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Enhanced expectancies benefit performance under distraction, but compromise it under stress: Exploring the OPTIMAL theory

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ABSTRACT

Motor learning can benefit from practice under enhanced expectancies; that is, the belief one can generate an intended positive outcome. According to the OPTIMAL (Optimizing Performance Through Intrinsic Motivation and Attention for Learning) theory, this benefit manifests from a greater coupling between action and its external consequences, which potentially coincides with a more automatic mode of control. The aim of the study was to examine this possibility, and in so doing, understand more about the psycho-motor processes underpinning the influence of expectancies. On Day 1, novice participants practiced a dart-throwing task under enhanced (EE) ($n = 11$), reduced (RE) ($n = 12$) or no (control; CTL) (n = 12) expectancies. Enhanced and reduced expectancies were indirectly manipulated by positively reinforcing shots that landed within the large or small circle on the dartboard, respectively. On Day 2, participants transferred to a dual-task (i.e., tone-counting) or stress (i.e., social-comparative threat, false feedback) setting. While there was no evidence of improvement across practice, RE was significantly worse than CTL for the dual-task, but EE was significantly worse than RE and CTL under stress ($ps < 0.05$). Therefore, the ability of EE to retain performance within the dual-task, but decline under stress, suggests a more automatic mode of control was adopted. Both theoretical and practical implications are discussed.

1. Introduction

Traditional views of motor learning heavily draw upon the informational properties of feedback for motor learning (e.g., Adams, 1971; Schmidt, 1975; see also, Salmoni, Schmidt, & Walter, 1984). Broadly speaking, they emphasise the importance of utilising information about the effects of any action attempts in order to progressively memorize or program a movement that will eventually reach the intended goal and succeed at the task. However, it could be argued that the theoretical frameworks advocating for the importance of informational properties may neglect the role of motivational properties. While there have been numerous theories on the role of self-efficacy for general learning (e.g., Bandura, 1977), as well as empirical accounts of the influence of self-efficacy within motor learning settings (e.g., Weinberg, Gould, & Jackson, 1977), the more recently devised OPTIMAL (Optimizing Performance Through Intrinsic Motivation and Attention for Learning) theory (Wulf & Lewthwaite, 2016; see also, Lewthwaite & Wulf, 2017) poses one of the outstanding theoretical frameworks that may appropriately capture the importance of available information and intrinsic

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motivation during practice for motor learning.

Perhaps the most abundant of all investigated motivational variables that encompass the OPTIMAL theory includes expectancies, which surrounds the belief of the learner regarding their capability to bring about particular task outcomes. Expectancies have been most often examined through manipulations in false social-comparative feedback, perceived competence and task difficulty. For example, learning outcomes are enhanced when learners are presented with positive ("greater than the average") compared to negative ("below the average") social-comparative feedback (Lewthwaite & Wulf, 2010; see also, Eliasz, 2016). In a similar vein, learning outcomes are enhanced when the criterion for "good" performance is made easier by changing the task constraints either physically (i.e., small vs. large target boundaries Palmer, Chiviacowsky, & Wulf, 2016; for alternative findings, see Ong, Lohse, & Hodges, 2015), or perceptually (i.e., large annuli (small target) vs. small annuli (large target); Chauvel, Wulf, & Maquestiaux, 2015; see also, Witt, Linkenauger, & Proffitt, 2012) (for examples related to task efficacy, see Wulf & Lewthwaite, 2009; Wulf, Lewthwaite, & Hooyman, 2013). In combination with other motivational variables—namely, the sense of autonomy, where learners have the freedom to choose or control elements of their practice (e.g., self-determined feedback: Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997; Patterson & Carter, 2010; innocuous/task-irrelevant choices: Hartman, 2007; Wulf, Chiviacowsky, & Cardozo, 2014; Wulf & Toole, 1999)—these findings resonate with the tenets of self-determination theory, where intrinsic motivation hinges on three basic psychological needs: competence, autonomy, and relatedness (Ryan & Deci, 2000).

From a neurobiological perspective, the role of motivational variables could be explained by the involvement of the dopaminergic systems; namely, the mesocortolimbic and nigrostriatal. The former originates from the ventral tegmental area (mid-brain) and projects toward numerous telencephalic sites; none-more-so than the nucleus accumbens, which plays a role in motivation and reward. Meanwhile, the latter originates from the substantia nigra (mid-brain) and projects toward the dorsal striatum, which can be heavily linked to voluntary movement production and implicit learning (Knowlton, Mangels, & Squire, 1996; Schwabe & Wolf, 2012). Importantly, these two systems may to some extent intermingle with one another (Schmidt, Lebreton, Daunizeau, & Pessiglione, 2012), while the dopaminergic neurons within the nigrostriatal system are also known to project to the primary motor cortex (precentral gyrus) (Hosp, Pekanovic, Rioult-Pedotti, & Luft, 2011).

