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MAXIMISING ATHLETIC PERFORMANCE: ENHANCING STRESS TOLERANCE WITH THE CONCENTRATION GRID

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ABSTRACT

The influence of stress on athletic performance is well-acknowledged in sports psychology (Jones et al., 2020). Stress is a critical determinant of athletic performance, and it varies in interpretation and management among athletes, especially in individual sports (Hill et al., 2020). This study aimed to investigate the potential of a mobile-based application intervention, specifically the Autumn Arcade (2022) concentration grid-based mobile application, in enhancing the reactive stress tolerance (RST) of table tennis players. 8 national-level table tennis players (4 males and 4 females) aged 18-20 years were selected using a convenience sampling method. Participants were divided into experimental and control groups. The experimental group engaged with the mobile application for 25 days, while the control group continued their regular training. RST was measured using the Vienna Test System's determination test (S1). Post-intervention, the experimental group demonstrated significant improvements in RST. In contrast, the control group showed no significant changes. Effect sizes for the experimental group were substantial, indicating the practical relevance of the intervention. The study underscores the potential of technology in enhancing athletes' stress tolerance, especially in individual sports. While promising, the findings should be interpreted with caution due to the limited sample size and convenience sampling method. The integration of technology in sports training, as evidenced by the positive impact of the Autumn Arcade (2022) mobile application, suggests that mobile-based application interventions could be pivotal in achieving athletic excellence.

Keywords: Application, Concentration, Grid, Intervention, Psychology, Sport, Stress, Testing, Vienna

1. INTRODUCTION

"It's not stress that kills us, it's our reaction to it" (Seyle, 1974).

Athletes' mental resilience is their adaptive functioning in a stressful situation and can often be the determining factor between success and failure, so, stress tolerance would be an attribute of mental resilience, and both would have a reciprocal influence on each other (Baumeister, 1984). Stress tolerance has been defined as the ability of an individual to handle stressors without succumbing to their effects (Bland et al., 2012). Mental resilience stands for one's capacity to recover from extremes of trauma and stress, and it reflects a union of factors that encourage positive adaptation despite exposure to adverse life experiences. (Lantman et al., 2017). The theory of behavioral resilience states that a stressful experience can enhance the resilience of the individual to a subsequent stressor (Lewitus & Schwartz, 2009). Stress, an ever-present element in competitive sports, can serve as both a motivator and a barrier to optimal performance and the intricacies of stress in sports that arise from various sources, both external (e.g., competitive demands, expectations, and environmental conditions) and internal (e.g., personal performance goals, self-doubt, and mental fatigue), could lead athletes to sometimes falter under pressure (Baumeister, 1984; Panatier, 2022).

A study by Anshel et al (2001) underscores the significance of individual perceptions and interpretations of stressors and also mentions that two athletes, when faced with the same challenge, might exhibit different reactions based on their personal evaluations and coping strategies. The personal evaluations could be subjective assessments that each athlete would make about the nature and severity of a stressor, which could be influenced by their personal experiences, beliefs, attitudes, and psychological traits (Anshel et al., 2001). For example, one athlete might view a high-stakes competition as an exciting challenge and an opportunity to excel, while another might see the same event as an overwhelming pressure and a potential for failure. Individual sports, devoid of the team support system, can intensify this stress experience (Mamassis & Doganis, 2004; Highlen & Bennett, 1983).

Reactive stress tolerance (RST) assesses an individual's ability to maintain focus and respond appropriately when placed in a stressful situation where stress is induced (Ong 2017). The notion of RST offers a comprehensive gauge of an athlete's capacity to sustain performance amidst immediate stressors (Ong, 2017). It has also been studied that athletes performing at a higher level in combat and non-combat sports have higher levels of RST, which could signify a positive relation between performance and RST and/or skill level and RST (Ferreira et al., 2020). Racket sports, characterized by their rapid tempo, underscore the significance of RST in determining outcomes (Pahan & Singh, 2022; Bhabhor et al., 2013). RST refers to an athlete's ability to effectively respond to stressors in real-time, particularly under high-pressure situations. Research by Pahan & Singh (2022) and Bhabhor et al. (2013) supports this, showing that in sports like tennis or badminton, where players must rapidly adapt to unpredictable and stressful situations, a high level of RST can be a critical determinant of success. These studies suggest that athletes with better RST are more adept at managing the intense, immediate stressors typical in racket sports, leading to improved performance. Nevertheless, there is very limited research within this area of racket sports, therefore this study investigates RST in elite table tennis players following an intervention.

