The contribution of coping related variables and cardiac vagal activity on the performance of a dart throwing task under pressure

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Abstract

The aims of this study were 1) to assess the predictive role of coping related variables (CRV) on cardiac vagal activity (derived from heart rate variability), and 2) to investigate the influence of CRV (including cardiac vagal activity) on a dart throwing task under low pressure (LP) and high pressure (HP) conditions. Participants (*n* = 51) completed trait CRV questionnaires: Decision Specific Reinvestment Scale, Movement Specific Reinvestment Scale and Trait Emotional Intelligence Questionnaire. They competed in a dart throwing task under LP and HP conditions. Cardiac vagal activity measurements were taken at resting, task and during recovery for 5 minutes. Self-reported ratings of stress were recorded at three time points via a visual analogue scale. Upon completion of the task, self-report measures of motivation, stress appraisal, attention, perceived pressure and dart throwing experience were completed. Results indicated that resting cardiac vagal activity had no predictors. Task cardiac vagal activity was predicted by resting cardiac vagal activity in both pressure conditions with the addition of a trait CRV in HP. Post task cardiac vagal activity was predicted by resting cardiac vagal activity in both conditions with the addition of a trait CRV in HP. Cardiac vagal reactivity (difference from resting to task) was predicted by a trait CRV in HP conditions. Cardiac vagal recovery (difference from task to post task) was predicted by a state CRV only in LP. Dart throwing task performance was predicted by a combination of both CRV and cardiac vagal activity. The current research suggests that coping related variables and cardiac vagal activity influence dart throwing task performance differently dependent on pressure condition.

Keywords: Psychophysiology, cardiac vagal activity, heart rate variability, pressure, self-regulation, dart throwing

1. Introduction

Pressure can lead to differing levels of physiological arousal (Steptoe & Brydon, 2009) which in turn can influence athletic performance (Laborde, Lautenbach, & Allen, 2015), therefore understanding the effects of pressure on psychophysiological processes and performance is crucial. A variable of current interest, is the activity of the parasympathetic nervous system, also refered to as cardiac vagal activity (Shaffer, McCraty & Zerr, 2014). Cardiac vagal activity can be derived from heart rate variabilty (HRV) which is the time interval between heartbeats (Appelhans & Lueken, 2006). Cardiac vagal activity has been considered a measure of adaptation and self-regulation which has been validated through the theoretical work of Thayer, Hansen, Saus-Rose and Johnsen model of Neurovisceral Integration (2009). Cardiac vagal activity has also been combined with other coping related variables such as trait emotional intelligence (Laborde, Brull, Weber, & Anders, 2011), decision reinvestment (Laborde, Furley & Schempp, 2015) and stress appraisals (Laborde et al, 2015). This combination has shown that coping related variables and cardiac vagal activity influence performance under pressure particularly in cognitive tasks (Laborde et al., 2011; Laborde, Raab & Kinrade, 2014; Laborde et al., 2015; Laborde et al., 2015). Combining variables from different facets of psychology to study performance under pressure is crucial for a holistic perspective. Therefore, the aims of this study were 1) to assess the predictive role of CRV (trait emotional intelligence and reinvestment, challenge and threat appraisals) on cardiac vagal activity (derived from heart rate variability), and 2) investigate the influence of the predictive role of CRV and cardiac vagal activity on a dart throwing task under low and high pressure conditions. This is an important research question as coping related variables (CRV) and cardiac vagal activity have seldom been studied together in order to understand contributions to psychomotor performance under pressure.

In order to meet the aim of this study, firstly the function of cardiac vagal activity as an indicator of self-regulation will be contextualised within performance under pressure. Cardiac vagal activity can reflect self-regulation because of the functional network linking the heart to the prefrontal cortex, which is involved in self-regulatory processes such as emotional regulation (Thayer, Ahs, Fredrikson, Sollers & Wager, 2012; Thayer et al, 2009). Two measures of cardiac vagal activity can reflect self-regulation under pressure, tonic and phasic. Tonic cardiac vagal activity is an average measure taken over a period of time (Malik, 1996), this is typically carried out at three stages: resting, task and post task (see Figure 1). Phasic cardiac vagal activity represents the change in cardiac vagal activity from resting to a task, named reactivity, or change from a stressful event to post task, named recovery (Laborde et al 2017; Park, Vasey, Van Bavel & Thayer, 2014) (see Figure 1).