While there is much evidence to indicate a role of motivation, and more specifically, a benefit of enhanced expectancies for subsequent learning outcomes, there is perhaps further scope to examine precisely how such outcomes unfold. Indeed, it is of interest to understand more about the underlying psycho-motor processes that underpin learning with enhanced and reduced expectancies. In this regard, we may turn to motor learning research that has featured transfer tests, where learners have to contend with a dual-task and/or performance-related stress. The logic here revolves around the extent of automaticity or reinvestment, where a skill is executed either using a self-organized automatic mode of control (non-verbalizable) or by consciously reinvesting the movement (verbalizable), respectively (for an original conceptual framework, see Anderson, 1982; Fitts & Posner, 1967). To elucidate, a dual-task setting would rely almost exclusively on automatic control having had attentional resources limited for any possible reinvestment (Beilock, Bertenthal, McCoy, & Carr, 2004; Beilock, Carr, MacMahon, & Starkes, 2002; Gray, 2004; see also, Wulf, McNevin, & Shea, 2001). Alternatively, a stressful situation would typically limit automatic control in favour of using the available attentional resources to engage in a step-by-step breakdown of the individual elements comprising a skill (Baumeister, 1984; Beilock & Carr, 2001; Masters, 1992; Masters & Maxwell, 2008; for a potentially alternative perspective, see Eysenck, Derakshan, Santos, & Calvo, 2007; Wilson, 2008). Thus, in the event that enhanced and reduced expectancies operate differently in terms of their automaticity or reinvestment, then we should expect to see opposing outcomes for each of these transfer tests.

To date, there is a suggestion that the influence of expectancies may be at least partially attributed to the degree of coupling between the action and task goal, and with it, the focus of attention (see Fig. 3 from Wulf & Lewthwaite, 2016). To elucidate, enhanced expectancies may more likely cause the learner to match internally-generated actions (i.e., flexion-extension arm movement around the elbow when dart-throwing) and their effects (e.g., position of the dart on the dartboard), which would render a greater need for the movement to be automatically controlled (Wulf et al., 2001; Wulf & Prinz, 2001; see also, Elsner & Hommel, 2001). Meanwhile, reduced expectancies may become more pre-occupied by the movement itself having placed less emphasis on the distal effects of the action, which would constitute greater conscious reinvestment of the key verbalizable elements of the skill (Masters & Maxwell, 2008; Wulf et al., 2013; for an example involving autonomy support, see Chiviacowsky, Wulf, Lewthwaite, & Campos, 2012).

Consequently, learning with enhanced expectancies may help transfer to a dual-task setting, while reduced expectancies may help transfer to a stressful situation. This logic is adapted from the knowledge that practice may help in transfer providing the psycho-motor processes engaged within practice are also present within transfer (a phenomenon otherwise referred to as specificity of practice; Proteau, Marteniuk, Girouard, & Dugas, 1987; Proteau, Marteniuk, & Lévesque, 1992; see also, Khan, Franks, & Goodman, 1998; Tremblay & Proteau, 1998). For example, when learners practice with their attention divided or concentrated toward the skill, they tend to transfer better to more habitual (automatized) and novel (reinvested) skills, respectively (Beilock et al., 2002; Beilock et al., 2004). In a similar vein, learning either with concentration toward the skill (Beilock & Carr, 2001; cf. Masters, 1992; Mullen, Faull, Jones, & Kingston, 2012) or under performance-related stress (Cassell, Beattie, & Lawrence, 2018; Lawrence, Gottwald, Khan, & Kramer, 2012; Lawrence et al., 2014; Oudejans & Pijpers, 2009, 2010; Alder, Ford, Williams, & Causer, 2016) can help learners to positively transfer to a stressful situation.

To this end, the present study involved a procedure that was partially adapted from previous studies, where target size/goal-criterion conditions have been used to manipulate perceived success and task expectancies (Chiviacowsky, Wulf, & Lewthwaite, 2012; Ong et al., 2015; Palmer et al., 2016; Trempe, Sabourin, & Proteau, 2012). That is, novice participants attempted to learn a dart-throwing task under enhanced or reduced expectancies by providing positive ("good") feedback whenever they reached within the boundaries of a large or small circle, respectively. Therein, they would transfer to a dual-task involving tone-counting and stressful situation involving false social-comparative negative feedback. A further control group that attempted to learn the same dart-throwing task, but without receiving any augmented feedback, was incorporated in order to observe the direction of effects caused by the enhanced/reduced expectancies (e.g., Chiviacowsky, Wulf, & Lewthwaite, 2012; Lewthwaite & Wulf, 2010). While this particular group were arguably exposed to a smaller target or criterion (i.e., "bulls-eye"), it consequently did not incur any disproportionate positive/negative feedback, and thus was regarded as depending on only their inherent task expectancies without them necessarily being manipulated (for self-efficacy ratings, see *Results*). It was predicted that there would be better performance and retention for those under enhanced compared to reduced expectancies. However, we predicted that there would be better transfer to the dual-task, but poorer transfer under stress, when under enhanced compared to reduced expectancies. The precise direction of these effects could be further explored depending on the differences to the control condition (no expectancy). That is, a similarity between the control and enhanced/reduced expectancy would respectively render a default high/low self-efficacy surrounding the present dart-throwing task.

2. Method

2.1. Participants

Thirty-six healthy participants (18 males, 18 females; age $M = 22.74$ years, $SD = 3.40$) agreed to take part in the study. Participants were randomly allocated into equal numbers to one of three gender-matched groups: enhanced expectancies (EE) ($n = 12$), reduced expectancies (RE) (n = 12) and control (CTL) (n = 12). All participants self-reported being novices to dart-throwing (i.e., no competitive experience or deliberate practice in dart-throwing). Participants provided written informed consent at the start of the study and remained naive as to the true purposes of the study throughout the data collection. Participants re-signed their consent forms near the end of the study after they were debriefed and made aware of the stress manipulation (for details, see *Procedures*). The study was approved by the local research ethics board and conducted in accordance with the Declaration of Helsinki (World Medical Association, 2013).

