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Bullseye: Effects of autonomy support and enhanced expectancies on dart throwing

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Abstract

The present study examined the combined influence of two motivational key factors in the OPTIMAL theory of motor learning,[1] enhanced expectancies (EE) and autonomy support (AS), on the learning of a dart-throwing task. In one group (AS/EE), participants were provided with a success criterion that could be met relatively easily (EE) and two small choices (AS). A control group practiced under neutral conditions. On Day 1, participants completed a pretest and six 12-trial blocks of practice from a 2 m distance to the bullseye. Two days later, retention and transfer (novel distance of 2.37 m) tests were conducted. Self-efficacy was assessed throughout the practice phase and before the retention test. The results showed that the AS/EE group had higher self-efficacy during practice and demonstrated greater dart-throwing accuracy on the retention and transfer tests compared with the control group. The findings have implications for practical settings: They show that providing learners with a liberal definition of success and minor choices can be sufficient to enhance motor skill learning.

Keywords

Motivation, OPTIMAL theory of motor learning, practice, retention

Introduction

In the OPTIMAL theory of motor learning,[1] two of three key factors for optimizing motor learning and performance are motivational in nature: Enhanced expectancies (EE) and autonomy support (AS). (A third factor is an attentional factor, an external focus of attention.) Each factor has been shown to have multiple benefits for both performance and learning. For example, advantages for immediate performance as a function of EE or AS have been demonstrated with respect to movement accuracy[2,3] and efficiency.[4–6] Also, practice conditions that include EE or AS have been demonstrated to have benefits for skill learning, as measured by delayed retention or transfer tests,[7] including accuracy,[8] movement form,[9] or balance.[10]

Expectancies for future performance (EE) can be enhanced in various ways. In several learning studies, participants were provided with positive feedback. Learners who were given feedback after relatively successful trials showed more effective learning than did those who were provided feedback after less successful trials.[11–13] Also, (falsely) informing learners that they are performing above average typically leads to more effective learning than does feedback suggesting below-average performance or neutral control conditions.[8,10,14–16] Positive feedback enhances learners' self-efficacy beliefs and results in advantages for learning compared with no such information, or negative feedback.[11] Even simple suggestions that peers perform well on a given task can enhance learning. In one study, in which older adults were asked to learn a challenging balance task, one group was informed that "people like them" typically did well on that task.[10] That group of participants showed enhanced learning compared with a control group. Furthermore, visual illusions that make the size of a target look larger can

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increase self-efficacy expectations and learning.[17,18] Finally, providing criteria for "success" that are relatively easy to meet has been shown to result in more beneficial effects for learning than criteria that are more difficult to achieve.[19–21] In a study by Trempe et al.,[20] participants who were given a relatively easy movement goal, and who therefore experienced greater success during practice, demonstrated superior performance on a delayed test than did those who had been given a goal that was harder to achieve. Rewarding circumstances that enhance expectancies for future performance ready the system for performance by directing attention to the task goal and suppressing task-irrelevant or self-related thoughts.[1] Expectations of rewarding experiences trigger a dopaminergic response that facilitates short-term performance and longer-term learning through functional and structural connectivity.[22,23]

Practice conditions that support learners' need for autonomy (AS) by providing them with choices also enhance motor learning. In one of the first studies to demonstrate this effect, allowing learners to choose when to receive feedback about their performance was found to lead to enhanced retention test performance relative to a yoked control group.[9] (Yoked control conditions in studies involving AS include participants who are each "yoked" to a participant in a choice group. Control group participants perform under the same conditions as their choice-group counterparts – for example, receive feedback on the same trials – sans the choice.) Subsequent studies have shown that letting learners decide when to use assistive devices,[24–26] how much to practice,[27] when to watch a demonstration of the skill,[28,29] or in which order to practice different tasks[30,31] facilitated learning relative to control groups. Intriguingly, even small or incidental choices, such as being able to choose the color of objects to be used,[32,33] or choices that are completely unrelated to the task (e.g., asking participants for their opinion about pictures[32]) can have benefits for learning. Opportunities for choice enhance expectations for positive outcomes and often result in higher self-efficacy and intrinsic motivation compared with conditions that don't include choices.[29,34,35] They allow performers to maintain their attentional focus on the task goal, without the need to engage in self-regulatory activity.[1] Similar to EE, potential consequences of autonomy support include facilitation of performance and learning through enhanced processing of task errors and greater self-regulatory responsiveness.[36]