There was a lack of interventions in increasing the reactive stress tolerance (RST) of an athlete, in the current literature pool. On the other hand, the available research only discussed the use of the concentration grid as a testing method, and no interventions are presently available. Taking all of this into consideration, trying to make the intervention easy to follow was another concern, and the idea of being able to conduct the intervention using a convinient, and more method was considered. The mobile-based concentration grid application by Autumn Arcade (2022) was eventually confirmed after rigorous testing and research (Greenlees et al., 2006).

As technology advances, there's growing potential for mobile application-driven strategies in sports psychology to bolster RST and other mental aspects (Stenzel et al., 2021; Schack et al., 2014). While existing research vouches for the effectiveness of mobile-based application interventions, there is a noticeable gap in the literature exploring their real-world application, especially concerning RST in adolescent individual sports athletes (Kittler et al., 2021; Morrison et al., 2017). At present, the research concerning RST and its effectiveness in sports is also limited. New research would be needed to understand the real-world implications of improved RST.

Consequently, this research aims to fill this gap, focusing on table tennis players. The objective is to delve into the potential advantages of a mobile-based application concentration grid intervention on RST on table tennis players. The concentration grid mobile application used in this research was developed by Autumn Arcade (2022), after coming across the major downsides of using the pen-paper concentration grid to train athletes, some of which included being able to recognize when a number is marked by the pen/pencil, athletes being sweaty and trying to fill the paper sheet eventually rendering the paper unusable and the 10x10 grid benign too cumbersome to fill during training (Greenlees et al., 2006). Recognizing the pivotal role of RST and the promise of mobile-based application interventions, this study seeks to pioneer insights into enhancing RST among elite table tennis players, aspiring to influence the trajectory of sports psychology and athlete training (Bhabhor et al., 2013; Wilson et al., 2006; Fox et al., 2000).

This study hypothesizes that the use of the mobile-based application intervention, Concentration Grid, will significantly increase Reactive Stress Tolerance (RST) in elite table tennis players.

2. METHOD

2.1 Participants and Design

After obtaining ethical clearance, eight national-level table tennis players (4 males and 4 females) aged 18-20 years (M=19.12; SD=0.85) participated in the study. These participants, training at an elite level for the past 5 years, competing nationally for at least 12 months, and ranked inside the top 20, were selected using a convenience sampling method due to challenges in accessing this specific athlete cohort (Brown et al., 2017; Manna, 2014). Convenience sampling is a non-probability sampling technique where participants are selected based on their availability and willingness to take part in the research, as well as their proximity to the researcher. It was used because the accessibility of participants was not possible. This method is considered convenient for the researcher but may not always represent the larger population accurately (Brown et al. 2017; Manna 2014).

A pilot intervention design was employed to investigate the impact of the Autumn Arcade (2022) mobile-based application on a concentration grid, specifically the concentration grid component, on the reactive stress tolerance of table tennis players. Participants were randomly assigned blindly to either an experimental group or a control group, ensuring an equal gender distribution with 2 males and 2 females in each group.

2.2 Procedure

After a thorough briefing, participants provided informed consent. Baseline measurements of reactive stress tolerance were taken using the determination test (S1). Participants then went through the intervention which consisted of completing the concentration grid 5 times one after the other, every day in a single session. Every 5 days, the difficulty increased by either increasing the time or the size of the grid. Performance metrics for the experimental group, including scores, time taken, and errors, were recorded daily during the intervention. Data from the concentration grid was not analyzed for this research. Post-intervention, all participants were re-tested using the determination test (S1).