2.2. Materials and task

The main task involved a standard dart throw to a dartboard (outer diameter = 45.72 cm, inner target diameter ("bulls-eye") = 1.20 cm, ground height = 172 cm) at a distance of 237 cm (American Darts Organisation, 2010). There were two paper concentric circles attached to the dartboard that were centred around the central target (Fig. 1a) (for a similar task set-up, see Ong et al., 2015; Palmer et al., 2016). The sizes of the concentric circles were adapted from pilot data of dart throws taken from 10 separate volunteers across 30 trials. That is, the radius of the large circle was equivalent to the sample mean radial error (i.e., distance between the dart and centre of the target) ($M = 10.56$ cm; diameter = 21.12 cm), and the radius of the small circle was equivalent to subtracting a multiple

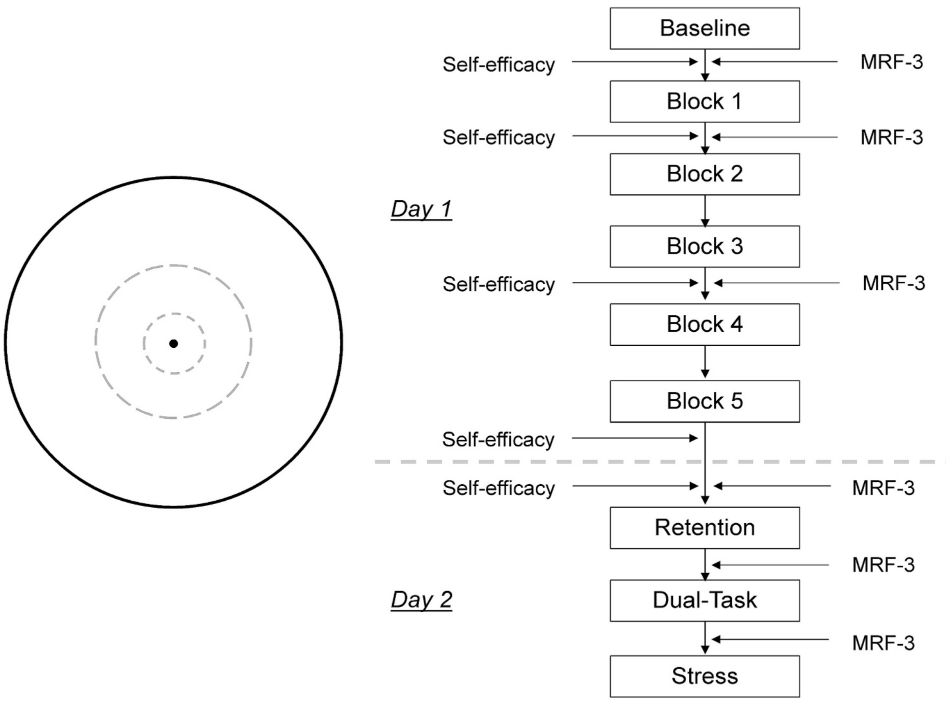

Fig. 1. Representative illustration of the dartboard configuration drawn to scale including the central target (*black dot*), and large and small circles (*dotted lines*) that were related to the enhanced and reduced expectancies, respectively (A). Outline of the procedures across Day 1 and Day 2 including the order of blocks and measurements (B).

(x3) of the sample mean within-participant standard deviation from the radius of the large circle (3SDs = 6.42 cm; diameter = 8.28 cm). Performance outcomes were captured by the experimenter using a measuring tape to manually record the distance between the dart and centre of the target for each individual trial, and then afterwards calculating the total variability from the trials within each block: $\sqrt{}$ sum of squared errors / number of trials) (Schmidt, Lee, Winstein, Wulf, & Zelaznik, 2019).

Levels of stress surrounding the upcoming attempts at the dart-throwing task were rated using the Mental Readiness Form-3 (MRF-3), which offers a more expedient but still reliable measure of state anxiety (Krane, 1994). This form requires a rating from 1 to 11 on separate Likert scales that each pertain to cognitive anxiety (not worried – worried), somatic anxiety (not tense – tense) and confidence (confident – not confident). For the purposes of the present study, we focused on the ratings within the cognitive anxiety scale, where the taxing of attentional resources following any worry could be more closely assessed (for similar procedures, see Lawrence, Khan, & Hardy, 2013; Roberts, Wilson, Skultety, & Lyons, 2018; Wilson, Chattingham, Marple-Horvatt, & Smith, 2007).

A measure of self-efficacy was adapted from Wulf et al. (2014) for the two groups with altered expectancies (i.e., EE and RE groups). This measure required a rating from 1 to 10 on the level of confidence in reaching the inner circle on at least 5 out of 10 attempts by the end of today or tomorrow (for details, see *Procedures*).