In addition to each factor, AS and EE, individually benefiting motor learning, their benefits seem to be additive in nature. In one study,[37] the combined effects of AS and EE on the learning of a throwing task were examined, relative to the presence of only one factor (AS or EE), or none. In addition to each factor alone enhancing learning, the AS/EE group demonstrated greater learning advantages than the other groups, suggesting additive effects of these motivational variables. In that study, EE involved false positive social-comparative feedback, suggesting that learners threw more accurately than other participants. To provide AS, participants were allowed to choose the color of the ball to be used several times during the practice phase.

One purpose of the present study was to replicate those findings with a different task. Yet, rather than examining effects of individual factors (EE, AS),[1] we wanted to build upon the developing body of evidence that indicates additive advantage (and not competing effects) to the deployment of various factors in the OPTIMAL theory,[38] in particular EE and AS. Importantly, we had a practical application in mind. We not only wanted to provide a small choice but also use a more applicable EE manipulation. Many previous studies examining EE used deception such as providing false feedback.[14,15,39] Even visual illusions[17,18] involve a form of deception, in addition to being somewhat cumbersome to use in practical settings. Approaches to enhancing expectancies such as these are not suitable for translation into practice. A more practical way to enhance expectancies in applied settings might be to provide success criteria that can be reached relatively easily.[19,20] Palmer and colleagues,[19] for example, provided participants with instructions that putting to a target located within a given concentric circle would constitute "good" golf putts. A group for whom a larger circle was identified putted more accurately than did a group with a smaller circle, or higher standard of success. This was the case not only during the practice phase, when the circles were present, but importantly also on 24-hour retention and transfer tests without circles. Thus, the more liberal success criterion during practice resulted in benefits for learning.

In the present study, we followed up on those findings. Participants practiced a dart-throwing task, and we attempted to enhance the expectancies of participants in one group (AS/EE) by providing a criterion for success (i.e., circle on a bullseye target) (EE). In addition, AS/EE group participants were given two small choices. They were able to occasionally choose the colors of the dart flight and bullseye (AS). A control group performed the task under neutral conditions, that is, without a success criterion and with "yoked" colors. We hypothesized that the AS/EE group would demonstrate enhanced learning, as measured by 48-hour retention and transfer tests. We also expected to see higher self-efficacy ratings in the AS/EE relative to the control condition. Self-efficacy was measured before and during the practice phase, as well as before the retention test. If our hypotheses were supported, the results could have important practical implications as they would be directly applicable to settings in which motor skills are learned and taught (e.g., sports, performing arts, physical rehabilitation).

Method

Participants

A sample size of 30 participants was estimated via a power analysis using G*Power 3.1, with an estimated η^2_p value of .05, an α value of .05, and a power value of .90. Thirty university students (18 females, 12 males) with a mean age of 26.1 years (*SD*: 8.28) participated in this experiment. Participants were naïve as to the purpose of the study, and none of them had extensive dart-throwing experience. All participants stated that they played darts less than two times in the last year. Participants gave their informed consent before participating. The study was approved by the university's institutional review board.

Apparatus and task

The task was to throw regulation-sized darts, with a weight of 26 g, at a dartboard. Different color flights (i.e., as aerodynamic fins at the back of the dart) were used throughout the experiment (see the Procedure section). Aside from the color, the flights were identical with respect to shape and material. The dartboard was 29.3 cm (11.5 in) in diameter (regulation size). It was printed on photo-quality paper and attached to a Styrofoam wall. The bullseye was 1.5 m above the floor (i.e., lower than the regulation height of 1.73 m), and participants stood behind a line that was at a distance of 2 m from the dartboard during the pretest, practice phase, and retention test. For the transfer test, the distance was increased to 2.37 m (regulation distance). Seven concentric circles surrounded the bullseye that had a diameter of 12.7 mm (regulation size). The circles were alternately gray and white, and 2 cm in width. They were labeled 10 (outermost) to 70 (innermost circle surrounding bullseye).

