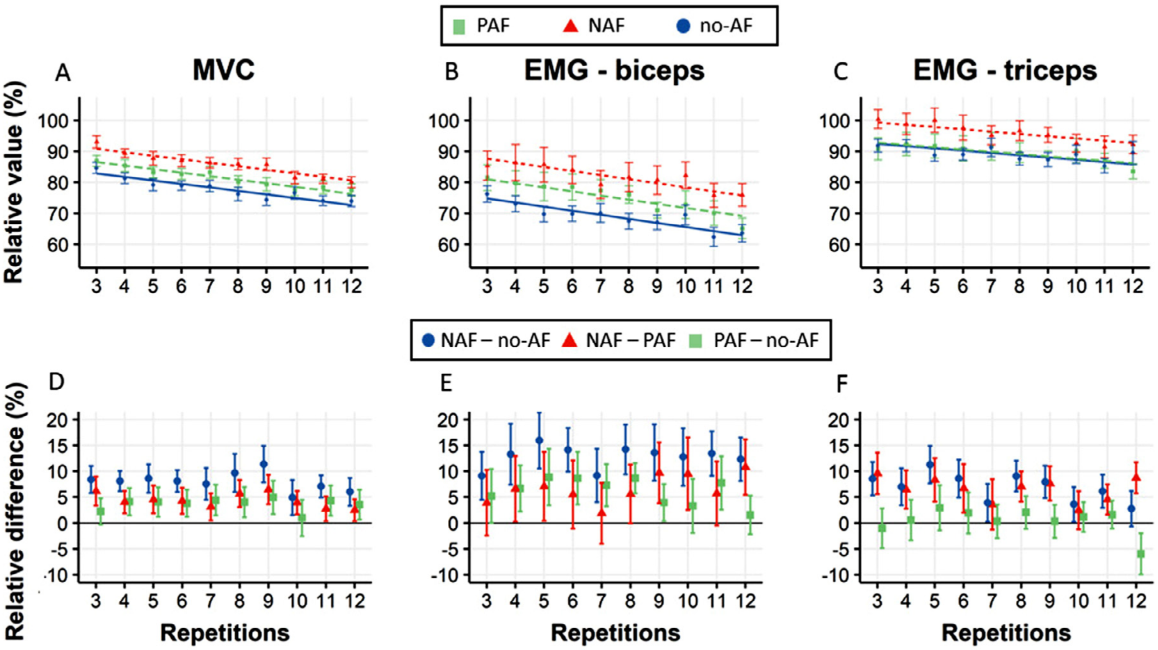

**Fig. 1.** Panels A-C show the between-subject difference and standard errors for each repetition, under the three conditions, overlaid with the lines obtained from the mixed effects model (Table 1). Panels D-F show the within-subject difference and standard errorsbetween the three contrasts of conditions, for each repetition.

pitch and volume may have inadvertently fluctuated between sessions, which could have affected the results [14]. We did not examine which type of emotions were elicited by the feedback via questionnaires, which reduces our ability to explain the pathways accounting for the effects. Future studies inquiring how similar types of AF, as provided in the current study,influence motor performance, would do well to examine how subjectsactually feel as a result of it. Finally, we did not perform a deception check to discover whether any subjects suspected or were aware of the true intentions of this study.

The results of this studydemonstrate that NAF increases force production and EMG activity compared to PAF and no-AF. However, we are hesitant to provide concrete practical recommendations concerning NAFfor two main reasons.First, we are unaware of other studiesthat used a similar approach and observed similar effects. More studies are needed before concrete practical recommendationscan be provided. Second, it may be that certain types of NAF lead to superior motor performance under certain situations, as observed in the current study. However, implementing such a strategy over time, could hinder motivation [2]and self-efficacy[23]. Thus, in case thatcertain NAF improves force and power production, it is important to consider whom, when,and how often it should be provided, before being implemented in practice. Future research examining and comparing the effects of different PAF and NAF would shed light on this issue. PAF led to better performance compared to no-AF condition, which is aligned with the literature, and not expected to lead to adverse effects.Hence, from a practical point of view, PAF should be preferred over no-AF.

## Declaration of Competing Interest

None

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