2.3. Procedures

The procedures can be found summarised within Fig. 1b. Participants attended the laboratory on two separate occasions that were separated by 24 h. For Day 1, an initial baseline measure of dart-throwing was taken from participants without any instruction surrounding expectancy. Therein, physical practice of the dart-throwing task was undertaken alongside instructions that were contingent upon the allocated groups. Prior to practice, the EE group was instructed that any attempts landing inside the large circle would be considered “good”, while the RE group was instructed that only attempts landing within the small circle would be considered “good”. During practice itself, the EE group was provided positive verbal feedback from the experimenter by uttering the word “good” following each attempt that landed inside the large circle, while the RE group received the same “good” feedback following each attempt that landed inside the small circle only. There was no verbal feedback provided whenever there was an attempt that landed outside of these respective circles. Meanwhile, the CTL group similarly attempted to land as close as possible to the centre target, and see where their attempts had landed. However, they did not receive any additional instructions about what would constitute as “good” prior to practice, nor were they offered any augmented verbal feedback during practice itself. In this regard, the CTL group would presumably manifest in naturally unfolding or inherent expectancies surrounding the task (for similar procedures, see Chiviacowsky et al., 2012; Lewthwaite & Wulf, 2010). While there were clearly different sets of expectancy instructions, we tried to control for any confounding influence of visual task constraints by presenting the large and small circles together at the same time for each of the groups (for similar procedures, see Palmer et al., 2016).

For Day 2, the small and large circles were completely removed from the dartboard. Firstly, participants completed a retention test to once more assess their dart-throwing. Therein, participants completed two transfer tests: dual-task and stress. The dual-task test involved the presentation of high- (2938 Hz), medium- (2188 Hz) and low-pitched (400 Hz) auditory tones (250-ms duration) that occurred at random while simultaneously performing dart throws.[1] In the event that participants heard a target high-pitched tone, then they would have to report it back to the experimenter by immediately uttering the word “tone”, while effectively ignoring the any medium- and low-pitched tones (for similar procedures, see Beilock et al., 2002). Digital recordings were made to later evaluate the number of tones and responses to them.

The stress test involved a combination of a social-comparative threat (e.g., Englert & Oudejans, 2014; Lawrence et al., 2013) and false negative performance feedback (e.g., Roberts et al., 2018; Wilson, Vine, & Wood, 2009). That is, participants were instructed that their performance scores would be compared against all other participants, and a table of the rankings would be disseminated amongst everyone involved. Therein, the experimenter pretended to calculate an index of performance for a short period of time (~2 mins), and then informed the participants that they were currently in the bottom third and must improve their performance over the next series of attempts if they were to move into a more favourable position within the rankings.

There were 10 trials in each block with 5 blocks designated for practice and a single block for each of the test phases (baseline, retention, dual-task, stress). The order of measures on Day 2 were not randomized in order to uphold the integrity of the stress manipulation,[2][2] while any confounding order effects could be easily detected by an independent main effect of test (for details, see *Statistical Analysis*). Self-efficacy ratings on the level of confidence in dart-throwing for later on in that same day (“today”) were taken after baseline, after block 1, after block 3 (Day 1) and before retention (Day 2), while confidence in dart-throwing for the next day (“tomorrow”) was taken after block 5 (Day 1) (for similar procedures, see Wulf et al., 2014). MRF-3 ratings were taken at corresponding times in Day 1, but because they alluded to feelings immediately in preparation for a block of trials, then they were alternatively labelled: before block 1, before block 2, before block 4 (Fig. 1b). Meanwhile, ratings were also taken prior to retention, dual-

[1] Standardizing the decibel level was somewhat overlooked for the auditory stimulus of this study. However, the volume was set to ensure tones were subjectively audible as indicated by an initial tone familiarisation phase, where participants could positively discriminate between the high-, medium- and low-pitched tones.

[2] Randomizing the order of stress conditions including the transition from high to low stress can often be difficult because of the inability to realistically return to low/standard levels of stress after entering into a stressful situation. In line with the present study, previous accounts have tried to combat this issue by alternatively retaining the order of low to high stress conditions, but within a between-measures transfer design (e.g., Allsop, Lawrence, Gray, & Khan, 2017; Cassell et al., 2018; Lawrence et al., 2013).

task and stress test phases in Day 2.

2.4. Statistical analysis

Data are available via the Open Science Framework (https://osf.io/pcxe6). Data for one participant (within the EE group) was removed prior to the statistical analysis having failed to attend the laboratory for the second visit. A series of manipulation checks were undertaken on self-efficacy ratings, tone-counting and MRF-3 ratings. For the self-efficacy ratings, Day 1 data was analysed using a 3 group (EE, RE, CTL) x 4 block (after baseline, after block 1, after block 3, after block 5) mixed-measures ANOVA. Meanwhile, Day 2 data taken from before the retention test was analysed using a one-way between-measures ANOVA to compare each of the groups. To assess compliance and potential group differences in tone-counting within the dual-task test, we conducted a one-way between-measures ANOVA on the proportion of correctly identified tones. For the MRF-3 ratings, Day 1 data was analysed using a 3 group (EE, RE, CTL) x 3 block (before block 1, before block 2, before block 4) mixed-measures ANOVA. Meanwhile, Day 2 data involved a 3 group (EE, RE, CTL) x 3 test (retention, dual-task, stress) mixed-measures ANOVA. For performance outcomes, Day 1 data was analysed using a 3 group (EE, RE, CTL) x 6 block (baseline, 1–5) mixed-measures ANOVA. Meanwhile, Day 2 data was analysed using a 3 group (EE, RE, CTL) x 3 test (retention, dual-task, stress) mixed-measures ANOVA.

The homogeneity of the variance of differences (sphericity) assumption was assessed using Mauchly's test. In the event of a violation, the Huynh-Feldt correction was adopted when Epsilon was >0.75, although the Greenhouse-Geisser correction was adopted if otherwise (original sphericity-assumed degrees-of-freedom are reported). Significant effects featuring more than two means were decomposed using the Tukey HSD post hoc procedure. Effect sizes were indicated using partial eta-squared (η_p^2) and Cohen's *d* for any factorial and pairwise designs, respectively. Significance was declared at $p < .05$.

