Mental Rehearsal Improves Passing Skill & Physiological Stress Resilience in Rugby Players

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1 Mental Rehearsal Improves Passing Skill & Stress Resilience in Rugby Players.

PURPOSE: Mental rehearsal is commonly employed, with positive visualization proposed to enhance complex skill performance. Additionally, video stimulus has been associated with enhanced kinesthetic sensations and rapid hormone fluctuations that may contribute to enhancing mental rehearsal and the conscious and unconscious emotional state for skill execution. Here we assessed the impact of a 15-min mental rehearsal interventions on rugby-specific tasks and the associated hormone profile. **METHODS:** Professional rugby players (n=10) volunteered for a randomized cross-over study. They completed three 15-min preparatory phases (Positive or Negative video-guided mental rehearsal, or self-directed mental rehearsal alone) prior to an exercise stressor and rugby-specific passing task. Salivary testosterone and cortisol were monitored to assess stress responses. **RESULTS:** Performance during the rugby passing task was improved following the positive video condition (91 ±7.4%) compared to the negative video (79 ±6.0%; ES: 1.22 ±0.75) and self-visualization (86 ±5.8%; ES: 0.58 ±0.75), with a significant correlation observed between passing performance and salivary testosterone ($r = 0.47 \pm 0.34$, $p = 0.0087$). Positive video imagery prior to an exercise stressor also significantly enhanced physiological stress resilience ($r = 0.39 \pm 0.36$, $p = 0.0352$). **CONCLUSIONS:** This pilot demonstrates that mental rehearsal was enhanced by appropriate, context-specific video presentation. We propose that the interaction between sex steroids, the adrenal axis, and subsequent conscious and unconscious behaviours may be relevant to competitive rugby. Specifically, we suggest that relatively elevated free testosterone imparts a degree of stress resilience, which may lead to enhanced expression of competitive behaviours and provide an enhanced state for rugby skill execution.

Keywords: Testosterone; Cortisol; Visualization; Video; Motivation
Word Count: 249
Text-only Word Count: 2,529
The authors report no conflict of interest.

Introduction

The ability of humans to reason through problems in virtual space, and envisage future actions in order to improve subsequent performance, has been suggested to differentiate humans from non-human primates.[1] Interestingly, brain imaging studies have demonstrated that the act of mental rehearsal elicits remarkably similar activation patterns to those induced by actual motor execution.[2,3] As a result, the extrapolation of mental rehearsal as an adjunct to aspects of skill acquisition, performance improvement, and as a stress-coping strategy has been applied in a variety of fields including music,[4] public speaking[5] and sporting environments.[6]

In a sporting context, variants of mental rehearsal have proved effective in enhancing performance across a range of diverse activities including golf,[7] volleyball,[8] basketball,[9] figure skating,[10] and athletics.[6] The ability to enhance complex coordinated movements in sport-related open-ended motor activities using mental rehearsal has been suggested to manifest via the construction of a schema that can be accessed and implemented without conscious preparation.[8] Interestingly, negative imagery (visualizing narrowly missing the hole) has been associated with impaired golf putting accuracy[7] and "excessive autonomic discharge" shown to be detrimental to performance in a volleyball serve-receipt task.[8]

One of the limitations of mental rehearsal is the inability to standardize or control the nature of the mental imagery. Ryan and Simons[11] demonstrated superior performance in a novel balancing act in participants reporting strong visual and kinaesthetic imagery compared to those reporting less vivid imagery. Hall and Erffmeyer[9] compared the visualization incorporating a video tape with visualization alone, and reported that the use of a sports-specific visual cue enhanced the kinesthetic sensations resultant from mental rehearsal and improved basketball shooting performance. Thus, the use of mental rehearsal incorporating a video has the potential to improve subsequent sport-specific tasks with the additional benefit of providing a standardized stimulus that can be tailored with sports-specific cues.