Procedure

Participants were quasi-randomly assigned to one of two groups, the AS/EE and control groups, with the stipulation that there be an equal number of females and males in each group. The experimenter first provided each participant with a demonstration of the task and some general instructions. Specifically, participants were asked to put the same-side foot (i.e., right foot for a right-handed thrower) behind the line, and to hold the dart like a pen. They were also informed that the goal of the task was to score the highest number of points, and if they hit the bullseye, they would get 80 points and so forth. Subsequently, and before the data collection began, participants completed six throws to familiarize themselves with the task. Next, they performed a pretest that consisted of 12 trials for which darts with golden flights were used. The practice phase consisted of six blocks of 12 trials. Participants in the AS/EE group were informed that they could choose the color of the dart flights (blue, red, yellow) as well as the color of the bullseye (blue, red, yellow) before each block (AS). That is, they were able to choose those colors six times during the practice phase. Depending on the participant's choice, the respective color flights were put on the darts. Also, a sticker (12.7 mm in diameter) in the color of their choice was placed on the bullseye and exchanged if the participant requested a different color on the following block. In addition, participants in the AS/EE group were told that, if a dart hit the board between the number 40 circle and bullseye, it would be considered a "good" trial (EE). Control group participants were informed that the experimenter would occasionally change the dart flight and bullseye colors before a block of trials. Unbeknownst to them, the colors were those that were requested by their assigned AS/EE group counterpart. Between practice blocks, participants had 1-minute rest periods. During these breaks, the experimenter replaced the dartboard and changed the flight and bullseye colors, if necessary. Two days later, participants returned to the lab and completed retention and transfer tests, each consisting of 12 trials. There was a 1-minute break between tests. The retention test was performed from the same distance (2 m), whereas the transfer-test distance was 2.37 m (regulation distance). Golden flights and a white bullseye were used on both tests. After the pretest as well as after the second, fourth, and sixth block of practice and before the retention test, participants were asked to fill out a self-efficacy questionnaire. They were asked to rate their confidence that they would be able to achieve an average score of at least 30, 40, 50, or 60 – referring to the scores on the dartboard – on the next two blocks on a scale from 1 (not confident at all) to 10 (extremely confident).

Data analysis

Each dartboard containing 12 hits (holes) and four calibration crosses in each corner was photographed using an iPhone 8 (Apple Inc., Cupertino, CA) with a 12-megapixel camera. The iPhone 8 was positioned on a tripod 35 cm above the dartboard. The photos

(3024 × 3024 pixels) were uploaded to a computer using JavaScript. To obtain individual pixel coordinates of each hit relative to the center of the bullseye, each calibration cross, the center of the bullseye, and each dart hit were clicked on manually. The distances between calibration crosses were known (same distance from corner to corner). Based on those distances and the pixels of the photos, the Python script rectified the orientation of the photo and measured the radial distances of each hit from the bullseye in mm. These distances, or deviations from the bullseye, were averaged across 12 trials. They were analyzed in a one-way analysis of variance (ANOVA) for the pretest. The retention and transfer tests were analyzed in analyses of covariance (ANCOVA), with pretest performance as a covariate. For the practice phase, deviations were analyzed in a 2 (group: AS/EE, control) × 6 (blocks of 12 trials) ANOVA, with repeated-measures on the last factor. We also compared the number of hits within the number 40 circle for each group in a one-way ANOVA. Self-efficacy ratings were averaged across the four items (30, 40, 50, 60) on each questionnaire. Ratings after the pretest were analyzed in a one-way ANOVA, and in a 2 (group) × 3 (block) repeated-measures ANOVA for the practice phase. Self-efficacy ratings before the retention test were analyzed in an ANCOVA, with the pretest rating as covariate. The alpha level was set to a value of .05, and partial eta squared (η_p^2) was used to determine effect size.