2.3 Reactive Stress Tolerance

The adaptive short form (S1) from the Vienna Test System's determination test was used (Rentz et al., 2021; Neuwirth & Benesch, 2012). The Determination Test (DT) is a test is a valid measure of reactive stress tolerance and the associated ability to react (Ong, 2017). The respondent is presented with color stimuli (red, blue, yellow, green), acoustic signals, and left/right foot stimuli. He/she reacts by pressing the appropriate buttons on the response panels (Schuhfried, 1980). This test, significant in measuring reactive stress tolerance, evaluates athletes' overall Reactive Stress Tolerance, Missed Reactions, Total Reactions, and Median Reaction Time. The overall reactive stress tolerance is a proprietary formula from Schuhfried (1980) which includes the respondent's total amount of reactions, missed reactions, and their median reaction time. These subfactors help explain how the athlete would respond to a stressful situation (Ong, 2017).

2.4 Intervention

For 25 days, the experimental group engaged with the Autumn Arcade (2022) mobile application in a controlled, distraction-free lab environment (Turner et al., 1996). Athletes completed the concentration grid task five times every session, which took approximately 10 minutes in total (Monsma et al., 2017; Gutner et al., 2016; Moran, 2004). The concentration grid, as the name suggests, is a grid of randomized numbers with varying - 5x5, 6x6, and 7x7. To complete the athlete would need to start by selecting the first number which is 0, and then continue in ascending order till all the numbers have been selected. Making any mistake will end the test abruptly. Once finished, the score is shown on the screen which is the time taken to finish the test. The difficulty can be changed by altering the size as mentioned above or restricting the time in which the athlete needs to complete the test - 30, 60, 90, and 120 seconds. Difficulty levels increased every five days. As seen in multiple studies, increasing the difficulty multiple times through the duration of an intervention can significantly increase adherence and develop interest in performing well (Röthlin & Birrer, 2020; Curry et al., 2010; Greenless et al., 2006). According to research, computer and application-based interventions have been shown to be very efficient and useful in training athletes (Kittler et al., 2021; Mead & Drasgow, 1993). The control group continued their standard training regimen.

Time Table for Intervention

Week 1: 5x5 Grid, 60 seconds.

Week 2: 5x5 Grid, 30 seconds.

Week 3: 6x6 Grid, 90 seconds.

Week 4: 6x6 Grid, 60 seconds.

Week 5: 7x7 Grid, 120 seconds.

2.5 Data Analysis

Data was analyzed using IBM SPSS Statistics (Version 29). Descriptive statistics were generated, and after confirming normal distribution, parametric tests were applied. A Mixed MANOVA was conducted to assess changes for all dependent variables, and to assess RST between and within groups. Supplementary dependent t-tests for both the control and experimental groups were assessed to for changes from pre-to-post scores for each group and RST variable. For each T-test, Cohen's d, a measure of effect size was calculated (Cohen, 1992).

3. RESULTS

3.1. Descriptives

Descriptive statistics as observed in Table 1 were computed for variables measuring reactive stress tolerance, missed Descriptive reaction, and median reaction time before and after the intervention.

TABLE 1
DESCRIPTIVE STATISTICS OF GROUPS, TIMES, AND VARIABLES
Descriptives

Variables	Control Group					Experimental Group			
	Pre		Post			Pre		Post	
	M	SD	M	SD		M	SD	M	SD
Reactive Stress Tolerace	207.25	40.9	205.5	43.73		205	40	249.5	26.6
No. of Missed Reactions	26.5	17.55	28.25	17.68		20.25	9.74	17.5	8.1
No. of Total Reactions	252.5	55.52	211.5	12.79		256.5	25.21	274.25	28.99
Median Reaction Time	0.81	0.05	0.88	0.01		0.84	0.11	0.75	0.08

The normality of data distributions was examined using the Shapiro-Wilk tests for each variable before and after the intervention. The Shapiro-Wilk test indicated that the data for all variables before and after the intervention did not significantly deviate from a normal distribution (all $p > .05$). These findings suggest that the data can be considered approximately normally distributed for subsequent analyses.