Moreover, in order to corroborate the fore mentioned frequentist statistical testing and considering the issues surrounding null hypothesis testing (Masson, 2011; Wagenmakers, 2007), we also determined Bayes Factor for each run of the statistical analyses using JASP (v.0.14.1). This provides an odds ratio pertaining to predictive power of the alternative hypothesis over the null, with the former taken as the numerator and the latter as the denominator (BF_{10}). Thus, a value <1 favours the null hypothesis, and a value >1 begins to favour the alternative hypothesis. When it came to any multi-factorial Bayesian ANOVAs consisting of interaction effects, we compared only matched models so any main and interaction effects were not compared against models that also featuring interaction and main effects, respectively (van den Bergh et al., 2019).

3. Results

3.1. Manipulation checks

For self-efficacy ratings on Day 1, the 3 group × 4 block ANOVA revealed a significant main effect of group, $F(1,32) = 6.56$, $p = .004$, $\eta_p^2 = 0.29$, 95% CI [0.04 0.48], $BF_{10} = 11.07$, and no significant main effect of block, $F(3,96) = 0.34$, $p = .70$, $\eta_p^2 = 0.01$, 95% CI [0.00 0.09], $BF_{10} = 0.06$. In addition, there was a significant group x block interaction, $F(6,96) = 3.23$, $p = .02$, $\eta_p^2 = 0.17$, 95% CI [0.00 0.30], $BF_{10} = 7.15$ (Fig. 2). Post hoc analysis indicated that while there was no significant difference between the EE and RE groups at baseline (before the expectancy manipulation), there was a significantly higher rating (more confidence) for the EE group compared to the RE group after blocks 1, 3, and 5 (Tukey HSD = 1.47). In a similar vein, there was a significantly higher rating for the CTL group compared to the RE group within all of the blocks (Tukey HSD = 1.47), although there was no significant difference between the EE and CTL groups in any of the blocks on Day 1 (Tukey HSD = 1.44). At the beginning of Day 2, the one-way ANOVA revealed a significant main effect of group, $F(2,32) = 7.05$, $p = .00$, $\eta_p^2 = 0.31$, 95% CI [0.05 0.47], $BF_{10} = 14.67$, as there was a significantly lower rating for the RE group compared to the EE (Tukey HSD = 2.11) and CTL (Tukey HSD = 2.06) groups, although there was no significant difference between the EE and CTL groups (Tukey HSD = 2.11).

For the proportion of correctly identified tones during the dual-task test, the one-way ANOVA revealed no significant main effect of group, $F(2,32) = 0.53$, $p = .59$, $\eta_p^2 = 0.03$, 95% CI [0.00 0.17], $BF_{10} = 0.27$ (*grand M* = 90.46%) (Fig. 3). In addition, there were no incorrectly identified tones (i.e., false alarms).[3],[4]

For MRF-3 ratings on Day 1, the 3 group × 3 block ANOVA revealed no significant main effect of group, $F(2,32) = 0.92$, $p = .41$, $\eta_p^2 = 0.06$, 95% CI [0.00 0.21], $BF_{10} = 0.52$, and block, $F(2,64) = 0.35$, $p = .71$, $\eta_p^2 = 0.01$, 95% CI [0.00 0.11], $BF_{10} = 0.12$, nor a significant group x test interaction, $F(4,64) = 0.84$, $p = .51$, $\eta_p^2 = 0.05$, 95% CI [0.00 0.15], $BF_{10} = 0.19$. Meanwhile, on Day 2, there no significant main effect of group, $F(2,32) = 2.05$, $p = .15$, $\eta_p^2 = 0.11$, 95% CI [0.00 0.30], $BF_{10} = 0.89$, although there was a significant

[3] Because of the absence of any incorrectly identified tones, it could be argued that the dual-task was comparatively simple and taxed only limited attentional resources. That said, the alternative of incurring a larger number of errors would potentially raise concerns around participants' genuine attempts at the dual-task. By accurately reporting the tones, participants indicated that they were at least forced to split their attention and execute the dart-throwing task with greater automaticity than they perhaps normally would without a dual-task requirement.

[4] Due to the self-paced nature of the dart-throwing task, as well as the random presentation of the tones, we needed to ensure that there were a relatively equal number or no systematic differences between the groups in terms of the total number of tones and rate of target tones, respectively. Along these lines, one-way between-measures ANOVA revealed no significant main effect of group for the total number of tones, $F(2,32) = 0.16$, $p = .86$, $\eta_p^2 = 0.01$, 95% CI [0.00 0.11], $BF_{10} = 0.22$. (*grand M* = 29.45 (within 10 trials)), nor the rate of target tones, $F(2,32) = 1.50$, $p = .24$, $\eta_p^2 = 0.09$, 95% CI [0.00 0.26], $BF_{10} = 0.52$. (*grand M* = 33.15%). Note, the rate of target tones assumed an average of 1 in nearly every 3 tones.