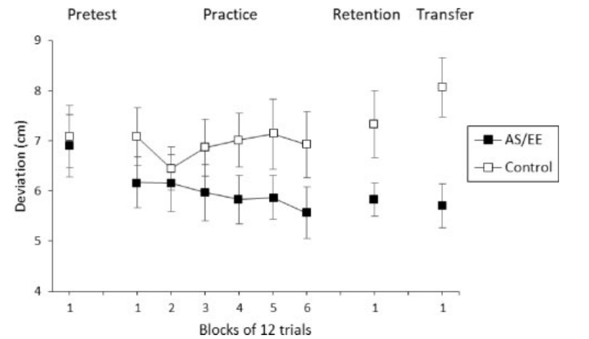

Figure 1. Deviations from the target for the AS/EE and control groups. Error bars indicate standard errors.

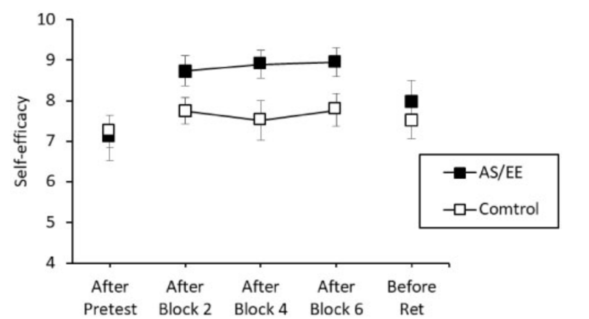

Figure 2. Self-efficacy ratings for the AS/EE and control groups after the pretest, after practice blocks 2, 4, and 6, and before the retention test. Error bars indicate standard errors.

Results

Dart-throwing accuracy

We first determined the number of hits within the number 40 circles that served as the "success" criterion for the AS/EE group. On average, the AS/EE group had 78.7% successful hits during the practice phase. For the control group, the corresponding number of hits was 71.4%. The group difference was not significant, F (1,28) = .743, p = .396, η_p^2 = .026.

Figure 1 shows deviations from the target for all phases of the experiment. There were no group differences on the pretest, F (1,28) = .045, p = .834, η_p^2 =.002. Deviations tended to decline across practice in the AS/EE group, but not in the control group. There was no interaction of group and block, F (5,140) = .704, p = .622, η_p^2 = .025, however. Also, the main effects of block, F (5,140) = .351, p = .881, η_p^2 = .012, and group, F (1,28) = 2.253, p = .145, η_p^2 = .074, did not reach significance. On the retention test two days later, the AS/EE group outperformed the control group. The Group effect was significant, F (1,27) = 4.576, p = .042, η_p^2 = .145. Similarly, on the transfer test, performed from a greater distance to the target, the AS/EE group had clearly smaller errors than the control group, F (1,27) = 11.604, p = .002, η_p^2 = .301. Thus, learning, as measured by both retention and transfer performance, was enhanced by the combination of AS and EE.

Self-efficacy

Self-efficacy ratings can be seen in Figure 2. Both groups showed similar levels of self-efficacy on the pretest. The group difference was not significant, F (1,28) = .059, p = .810, η_p^2 = .002. During the practice phase, however, self-efficacy was significantly higher for the AS/EE group compared with the control group, F (1,28) = 5.046, p = .033, η_p^2 = .153. There was no change across blocks, F (2, 56) = .773, p = .467, η_p^2 = .027. The interaction of group and block was not significant, F (2, 56) = 1.246, p = .296, η_p^2 = .043. Two days later, before the retention test, self-efficacy was again similar for both groups, F (1, 27) = 1.358, p = .254, η_p^2 = .048.