3.2. Pre-to-post comparison

A dependent samples t-test was conducted to assess the significance of differences between the pre and post-intervention measures for reactive stress tolerance, number of missed reactions, number of reactions, and median reaction time.

For the control group as observed in Table 2, the dependent samples t-tests revealed that the differences between pre and post-intervention measures were not statistically significant for all factors, as the p-values values of all variables are higher than .05 i.e. $p>.05$.

Effect sizes were calculated for dependent sample comparisons of pre and post-intervention measures. Cohen's d was used as a standardized measure of effect size. Cohen's d suggested a substantial effect on reactive stress tolerance ($t(3) = 1.09$, $p = 0.35$, $d = 0.55$), a moderate effect on the number of missed reactions ($t(3) = -2.04$, $p = 1.71$, $d = -1.03$), a large effect on the total number of reactions ($t(3) = 1.66$, $p = 0.19$, $d = 0.83$), and a small effect on the median reaction time ($t(3) = 0.61$, $p = 0.58$, $d = 0.31$).

TABLE 2
PRE-TO-POST OF CONTROL AND EXPERIMENTAL GROUP

Variables	Control Group					Experimental Group			
	Paired Differences			Significance		Paired Differences			Significance
	M	SD	t	p		M	SD	t	p
Pre Reactive Stress Tolerance - Post Reactive Stress Tolerance	1.75	3.20	1.09	0.35		-44.50	21.49	-4.14	0.03
Pre Number of missed reactions - Post Number of missed reactions	-1.75	1.71	-2.04	0.13		2.75	8.54	0.64	0.57
Pre Number of Total Reactions - Post Number of Total Reactions	41.00	49.30	1.66	0.19		-17.75	30.09	-1.18	0.32
Pre Median Reaction Time - Post Median Reaction Time	0.01	0.49	0.61	0.58		0.09	0.67	2.82	0.07

For the experimental group as observed in Table 2, The dependent samples t-tests indicated that there were statistically significant differences in reactive stress tolerance and median reaction time with $p<.05$ between pre and post-intervention measures, which indicated scores for reactive stress tolerance significantly increased and scores for median reaction time significantly decreased after the intervention.

However, no statistically significant differences were observed for the number of missed reactions and the total number of reactions, with p>.05.

Effect sizes were calculated for dependent sample comparisons of pre and post-intervention measures. Cohen's d was used as a standardized measure of effect size. Cohen’s d suggested a large effect for reactive stress tolerance (t (3) = -4.14, p = .03, d = -2.07) and the total number of reactions (t (3) = -1.18, p = 0.32, d = 0.32), it also signified moderate and small effects for the number of missed reactions (t (3) = 0.64, p = 0.57, d = -0.59) and median reaction time (t (3) = 2.82, p = .07, d = 1.41) respectively.

These effect sizes provide insights into the magnitude of changes between pre and post-intervention measures, thereby aiding in the interpretation of the practical significance of the observed differences.

3.3. Mixed MANOVA

3.3.1 Multivariate tests

Multivariate tests as were conducted to examine the effects of the intervention on the dependent variables which are reactive stress tolerance, the total number of missed reactions, the total number of reactions, and median reaction time. Wilks' Lambda was used as a multivariate measure of effect.

These multivariate tests assessed the impact of the intervention on the dependent variables which are reactive stress tolerance, total number of missed reactions, total number of reactions, and median reaction time. The results indicate a significant overall effect of the interaction results here, while the "group" (p = .283, p>.05) and "Time" (p = .157, p>.05) factors alone did not yield significant effects. However, the interaction between "Time" and "group" (p = .045, p<.05) showed a statistically significant combined effect on the variables (reactive stress tolerance, total number of missed reactions, total number of reactions, and median reaction time).

The results revealed that the overall impact of the intervention was significant, as indicated by the interaction effects. Although the factors of "group" and "Time" individually did not show significant effects, the combined interaction between these two factors demonstrated a statistically significant influence on all measured variables. This finding underscores the importance of considering both the timing and group dynamics in assessing the effectiveness of the intervention on these specific aspects of performance.