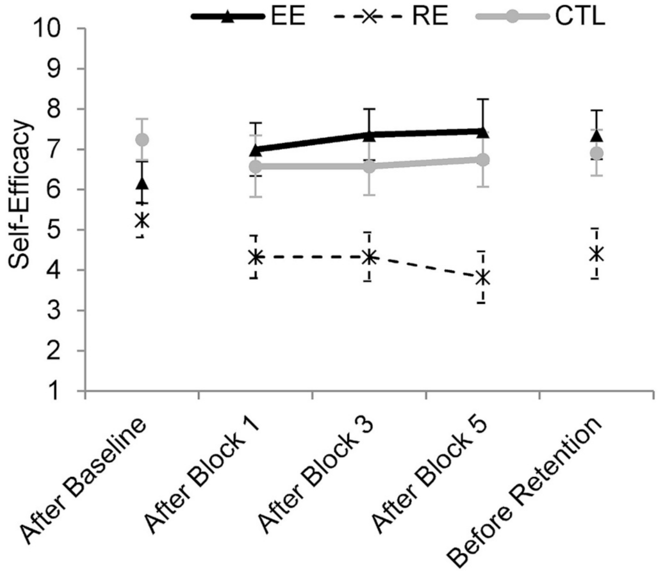

Fig. 2. Mean self-efficacy ratings during practice (after baseline, after blocks 1, 3, 5), and retention/transfer (before retention). Error bars indicate standard error of the mean.

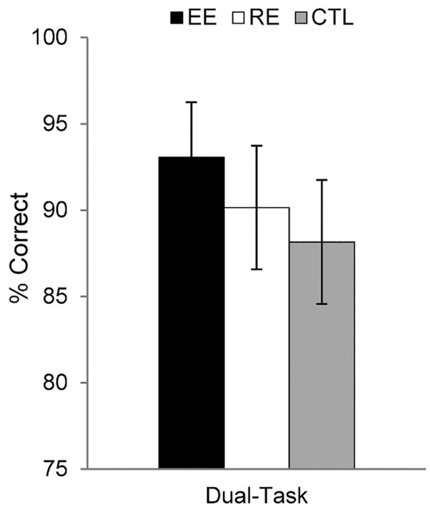

Fig. 3. Mean proportion of tones that were correctly identified within the dual-task. Error bars indicate standard error of the mean.

main effect of test, $F(2,64) = 25.03$, $p = .00$, $\eta_p^2 = 0.44$, 95% CI [0.00 0.14], $BF_{10} = 3.32 \times 10^5$. In addition, there was no significant group x test interaction, $F(4,64) = 2.36$, $p = .08$, $\eta_p^2 = 0.13$, 95% CI [0.00 0.26], $BF_{10} = 1.03$ (Fig. 4). Post hoc analysis indicated that there was a significantly higher rating following the stress manipulation ($M = 3.84$) compared to the retention ($M = 2.30$) and dual-task ($M = 2.53$) tests, which were not significantly different from each another (Tukey HSD = 0.63).

Taken together, the findings here indicate that the expectancy manipulation broadly served its intended purpose. That is, efficacy was reduced within the RE group, although it did not increase any further for EE group with respect to the default levels assumed by the CTL group that had no expectancy instruction. Meanwhile, the stress manipulation appeared to inflict an appropriate stress response prior to the stress transfer test with seemingly limited inherent or trait-based differences that were captured from before the delivery of this manipulation. Finally, the limited differences in response to the dual-task test reflect how any performance-related differences could not be realistically attributed to differences in attention toward the secondary auditory tones.

3.2. Performance outcomes

A posteriori sensitivity analysis conducted in G*Power (v.3.1.9.4) (Faul, Erdfelder, Lang, & Buchner, 2007; Perugini, Gallucci, &

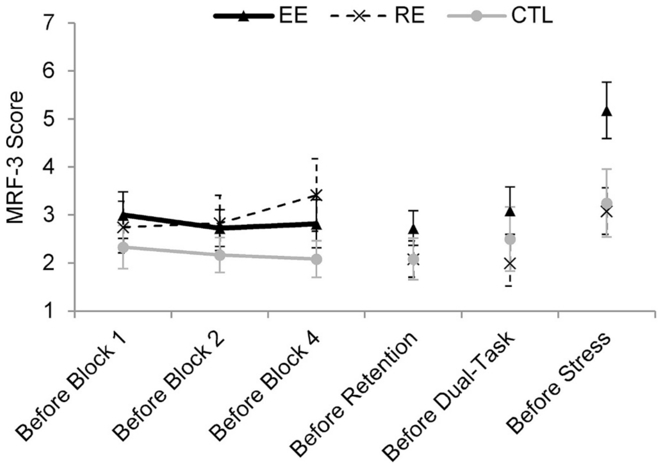

Fig. 4. Mean MRF-3 ratings of stress during practice (before blocks 1, 2, 4), and retention/transfer (before retention, before dual-task, before stress). Error bars indicate standard error of the mean.

Costantini, 2018), including the parameters of $n = 35$, $\alpha = 0.05$, and $1\text{-}\beta = 0.80$, revealed an effect size of at least $\eta_p^2 =. 039$ and $\eta_p^2 = 0.057$ could be detected from each of the factorial ANOVAs run on Day 1 and Day 2, respectively.

On Day 1, the 3 group × 6 block ANOVA revealed no significant main effect of group, $F(2,32) = 0.60$, $p = .56$, $\eta_p^2 = 0.04$, 95% CI [0.00 0.18], $BF_{10} = 0.41$, nor a significant main effect of block, $F(5,160) = 1.57$, $p = .19$, $\eta_p^2 = 0.05$, 95% CI [0.00 0.11], $BF_{10} = 0.14$. In addition, there was no significant group x block interaction, $F(10, 160) = 1.02$, $p = .43$, $\eta_p^2 = 0.06$, 95% CI [0.00 0.09], $BF_{10} = 0.10$.