Early work by Hellhammer and colleagues[12] demonstrated that the presentation of a movie clip could alter mood state and rapidly modulate salivary testosterone levels. There is direct evidence to support the thesis that testosterone is capable of influencing unconscious aspects of approach- and withdrawal-related emotion.[13] Within this construct, Cook and Crewther[14] identified the pre-exercise hormonal milieu as a "window of opportunity", whereby the hormonal modulation achieved by viewing a brief movie, altered subsequent voluntary performance. Further, strong relationships between voluntary workload and relative testosterone levels have been demonstrated in elite netball athletes in training ($r = 0.67$ to 0.83), suggestive of a behavioural driver that may underlie subsequent adaptive responses.[15] Stress related hormones including testosterone and cortisol have also been suggested to relate to attentive skill in rugby players and subsequent motor execution.[16] Given the potency by which sex steroids act on the adrenal axis,[17] here we test the hypothesis of whether the presentation of a brief movie to enhance mental rehearsal can improve performance in a sport-specific task (rugby passing) and potentially induce increased resilience to a subsequent physical stressor.

Materials and Methods

Subjects

Ten professional male rugby players (Mean ± SD, Age: 20.6 ± 1.3 y; Height: 1.85 ± 0.05 m; Body Mass: 97.6 ± 8.3 kg) were recruited and provided written informed consent. All subjects

were non-smokers, had a professional training history of at least 2 years, and were well accustomed to the repeated-sprints, strength exercises, and rugby-specific complex motor skill passing task employed in the current study. The study had a randomized cross-over design, was approved by a university ethics committee, and complied with national legislation and The Code of Ethical Principles for Medical Research involving Human Subjects of the World Medical Association (Declaration of Helsinki).

Experimental protocol

On three separate days within a 2-week period, and at the same time of day, the players arrived at the training facility where they were accustomed to training and sat quietly for five minutes before providing a saliva sample (pre-Preparatory Phase sample: T1; see Figure 1). The players were then instructed to enter a room alone and mentally rehearse the sport-specific task of accurately passing a rugby ball for 15 minutes using one of three preparatory methods. Two of the mental rehearsal methods consisted of the presentation of a movie constructed from real rugby game situations, while the third method (Self-Visualization) presented no movie and relied on self-visualization without visual cues. The two conditions that involved the presentation of a movie were either presented with a positive antecedent discriminatory stimulus that showed the player performing their individual tasks well (Positive Video), or a negative antecedent stimulus that highlighted errors in the individual's performance of the same task (Negative Video). Each player performed all three of the Preparatory Phase conditions (Self-Visualization, Positive Video, and Negative Video) in a randomized manner within the 2-week period. Five minutes after the Preparatory Phase a second saliva sample was collected (post-Preparatory Phase sample: T2; see Figure 1). The player was then instructed to warm-up on a cycle ergometer at 100 W for 10 minutes whilst continuing to mentally rehearse the specific aspects of their passing performance. Upon completion of the cycle warm-up a third saliva sample was collected (pre-stressor sample: T3; see Figure 1) and the physical stressor was then begun.

*** Insert Figure 1 About here ***

The physical stressor involved three 6 s maximum effort cycling sprints, followed shortly (~ 2 min) thereafter by three 10 m maximum effort running sprints. All sprint efforts were interspersed with 24 s active recovery. The players then performed 5 sets of 3 repetitions of heavy squats (3 repetition maximum; i.e. the maximum weight that could be lifted three times) with 3-min rest between sets. Similar brief high intensity exercise is known to elicit rapid increases in both testosterone and cortisol.[18] The players then completed the passing accuracy task that required the players to attempt to pass a rugby ball ten times through a hoop 5 m away alternating between their dominant and non-dominant hands. A time limit of two minutes was enforced for the passing accuracy task and accuracy was determined by the number of passes that went through the hoop. Five minutes after the completion of the accuracy test a fourth saliva sample was collected (post-stressor sample: T4; see Figure 1).

Hormone assessment

For each sample, participants were asked to provide 2 mL of saliva via passive drool into a sterile centrifuge tube. Saliva samples were stored at –20 °C until assay. Salivary steroid samples were taken in this study as they are minimally invasive and have the advantage of reflecting free steroid concentrations.[19] To minimize the possibility of any blood contamination of saliva, which would result in an overestimation of hormone concentrations, the players were advised to avoid brushing their teeth, drinking hot fluids or eating hard foods

(e.g. apples) in the 2 h before data collection. Saliva samples were analyzed in duplicate for testosterone using commercial enzyme-immunoassay kits as per manufacturer's instructions (Salimetrics LLC, USA). The detection limits for the testosterone and cortisol assays were 19 pmol·L^{-1} and the respective intra- and inter-assay coefficients of variation were < 7.7 %.