Discussion

We combined the two motivational factors in the OPTIMAL theory,[1] EE and AS, in one group and compared their learning of a dart-throwing task to that of a control group. We expected to find higher self-efficacy and superior learning for the AS/EE group. In line with our hypotheses, self-efficacy ratings were higher for the AS/EE group during practice. Also, AS/EE participants showed enhanced learning relative to the control group, as measured by throwing accuracy on retention and transfer tests two days after practice. Thus, providing learners with a success criterion and the opportunity for small choices resulted in more effective task learning relative to the absence of these factors.

In the only previous study,[37] in which the influence of a combination of AS and EE on learning was examined (and compared to the presence of individual factors and a control condition), EE involved false social-comparative feedback. In the present study, we wanted to enhance learners' expectancies without using deception. Instead we chose a more simple and applicable way of allowing learners to experience success while practicing. The success criterion (i.e., hitting the dartboard within the number 40 circle) was met by AS/EE participants on 78.7% of the trials. This proportion of trials was considerably higher than the percentages found by Palmer et al.[19] (22.0%) and Ziv et al.[21] (14.8%) for the learning of a golf-putting task, and Trempe et al.[20] (62%) for a visuomotor adaptation task. Moreover, the AS/EE group's number of hits within that circle were not significantly higher than those seen in the control group (71.4%). Thus, even though the criterion we provided turned out not to be particularly challenging, participants' perception that they were doing well was apparently sufficient to contribute to higher self-efficacy ratings during practice and enhanced learning. Given the lack of a criterion for good performance in the control group, participants may not have interpreted their performance as "successful" to the same degree as AS/EE participants did, as the self-efficacy results in practice suggest. Thus, control group participants presumably did not have the same rewarding experience as their AS/EE counterparts.

AS conditions have also been shown to enhance expectancies for future performance, including self-efficacy.[34,35] Interestingly, even if the choices learners are provided are small or incidental to the task – such as the color of balls to be used,[32] the color of a mat to be placed under a target,[33] or the order in which to perform different tasks[31] – learner confidence has been found to be higher and learning to be more effective than in no-choice conditions.[30] In a meta-analysis,[40] instructionally irrelevant choices were actually found to be more motivating than task-relevant ones. Therefore, we expected that the choice of dart flight and bullseye colors in the present study would increase AS/EE participants' self-efficacy and enhance their learning relative to the control condition.

The expectation of success or reward is associated with phasic increases in dopamine discharge that is believed to play a role in memory consolidation or learning.[22,23] Even though the self-efficacy difference between the AS/EE and control groups was no longer seen before the retention test two days later, the differential impact of the practice conditions on learning, as measured by retention and transfer test performance, persisted. This pattern of results is consistent with previous studies in which manipulations to enhance performance expectancies did not result in immediate performance benefits but did positively affect self-efficacy and learning.[18,20] It is also interesting to note that there was no significant performance improvement across practice that may have given learners a sense of accomplishment. What seems to be critical for effective learning is the temporal pairing of skill practice with conditions that enhance expectancies for positive outcomes and the associated dopaminergic response.[1] Both AS and EE – like the third key factors in the OPTIMAL theory, an external focus of attention – are thought to contribute to *goal-action coupling*, or the fluidity with which movement plans are translated into neuromuscular activation.[1] Because each factor promotes a focus on the task goal (e.g., hitting the target), thereby reducing a detrimental self-focus or other distracting thoughts, the functional connectivity of task-related brain networks is assumed to be facilitated.[41]

The main purpose of the present study was to test simple instantiations of EE and AS that could be used in applied settings. Our findings showed that providing learners with a liberal definition of success and minor choices can be sufficient to produce benefits for learning. These benefits included the ability to transfer what was practiced to novel situations such as performance under no-choice conditions (retention, transfer) and more challenging circumstances (transfer). Practitioners can easily take advantage of these positive effects by supporting learners' need for autonomy (AS) and competence (EE).[42,43] The motivational effects of AS and EE, such as confidence and positive affect,[18,30,33,34] may have additional benefits such as increasing performer engagement and interest in practicing,[29,44] which may further contribute to enhanced learning.

Declaration of Conflicting Interests

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