On Day 2, the 3 group × 3 test ANOVA revealed no significant main effect of group, $F(2,32) = 1.22$, $p = .31$, $\eta_p^2 = 0.07$, 95% CI [0.00 0.24], $BF_{10} = 0.56$, nor a significant main effect of test, $F(2,64) = 0.40$, $p = .67$, $\eta_p^2 = 0.01$, 95% CI [0.00 0.09], $BF_{10} = 0.12$. However, there was a significant group x test interaction, $F(4,64) = 3.77$, $p = .008$, $\eta_p^2 = 0.19$, 95% CI [0.02 0.31], $BF_{10} = 6.85$ (Fig. 5). Post hoc analysis indicated significantly more error for the EE group compared to the RE and CTL groups during the stress test (Tukey HSD = 2.67), while there was significantly more error for the RE group compared to the CTL group during the dual-task test (Tukey HSD = 2.62). There were no further significant differences within the pairwise comparisons ($ps > 0.05$).

4. Discussion

The present study aimed to examine some key tenets of the OPTIMAL theory (Wulf & Lewthwaite, 2016); namely, the potential differences in the underlying psycho-motor processes that coincide with differences in learning outcomes. Indeed, the coupling between internally-generated actions and their subsequent effects is suggested to be strengthened by enhanced compared to reduced expectancies. In so doing, learners may exhibit differences in the way that they process information and control the skill. Specifically, the proposed action-effect coupling following enhanced expectancies would assume a more automatic mode of control with limited need for attentional resources, while the comparatively limited coupling following reduced expectancies would inversely assume more conscious reinvestment that is synonymous with a step-by-step breakdown of individual elements of the skill.

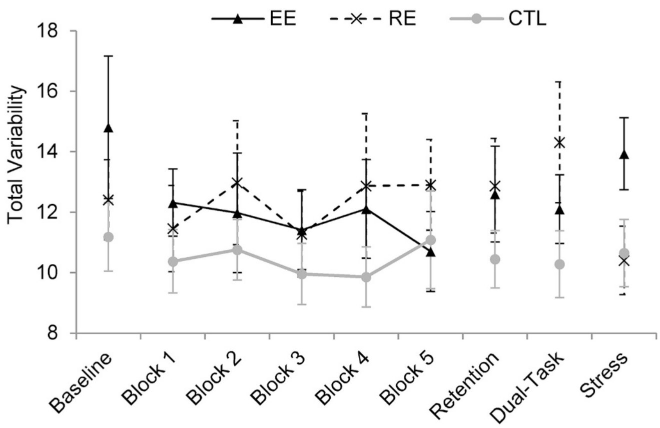

Fig. 5. Mean total variability during practice (baseline, blocks 1–5) and retention/transfer (retention, dual-task, stress). Error bars indicate standard error of the mean.

With this in mind, we incorporated additional transfer tests that would more directly examine these psycho-motor processes including a distracting dual-task requiring more automatic control (Beilock et al., 2004; Beilock et al., 2002; Gray, 2004; Wulf et al., 2001), and stress situation causing greater reinvestment (Baumeister, 1984; Beilock & Carr, 2001; Masters, 1992; Masters & Maxwell, 2008). Because there is an advantage when growing accustomed to the psycho-motor processes engaged within practice providing they are consistent with those required in transfer (e.g., Beilock & Carr, 2001; Cassell et al., 2018; Lawrence et al., 2012; Lawrence et al., 2014), then it was predicted that there would be an advantage for the enhanced compared to reduced expectancies within the dual-task, although the reverse would unfold when placed under stress.

The findings broadly concurred with this hypothesis. That is, the RE group were worse than the CTL group, which was no different to the EE group within the dual-task test. Meanwhile, the EE group was worse than the RE and CTL groups within the stress test. In line with our apriori hypotheses, if we are to assume that the advantages served by practice toward transfer manifest from a common or corresponding set of psycho-motor processes (Proteau et al., 1987; Proteau et al., 1992), then it is reasonable to suggest that enhanced and reduced expectancies coincided with greater automaticity and reinvestment, respectively. That is, practicing with enhanced expectancies enabled learners to transfer the skill despite being distracted or having their attentional resources compromised; thus, highlighting a more automatic mode of control. On the other hand, practicing with reduced expectancies enabled learners to transfer the skill under stress, where there tends to be more reinvestment of the individual elements of the skill (for alternative findings, see Ong et al., 2015).

However, it is important to at least consider the fact that there were limited differences between the groups during the practice phase of Day 1, where a superior outcome may have been otherwise predicted for the enhanced compared to reduced expectancies (e.g., Lewthwaite & Wulf, 2010; Palmer et al., 2016). While this may initially raise questions surrounding the intended manipulation, the fore mentioned performance effects within Day 2 along with the self-efficacy ratings, would suggest it is unlikely for there to have been no effect caused by the expectancy instructions. Indeed, further inspection of the frequency of target hits and subsequent instances of "good" feedback indicated that the respective target circles (small circle: grand $M = 1.69$ (out of 10)), large circle: grand $M = 6.10$ (out of 10)) were sufficiently weighted in order to induce a change in expectancies.