Statistical analyses

Differences in the means of the hormone responses and athletes' passing accuracy were assessed using a repeated-measures analysis of variance with mental rehearsal method as a factor. Changes and errors were expressed as percents via analysis of log-transformed values, to reduce bias arising from non-uniformity of error.[20] Data were analyzed for practical significance using magnitude-based inferences calculated using appropriate between-subject SDs. Magnitudes of the standardized effects were interpreted using thresholds of 0.2, 0.6, and 1.2 for small, moderate, and large ES, respectively.[20] Standardized effects of between −0.19 and 0.19 were termed trivial. Quantitative chances of higher or lower differences were evaluated qualitatively as follows: <1%, almost certainly not; 1–5%, very unlikely; 5–25%, unlikely; 25–75%, possible; 75–95%, likely; 95–99%, very likely; >99%, almost certain.[20] The effect was deemed 'clear' if the 95% confidence interval did not overlap the thresholds for small positive and negative effects. Bi-variate relationships between the salivary hormones and passing accuracy performance using absolute hormonal values (30 observations) were examined using Pearson product moment correlation coefficients (*r*). Magnitudes of correlations were interpreted using thresholds of 0.1, 0.3, 0.5, and 0.7 for small-, moderate-, large-, and very large- correlations respectively.[20] Significance was set at an alpha level of $p \leq 0.05$.

Results

The average resting salivary testosterone (Sal-T) and cortisol (Sal-C) concentrations were 487.6 ± 91.6 pmol·L^{-1} and 5.55 ± 1.08 nmol·L^{-1}. The salivary hormone levels are illustrated in Figure 2 and show a moderate difference between the Sal-T (ES: 0.47 ± 0.19) and Sal-C (ES: -0.46 ± 0.30) responses to the positive and negative video presentation (T2 – T1). There was also a significantly greater Sal-T response to the exercise stressor (T4 – T3) following the positive video presentation (ES: 0.26 ±0.15) and concomitantly a likely attenuation of the Sal-C response (ES: -0.35 ±0.34). In general, the Self-Visualization condition was intermediary; however, a very likely attenuation of the Sal-C response during the Preparatory Phase was observed when compared to the Negative Video condition (ES: -0.52 ± 0.27).

*** Insert Figure 2 About here ***

Accuracy during the passing task was enhanced in the positive video condition (91 ±7.4%) compared to the visualization (86 ±5.8%; ES: 0.58 ± 0.75) and the negative video presentation (79 ±6.0%; ES: 1.22 ± 0.75). A significant moderate correlation was observed between the rugby passing accuracy task and pre-stressor Sal-T (T3: r = 0.47±0.34; p = 0.0087; Figure 3A) but not the initial Sal-T (T1: r = 0.35±0.37; p = 0.0618). In addition, a moderate negative relationship was observed between the change in Sal-T during the Preparatory Phase (T2 – T1) and the acute Sal-C response to the physical stressor (T4 – T3: r = -0.39 ±0.36; p = 0.0352; Figure 3B).

*** Insert Figure 3 About here ***

Discussion

Here we provide some preliminary evidence that the presentation of a context-specific video can elicit distinct hormonal changes that are associated with improved rugby-specific motor skill execution, and impart a degree of physiological stress resilience (attenuation of the stress hormone response to a subsequent physical stress). Previous research with professional rugby players has demonstrated that the presentation of four-minute videos can positively influence hormone responses and weight lifting performance and suggested an effect of hormones on an athlete's motivation to perform.[14] Such associations have also been reported in elite female athletes whereby individuals presenting to training with relatively elevated testosterone lifted heavier loads during a self-selected near-maximal leg exercise suggestive of a positive relationship between Sal- T and training capacity or motivation.[15] Of note, video clips combined with positive feedback have also been demonstrated to positively affect subjectively-rated rugby performance indices in a real competitive environment.[21]