3.3.2 Univariate Tests

Univariate tests were employed to evaluate the impact of intervention factors, namely “Time” and “Group”, on key dependent variables such as reactive stress tolerance, number of missed reactions, the total number of reactions, and median reaction time.

"Time" Effect on Reactive Stress Tolerance: The analysis revealed a significant effect of the "Time" factor on reactive stress tolerance, with an F-value of 15.491. This significance (p = .008) and a high partial eta squared value (.721) indicate that about 72.1% of the variance in reactive stress tolerance can be attributed to the passage of time, signifying its critical role in influencing this variable.

"Time" Effect on Missed Reactions and Total Reactions: For the number of missed reactions and total number of reactions, the "Time" factor did not demonstrate a significant effect, with p-values of .826

and .451, respectively. This suggests that over time, these aspects of performance did not undergo statistically significant changes.

"Time" Effect on Median Reaction Time: The "Time" factor also significantly affected median reaction time, as indicated by an F-value of 6.96 and a partial eta squared value of .537. This implies that approximately 53.7% of the variation in median reaction time was due to the factor of time, marking it as a significant determinant in this context.

Interaction Effect of "Time" and "Group": The interaction between "Time" and "group" had a significant impact on reactive stress tolerance, with an F-value of 18.131 and a partial eta squared value of .751. This significant interaction ($p = .005$) highlights that about 75.1% of the variance in reactive stress tolerance can be explained by the combined effects of time and group factors.

Interaction Effect on Other Variables: However, for the number of missed reactions, the total number of reactions, and median reaction time, the interaction between "Time" and "Group" did not show a significant effect (p-values of .341, .088, and .104, respectively). This indicates that the combined influence of these factors did not significantly alter these specific performance metrics.

These results collectively underscore the nuanced and variable impact of time and group factors on different aspects of performance, with certain variables being more sensitive to these factors than others. This has implications for understanding the effectiveness of the intervention and guiding future research and practice in this area.

3.3.3 Tests of Between-Subjects Effects

This analysis as seen in Table 3, was used to examine the effects of different factors on the transformed variable "Average." This variable represents the average values of the measured variables across subjects. The Bonferroni adjustment for multiple comparisons was applied to control the familywise error rate.

The results of the study for the "Intercept" effect demonstrate a highly significant impact on all measured dependent variables: "Reactive stress tolerance," “number of missed reactions,” “total number of reactions,” and “median reaction time,” with p-values less than .001 in most cases. The partial eta squared values being .978, .793, .989, and .994 respectively indicate that a major portion of the variance in these variables can be attributed to the intercept effect. This suggests that the baseline levels of these variables, before considering other factors like the "Group" effect, are already exerting a strong influence.

In contrast, the "Group" effect did not show a significant impact on these variables, with p-values of .462, .412, .173, and .789, respectively. This implies that the differences between the groups in the study did not significantly alter the outcomes for "Relative stress tolerance," “number of missed reactions,” “total number of reactions,” and “median reaction time.” The error terms calculated for the between-subjects effects and their corresponding degrees of freedom and mean square values provide further statistical detail, but the lack of significant group differences suggests that the intervention's impact might not differ significantly between groups.

These findings highlight the importance of baseline characteristics in influencing these psychological and performance measures and suggest that the group-based intervention may not have had the anticipated differentiated impact across the study's cohorts.

TABLE 3
TESTS OF WITHIN-SUBJECT CONTRASTS

Source	Measure	F	Sig	Partial ETA Squared
Time	Reactivestresstolerance	15.49	0.01	0.72
	missedreaction	0.05	0.83	0.10
	noofreaction	0.65	0.45	0.10
	medianreactiontime	6.96	0.04	0.54
Time*Group	Reactivestresstolerance	18.13	0.01	0.75
	missedreaction	1.07	0.34	0.15
	noofreaction	4.14	0.09	0.41
	medianreactiontime	3.68	0.10	0.38

4. DISCUSSION

The present study aimed to explore the potential benefits of mobile-based application interventions, specifically the Autumn Arcade (2022) mobile application, on the reactive stress tolerance (RST) of table tennis players (Kittler et al., 2021; Mead & Drasgow, 1993). The findings provide a nuanced understanding of the role of technology in enhancing athletes' mental resilience, which is an individual's adaptive functioning in a stressful situation, particularly in the context of individual sports (Baumeister, 1984).