At this juncture, it is worthwhile noting that the failure of the present study to indicate differences during practice as a result of expectancies is not without precedence (delayed retention/transfer phase only: Chiviacowsky et al., 2012; Trempe et al., 2012; practice, retention and transfer phases combined: Ong et al., 2015; Ziv & Lidor, 2021) (for a meta-analysis, see Bacelar, Parma, Murrah, & Miller, 2022). For example, in one study that adopted a similar target size manipulation within dart-throwing, they found that while respective target (small/large) hits and self-efficacy ratings indicated some influence on expectancies in their intended direction, there was a limited impact on overall practice and delayed retention/transfer (Ong et al., 2015). As a result, the authors proposed that any potential influence of expectancies on learning are more likely to unfold following an obvious or unambiguous indicator of performance success (cf. Ong & Hodges, 2018).

Along these lines, the present findings may be explained by the inability of a target size manipulation to categorically mediate expectancies because the assigned dimensions may be such that other factors begin to influence the overall outcome. In the context of the present study, the dimensions of the large circle that were associated with enhanced expectancies may have been arguably too liberal a criterion for "good" performance. This suggestion may be supported by the evidence that self-efficacy ratings for the EE group, and the ability to consistently reach the criterion for "good" performance, were persistently high even as early as the first block of trials (see Fig. 5) (for similar findings, see Ong et al., 2015). Meanwhile, the previous occasions when this sort of manipulation has worked tends to feature a criterion that remains somewhat challenging within early practice such that it does not exceed the performance outcomes of any initial attempts (e.g., criterion timing error = 30 ms vs. coincident-anticipation timing error = ~100 ms (Chiviacowsky et al., 2012); target diameter = 14 cm vs. distance from the target = ~40 cm (Palmer et al., 2016); criterion angular error = 13.32° vs. target-directed aiming angular error = ~35° (Trempe et al., 2012)).

While unintended, this argument raises a highly important point for motor learning and any subsequent advances to theoretical frameworks. Indeed, it is relevant to consider here how expectancies may become almost too favourable that there is no longer any perceived need to learn or improve. Consistent with this notion is the Challenge Point Framework (Guadagnoli & Lee, 2004; see also, Hodges & Lohse, 2020; Lee, Swinnen, & Serrien, 1994), which broadly predicts that optimal learning conditions are directly proportional to the perceived value of available information within practice. The value that is attributed to this information can be linked to the functional task difficulty; that is, the extent of the challenge specific to the learner (e.g., throwing the dart within the small circle may be difficult for a novice, but much less so for an intermediate/expert). To elucidate, information of any real value for learning is comparatively limited when the learner is challenged by a low functional task difficulty because it does not present anything new or beyond what is already expected (e.g., throwing the dart into the criterion circle with relative ease). On the other hand, the amount of information may become too great when there is a really high functional task difficulty because it is somewhat onerous and no longer viable for the learner to adapt (e.g., throwing the dart almost exclusively outside the criterion circle). Accordingly, it is relevant to manage expectancies by avoiding them becoming too low or too high in order for an appropriate amount of information to be received by the learner. Instead, the task parameters may need to be sufficiently challenging by regulating the functional task difficulty (e.g., throwing with a criterion circle that is somewhere in between an extremely small and large circle). Of interest, a similar point on the value of challenges and rewards has also been raised within the OPTIMAL theory (Wulf & Lewthwaite, 2016).

At this juncture, we may re-evaluate the explanatory power and subsequent merits of the OPTIMAL theory. Indeed, while this theory uniquely recognises motivational variables that potentially influence motor learning—an area that has been traditionally steeped in information processing variables—it appears there are some potential caveats or factors for researchers and practitioners to consider. Specifically, inferring a direct linear relation between self-efficacy and motor learning may be mistaken, and perhaps somewhat of a misinterpretation of the OPTIMAL theory. Indeed, it is more relevant to gauge the appropriate amount of expectancies so that the learner is both efficacious and challenged at the same time. With this in mind, there may be some theoretical and practical value served in progressively adapting task parameters with a view to simultaneously manipulating different levels of expectancy and challenge. In this instance, future research may precisely quantify the task parameters that are needed for appropriately balancing these variables, and subsequently optimize learning conditions.

In conclusion, the present findings offer only marginal support for key tenets of OPTIMAL theory. Namely, the enhanced expectancies that traditionally favour more positive learning outcomes appear to be associated with a more automatized mode of control that does not require as much attention. Meanwhile, learning under reduced expectancies indicates the potential for greater conscious reinvestment, which could see a benefit for performance within stressful situations that would typically render more attention to the movement being executed. These are some of the first findings to highlight the precise psycho-motor processes underpinning the factors (i.e., expectancies) related to OPTIMAL theory. However, it is important to clarify that any conclusion is technically somewhat limited to findings related to “performance” rather than “learning” per se because the effects were not present within practice and/or retention, but solely transfer. Likewise, we should be mindful of the generalisability of the present findings given the comparatively small sample size; something that has been highlighted within motor learning research in general (Lohse, Buchanan, & Miller, 2016; see also, McKay et al., 2022), and particularly research on enhanced expectancies (Bacelar et al., 2022).

CRediT authorship contribution statement

Philip J. Simmonds: Conceptualization, Methodology, Investigation, Project administration, Formal analysis, Writing – original draft. **Caroline J. Wakefield:** Writing – review & editing, Supervision. **Ginny Coyles:** Methodology, Supervision. **James W. Roberts:** Methodology, Writing – review & editing, Supervision.

Declaration of Competing Interest

None.

Data availability

Data uploaded onto the Open Science Framework (OSF) (hyper-link provided within manuscript)

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