As a result, we have proposed the concept of testosterone influencing training motivation in an athletic context.[15] Testosterone has demonstrated a range of behaviour modifying effects in humans, including increasing unconscious motivation,[22] aggression[23], and risk-taking,[24] while decreasing empathetic behaviours[25] and fear.[26] Thus, rapid changes in the bioavailable concentration of testosterone, in addition to the known effects on cortical circuitry controlling voluntary muscular movements[27] and muscular excitation-contraction coupling,[28] may modulate motivation and punishment-reward sensitivity. Research has also suggested roles for cortisol and testosterone in both elite female netball competition and in attentive behaviours relative to motor tasks in rugby players.[18,19] These behavioural drivers have the potential to influence subsequent training adaptation and the expression of competitive behaviours likely to be beneficial to performance in a range of competitive contact sports, including rugby.

Our pilot data illustrate a relationship between rugby-specific motor skill performance after the physical stress and salivary testosterone, a relationship that was increased when the temporal proximity of the sampling time to the task was decreased (i.e. T3 versus T1). In addition to the discussed effects of testosterone on self-efficacy and motivation (*vide supra*), studies have demonstrated associations between endogenous bioavailable testosterone levels and visuospatial processing.[29] Researchers have suggested that elevated free testosterone concentrations may facilitate improved performance via modulation of information encoding and comparison, and the rate of the initiation of decision and response processes.[30] It is of note that we assessed salivary testosterone which allowed multiple, non-invasive sample collection time points in close temporal proximity to the mental rehearsal condition and the exercise stressor. Thus, salivary monitoring provided information regarding the concentration of free testosterone capable of passing the blood-brain barrier and thereby interact with receptors in the brain to influence cognitive processing and behaviours.[31]

Here we also provide preliminary data supporting the hypothesis that an enhanced acute testosterone response resultant from the Positive Video, when combined with mental rehearsal, is associated with a suppressed cortisol response to the subsequent exercise stressor in addition to the improved accuracy during the rugby-specific passing task. Similarly, it has been posited that attenuated autonomic nervous system responses are associated with better performance in volleyball players.[8] Testosterone has been demonstrated to inhibit the hypothalamic-pituitary-adrenal axis response to stress[32] and elicit anxiolytic properties that

can be effectively blocked via androgen receptor antagonism.[33] Indeed, van Honk, Peper and Schutter[13] demonstrated that, in contrast to a lack of effect on cognitively attributed anxiety measures, testosterone was effective in reducing an *unconscious* fear response and attributed their results to effects in the subcortical affective pathways of the brain. Speculatively then, the enhanced testosterone response observed herein may contribute to self-efficacy and confidence, and potentially enhance performance by providing a more optimal emotional state for skill execution.[34]

It should be noted that, while the video presentation was intended to enhance the kinesthetic sensations elicited by mental rehearsal and provide a standardized stimulus, individual differences in life experiences and personality types will undoubtedly contribute to inter-individual differences in how the stimulus was perceived and subsequent physiological responses.[35] A strong caveat is the low subject number in this study. Professional rugby players have large demands on their training time so recruitment was limited and thus we view this as a pilot study. Significantly higher numbers are needed to confirm this work although other studies with larger numbers, such as the work of Serpell and colleagues,[20] do support the general notion. We also acknowledge as a limitation that it is likely that prior experience with mental rehearsal training and individual imagery ability would affect the efficacy of the self-visualization condition.[10]

Conclusions

In this pilot study in elite rugby players, we have demonstrated that the effects of mental rehearsal were enhanced by utilising a context-specific positive antecedent discriminative video stimulus. This stimulus improved rugby passing motor skill execution and imparted a degree of physiological stress resilience to an acute physical stressor. As these observations were associated with an altered hormonal state, we suggest that there may be interactions between sex steroids, the adrenal axis, and subsequent conscious and unconscious behaviours. The ability to rapidly modulate bioavailable hormone concentrations via self-visualization or a context-specific 15 minute video is in line with previous research that has demonstrated positive priming in a similar cohort.[14,21]