Consistent with prior research, stress remains a pivotal factor in athletic performance, with its interpretation and management playing a decisive role in outcomes (Baumeister, 1984; Anshel et al., 2001). The current study's findings underscore the significance of individualized stress perceptions, reaffirming that athletes' reactions to stressors can vary widely based on personal evaluations and coping mechanisms. In a study, it is mentioned that individual sports athletes often experience heightened stress due to the absence of team support, placing greater emphasis on their personal coping mechanisms to manage the solitary pressures of competition. (Highlen & Bennett, 1983).

The mobile-application-based concentration grid by Autumn Arcade (2022) was developed to improve the efficiency and efficacy of the generally used pen-paper concentration grid test (Greenlees et al., 2006). The introduction of the Autumn Arcade (2022) mobile application as an intervention revealed significant improvements in RST for the experimental group. This aligns with Schack et al. (2014), who emphasized the potential of mobile application-driven strategies in sports psychology. The observed enhancements in RST among the experimental group post-intervention provide support for the integration of technology in athlete training, especially in sports demanding high levels of concentration like table tennis (Bhabhor et al., 2013).

It is worth noting that while the control group did not exhibit statistically significant changes in their pre and post-intervention measures, the experimental group showed significant improvements in the reactive stress tolerance. This suggests that the mobile-based concentration grid application intervention may have had a direct influence on enhancing certain aspects of RST, a proposition that warrants further exploration. This could also be due to the low sample size in which different athletes improved on different aspects of the determination test S5.

The effect sizes for the experimental group were substantial, indicating a statistical significance, although the practical (real-world) relevance is yet to be shown through future studies. Such findings could be pivotal for sports psychologists and trainers, as they could offer a quantifiable measure of the potential benefits of a mobile-based concentration gird application intervention.

While the study provides valuable insights, it is not without limitations. The sample size was relatively small, and the convenience sampling method, although justified, may introduce selection bias (Brown et al., 2017; Manna, 2014). Future research could benefit from larger, more diverse samples and perhaps a more extended intervention period to assess long-term effects. Future studies could also introduce the mobile-based concentration grid application intervention to different sports or groups of sports like, static and dynamic sports, racket sports, team and individual sports, etc. Additionally, removing or controlling additional effects like training, nutrition, hydration, sleep, recovery, training/living environment and life stressors could be helpful in understanding the total impact of the intervention in improving both RST and it's real-world impact.

The present study contributes to the growing body of literature emphasizing the role of technology in sports psychology. The positive outcomes associated with the Autumn Arcade (2022) mobile application suggest that such interventions can be pivotal in enhancing athletes' mental resilience, potentially influencing the trajectory of sports psychology and athlete training (Bhabhor et al., 2013; Fox et al., 2000). As technology continues to advance, its integration into sports training regimens could be the key to unlocking unprecedented levels of athletic performance and mental well-being.

5. CONCLUSION

The conclusion of this study highlights the effectiveness of the mobile-based concentration gird intervention application by Autumn Arcade (2022) in enhancing reactive stress tolerance (RST) in table tennis players, supporting the growing evidence in sports psychology about the benefits of technology-based interventions. This research aligns with previous studies, underscoring the importance of individual stress perceptions and the role of technology in improving athletes' mental resilience. The significant improvements observed in the experimental group, in contrast to the control group, suggest a direct positive impact of the mobile-based intervention on RST. These findings indicate a promising direction for the integration of technology in athlete training and stress management, although further research with larger and more diverse samples is needed to confirm these results and explore their practical relevance in the real world.

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