Practical Applications

The preliminary findings support the practical use of mental imagery to improve rugby training and match performance. Practitioners can use positive videos to increase passing accuracy and thus, video presentation may represent an effective tool to enhance other sport-specific skills, for example kicking and lineout throwing. Current practice of performance analysts involves the creation of video content to identify strengths and weaknesses of various opposition. These same processes could be utilised to provide content that specifically focuses on skill sets being performed well that could be incorporated into pre-match routines. The elevated testosterone levels resultant from the positive video presentation also have the potential to improve self-efficacy, motivation, and visuospatial processing, and decrease anxiety, all of which have the potential to directly impact on rugby skill performance.

Conflict of interest

The authors have no conflicts of interest relating to this study.

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Acknowledgments
We acknowledge with gratitude the athletes that contributed to this study.

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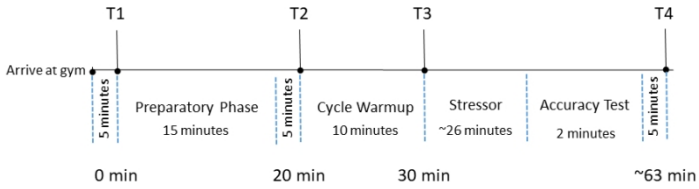
Fig. 1. Experimental design

Fig. 2. Salivary hormone responses to a 15-min mental rehearsal condition and subsequent exercise stressor
a: Substantially different to the Negative Video condition response, b: Substantially different to the Self-Visualization condition response.

Fig. 3. Correlations between hormone levels and performance
A: Correlation between passing accuracy and pre-stressor salivary testosterone (T3); B: Correlation between salivary testosterone response to the Preparatory Phase (T2 – T1) and salivary cortisol response to the stressor (T4 - T3).



Experimental design

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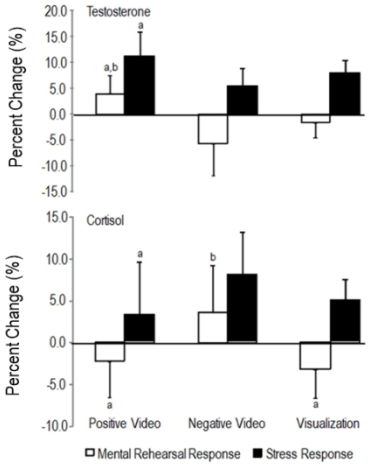

a: Substantially different to the Negative Video condition response, b: Substantially different to the Self-Visualization condition response.

Salivary hormone responses to a 15-min mental rehearsal condition and subsequent exercise stressor
a: Substantially different to the Negative Video condition response, b: Substantially different to the Self-Visualization condition response

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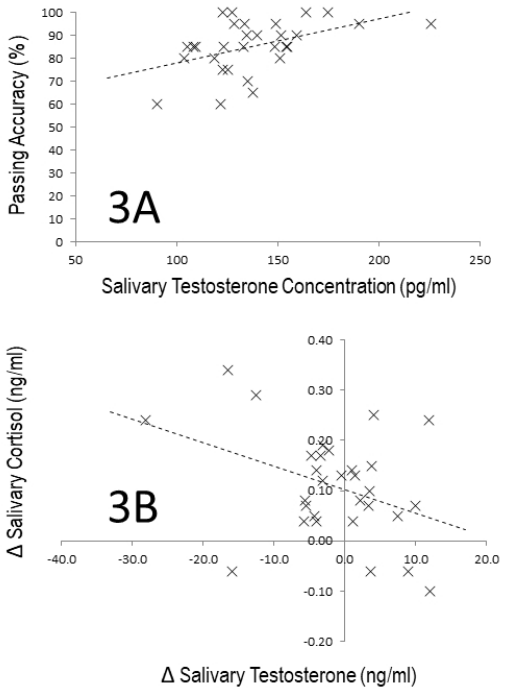

Correlations between hormone levels and performance
A: Correlation between passing accuracy and pre-stressor salivary testosterone (T3); B: Correlation between salivary testosterone response to the Preparatory Phase (T2 – T1) and salivary cortisol response to the stressor (T4 - T3).

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Response document for Manuscript ID IJSPP.2023-0117 entitled "Mental Rehearsal Improves Passing Skill & Physiological Stress Resilience in Rugby Players"

Reviewer: 1

Comments to the Author

Thank you for the opportunity to review this paper.

Overall, the paper was well written and provided insight into an interesting topic area. As this has been written as a pilot study, it would be interesting to see if the results were similar with a larger sample size.

Thank you for your insightful and detailed comments. We have integrated them to hopefully improve the clarity, readability, and informativeness of the submission. We agree that an investigation into these relationships in a larger sample would be worthwhile. Please see our responses to the specific comments in red below. Changes have been marked in red font in the revised manuscript also.

Please see specific comments below:

Page 3, line 13 – remove the word “also”.

Amended as requested.

Page 4, line 41 – as you have provided a single example here, it would be good to provide an example of what negative imagery is. For example, does imagery of a missed putt in golf lead to less accuracy when putting.

Amended to include additional information from the Woolfolk, Parrish & Murphy (1985) article and now reads: “…negative imagery (visualizing narrowly missing the hole) has been associated with impaired golf putting accuracy…”

Page 5, line 53 – please check the grammar for the sentence “demonstrated capacity for movie presentation to…”

Amended to read: “…demonstrated that the presentation of a movie clip could alter mood state and rapidly modulate salivary testosterone levels.

Page 6, line 86-89 – You have used specific wording to outline conditions throughout the paper (i.e. Negative Video, Self-Visualisation). Adding titles for conditions here would help to provide clarity and context to subsequent references to these conditions.

Amended as requested to include ‘Self-Visualization’, ‘Positive Video’, and ‘Negative Video’ titles.

Page 6, line 86-89 – Just to ensure it is clear, can you please provide details outlining the order of the video viewing and the mental rehearsal.

Amended to clarify and now reads: “Each player performed all three of the Preparatory Phase conditions (Self-Visualization, Positive Video, and Negative Video) in a randomised manner within the 2-week period.”

Page 7, line 98 – Can you please provide more details on the physical stressor. For example, what recovery was provided during the cycle and running sprints, and what constituted heavy squats (i.e. % body weight, % RM)? Were warm up repetitions performed?

Additional information has been included and now reads: “The physical stressor involved three 6 s maximum effort cycling sprints, followed shortly (~ 2 min) thereafter by three 10 m maximum effort running sprints. All sprint efforts were interspersed with 24 s active recovery. The players then performed 5 sets of 3 repetitions of heavy

squats (3 repetition maximum; i.e. the maximum weight that could be lifted three times) with 3-min rest between sets."

Please note that a 10 min cycling warm-up at 100 W is described in the previous paragraph.

Page 7, line 102 – Please provide more detail on the pass accuracy task. I assume accuracy was determined by the total passes that went through the hoop? If so, can you please highlight this.

Additional information has been included and now reads: "A time limit of two minutes was enforced for the passing accuracy task and accuracy was determined by the number of passes that went through the hoop."

Page 7, line 104 – You have indicated that "five minutes after the completion of the physical stressor a fourth saliva sample was collected", however in Figure 1, this is listed as 5 minutes post the accuracy test. Can you please amend the text or figure to reflect the correct procedure.

Amended to read: "Five minutes after the completion of the accuracy test a fourth saliva sample was collected (post-stressor sample: T4; see Figure 1)."

Page 7, line 119 – Where you have referred to "athletes' performance" consider amending this to include a reference to the pass accuracy. This would provide greater context to the performance you are referring to.

Amended to read: "Differences in the means of the hormone responses and athletes' passing accuracy were assessed…"

Page 9, line 160-163 – The sentence commencing with "previous research…" could be clearer.

Amended to read: "Previous research with professional rugby players has demonstrated that the presentation of four-minute videos can influence hormone responses and weight lifting performance and suggested an effect of hormones on an athlete's motivation to perform."

Page 9, line 168 – Please amend the word "environ" to be "environment".

Amended as requested.

Page 11, line 195 – Consider adding the word "positive" prior to "video response" to reflect the findings of the study more accurately. This would also more clearly align with your practical applications.

Amended to read: "Here we also provide preliminary data supporting the hypothesis that an enhanced acute testosterone response resultant from the Positive Video, when combined with mental rehearsal…"

Page 11, line 215 – The in-text reference to Serpell and colleagues is incorrect, with this reference listed as #20 on the reference list.

Amended to 20.

Reviewer: 2

Comments to the Author

General Comments

This work evaluating the effects of mental rehearsal, video presentation and rugby passing in a model of stress hormone resilience extends earlier work from this group, and others. The experimental approach is well-conceived with a thoughtful balance of underpinning physiology and rugby (passing) performance.

The conceptual model is sound, and the stated objectives and outcomes should be of interest to the rugby community and researchers. In some ways this is a pilot study noting the small samples, but the design, methodology and interpretation are solid, with some notable outcomes.

The practical implementation of these findings should be feasible in the elite rugby training environment. Could you provide a short statement on preparing a 15 min video constructed from real rugby game situations? Some brief details would be informative for practitioners and researchers looking to implement the outcomes in their work.

Thank you for your insightful and detailed comments. We have integrated them to hopefully improve the clarity, readability, and informativeness of the submission. We agree that the inclusion of the confidence limits was important, and we apologize for the oversight regarding US spelling and the text-only word count. Please see our responses to the specific comments in red below. Changes have been marked in red font in the revised manuscript also.

We have included a brief statement that is now included in the 'Practical Applications' section that reads: "Current practice of performance analysts involves the creation of video content to identify strengths and weaknesses of various opposition. These same processes could be utilised to provide content that specifically focuses on skill sets being performed well that could be incorporated into pre-match routines."

There are some minor presentations issue to address as highlighted below in the Specific Comments.

Specific Comments

Can you please indicate the word count of main document (introduction to the acknowledgements, but not the references)?

The main document (Introduction, Methods and Materials, Results, Discussion, and Practical Applications) is 2,577 words.

The manuscript should be single spaced throughout.
Amended to single-spaced.

line 7. A more details would be welcome 'a 15 min mental rehearsal intervention of a rugby-specific passing task'....

Amended as requested.

line 8. Convention holds not to start a sentence with a numeric. Suggestion 'Professional rugby players (n=10)...'.

Amended as requested to read: “Professional rugby players (n=10) volunteered…”

line 9. US spelling throughout for IJSPP. Here 'randomized'.
Amended throughout.

line 10. You could add '15 min' for the preparatory phases.
Added as requested.

line 13. 90 or 95% confidence limits or interval should be provided with the mean value here (91%). The same applies to line 14 as well.
95% CL have been added here and throughout and now reads: “Performance during the rugby passing task was improved following the positive video condition (91 ±7.4%) compared to the negative video (79 ±6.0%; ES: 1.22 ±0.75) and self-visualisation (86 ±5.8%; ES: 0.58 ±0.75)…”

lines 16 and 17. Strictly speaking it is good practice to show the 90 or 95% CI/CL for the r-values as well.
95% CL have been added here and throughout and now reads: “…a significant correlation observed between passing performance and salivary testosterone (r = 0.47±0.34, p=0.0087). Positive video imagery prior to an exercise stressor also significantly enhanced physiological stress resilience (r = 0.39±0.36, p=0.0352).”

lines 17-23. The conclusion is a little long and could be made more succinct. Some of these constructs (e.g. self-efficacy) were not measured in the study. These are good points that could be made in the main discussion.
The reference to “self-efficacy” and “emotional state” have been removed.

line 30. IJSPP referencing format. The superscript number comes immediately after (no space) the full stop or comma. Please revise throughout.
Revised throughout.

line 42. The sentence could be reworded slightly to remove repetition of 'has been'.
Amended to read: “Interestingly, negative imagery (visualizing narrowly missing the hole) has been associated with impaired golf putting accuracy[8] and “excessive autonomic discharge” shown to be detrimental to performance in a volleyball serve-receipt task.[10]”

line 44. US spelling 'standardize'.
Amended and revised throughout.

line 47. US spelling 'visualization'.
Amended and revised throughout.

line 48. Addition of a comma after 'visualization alone' would break up a very long sentence.
Amended as requested.

line 52. US spelling standardize
Amended as requested.

line 52. Check wording 'a movie presentation'.

Amended to read: "…demonstrated that the presentation of a movie could alter mood state and rapidly modulate salivary testosterone levels."

line 59. Could the r-value(s) be shown here for a quantitative touch?

Amended as requested to include data from Cook and Beaven (2013), and now reads "strong relationships between voluntary workload and relative testosterone levels have been demonstrated in elite netball athletes in training (r =0.67 to 0.83)…"

line 74. US spelling randomized

Amended and revised throughout.

line 90. US spelling randomized

Amended and revised throughout.

line 98. Should Stressor be a formal noun with a capital S or just lower case?

Amended to lower case and revised throughout.

line 111. US spelling minimize

Amended.

line 114. US spelling analyze

Amended and revised throughout.

line 116. Check correct usage of was (singular) and were (plural) here.

Amended "limit" to "limits" to now read: "The detection limits for the testosterone and cortisol assays were 19 pmol·L-1 and the respective intra- and inter-assay coefficients of variation were < 7.7 %."

line 122. US spelling analyzed

Amended and revised throughout.

lines 147. As before the mean effects should be presented with their 90 or 95% confidence limits or interval

Amended to read: "Accuracy during the passing task was enhanced in the positive video condition (91 ±7.4%) compared to the visualization (86 ±5.8%; ES: 0.58 ± 0.75) and the negative video presentation (79 ±6.0%; ES: 1.22 ± 0.75). A significant moderate correlation was observed between the rugby passing accuracy task and pre-stressor Sal-T (T3: r = 0.47±0.34; p = 0.0087; Figure 3A) but not the initial Sal-T (T1: r = 0.35±0.37; p = 0.0618). In addition, a moderate negative relationship was observed between the change in Sal-T during the Preparatory Phase (T2 – T1) and the acute Sal-C response to the physical stressor (T4 – T3: r = -0.39 ±0.36; p = 0.0352; Figure 3B)."

lines 150. See previous comment.

See previous response ☺

line 151. p=0.06. What's the effect size here and any resulting practical significance?

With the inclusion of the confidence limits (r = 0.35±0.37) being unable to make a definitive statement regarding the directionality of the relationship, we though it best to avoid making any strong comment regarding practical significance here; however, we did include the data such that readers can draw their own conclusions.

line 159. Suggest addition of a comma after 'skill execution' to break up a long sentence.

Comma added as requested.

lines 161-162. Awkward expression 'videos with hormone responses with voluntary weight lifting'. The double 'with' reads a little awkwardly to my eye. Can you check and improve if possible?

Reworded to now read: “Previous research with professional rugby players has demonstrated that the presentation of four-minute videos can positively influence hormone responses and weight lifting performance and suggested an effect of hormones on an athlete’s motivation to perform.”

line 166. Is this a 'positive' relationship?

Amended to read: “suggestive of a positive relationship between Sal- T and training capacity or motivation.”

lines 166-168. Useful presentation of likely relationships and practical outcomes in an elite environment. However 'environ' should read 'environment'.

Amended “environ” to “environment” as requested.

line 191. Perhaps a new sentence 'Moreover, the data indicate provision of information regarding the concentration ..' or something similar to break up a long sentence.

Reworded to read: “It is of note that we assessed salivary testosterone which allowed multiple, non-invasive sample collection time points in close temporal proximity to the mental rehearsal condition and the exercise stressor. Thus, salivary monitoring provided information regarding the concentration of free testosterone capable of passing the blood-brain barrier and thereby interact with receptors in the brain to influence cognitive processing and behaviours.”

A total of 45 references are listed which is almost 50% over the stated limit of n=30, and only n=10 subjects. Just double check if there are any references that are secondary in nature and could be deleted.

We understand the reviewers comment here, and we have culled from 45 to 35 references. We would like to humbly request that the remaining reference list is maintained.

Figure 2 caption. US spelling visualization.

Amended as requested.