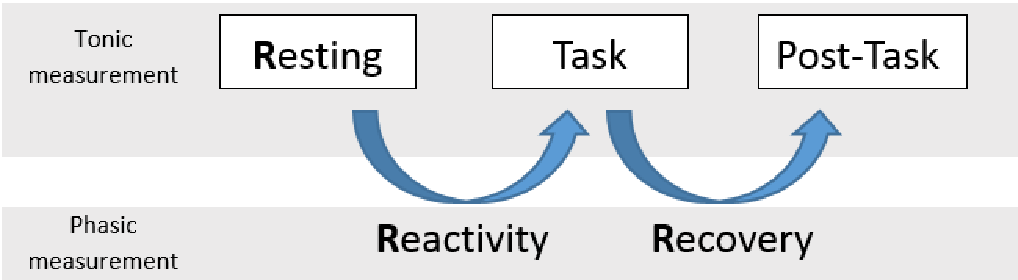

Figure 1: The three R's adapted from Laborde et al 2017

From the predictions of the Neurovisceral Integration Model (Thayer et al, 2009) higher levels of tonic cardiac vagal activity at rest have better stress management and emotional regulation. A larger phasic vagal withdrawal (reduction in cardiac vagal activity) is seen to be adaptive, due to an increased effort to cope within tasks that involve facing a direct stressor which can reflect better self-regulation (Park et al, 2014). In addition, research has assessed the recovery of HRV in stressful tasks in order to understand how quickly the individual can bounce back from a stressful event (Papousek, Nauschnegg, Paechter, Lackner, Goswami, & Schulter, 2010; McEwen, 1998). In such instances, tonic cardiac vagal activity at resting can influence phasic cardiac vagal activity (Park et al, 2014) and as such it can be predicted that tonic cardiac vagal activity at resting will positively influence phasic cardiac vagal activity.

Cardiac vagal activity has shown an association with other CRV and the influence they have on cardiac vagal activity and performance under pressure. There is a growing body of research that personality-trait-like individual differences can affect performance under pressure and coping responses (Laborde & Allen, 2016; Mosley & Laborde, 2015; Laborde et al, 2015; Laborde et al, 2014; Laborde et al, 2011). Recent research has begun to combine personality-trait-like individual differences with cardiac vagal activity in order to examine their effects on performance under pressure (Laborde et al, 2015; Mosley & Laborde, 2015; Laborde et al, 2014). Two particular traits that have been highlighted because of their role during performance under pressure: Firstly, Trait Emotional Intelligence (EI), which represents a constellation of emotional perceptions assessed via questionnaires and rating scales (Petrides Pita & Kokkinaki, 2007). Secondly, reinvestment, which entails two dimensions: movement reinvestment, "the manipulation of conscious, explicit, rule based knowledge, by working memory, to control the mechanics of one's movements during motor output" (Masters and Maxwell 2004, p. 208), and decision reinvestment, which refers to overthinking, through consciously controlling thoughts and/or ruminative thoughts, which is caused by high levels of cognitive effort under pressure that negatively affects performance (Kinrade, Jackson & Ashford, 2010).

Individuals with higher levels of trait EI have been shown to produce superior performance under pressure, through stress buffering effects, in a range of performance settings, such as experimental tasks (learning and decision-making) (Laborde, Dosseville & Scelles, 2010) and sport (Laborde et al, 2015). Furthermore, trait EI is positively linked to levels of cardiac vagal activity under pressure (Laborde et al, 2011). Therefore, it is predicted that trait EI will be positively related to cardiac vagal activity at resting and the task.

Reinvestment, which has two components concerning movement and decision-making can decrease an individual's performance when under pressure (Masters & Maxwell 2004; Kinrade et al, 2010). Higher levels of movement reinvestment have been shown to negatively affect performance (Mullen, Hardy & Tattersall, 2005; Chell, Graydon, Crowley & Child, 2003). Similar to movement reinvestment, decision reinvestment can also cause performance decrement under pressure (e.g. Laborde et al, 2015; Kinrade et al, 2010). From the psychophysiological perspective, higher levels of decision reinvestment caused a greater decrease in cardiac vagal activity during a pressurised tasks (Laborde et al 2015; Laborde et al, 2014). Although in one case cardiac vagal activity at resting predicted working memory score above decision reinvestment (Laborde et al, 2015). Therefore, it is predicted that decision reinvestment will be associated negatively to cardiac vagal activity during the task.

State CRV have also been shown to link to cardiac vagal activity under pressure. It has been shown athletes who view stressful situations as a challenge tend to perform superiorly to those who view the situation as a threat (Moore, Wilson, Vine, Coussens & Freeman, 2013). Laborde et al (2015) found that when performing a concentration grid task, a greater threat appraisal resulted in a larger decrease in cardiac vagal activity from resting to task. Although cardiac vagal activity is not a traditional indicator for challenge and threat, the predictions of the neurovisceral integration model suggest emotion regulation is connected to parasympathetic activity (Thayer & Lane 2000). Therefore, coping mechanisms, through the appraisal process may affect the levels of cardiac vagal activity during a stressful task (Laborde et al 2015). Therefore, within the current study it is predicted that a challenge appraisal will positively affect cardiac vagal activity reactivity.

A secondary aim of this experiment was to understand the influence of CRV (including cardiac vagal activity) on dart throwing task performance under pressure. Current research that has combined coping related variables and cardiac vagal activity has only looked at tasks involving purely cognitive tasks (Laborde et al, 2015; Laborde et al, 2014). To test psychomotor performance under pressure, aiming tasks are commonly used because they offer a simple way to assess performance with a clear point system (Nieuwenhuys & Oudejans 2010; Wilson, Vine & Wood, 2009; Wilson, Wood & Vine, 2009) and in research are often paired with a cognitive element, such as mental arithmetic to increase complexity and stress (Nibbeling, Oudejans & Daanen, 2012; Williams, Vickers & Rodrigues, 2002; Murray & Janelle, 2003). Some of the CRV of interest have been shown to effect psychomotor performance under pressure, namely cardiac vagal activity, challenge appraisals and reinvestment. Cardiac vagal activity promoted faster shooting in a police stimulation (Thompson et al, 2015) and more effective attention strategies in a navigation simulation task (Saus et al, 2012). Challenge appraisal improved golf putting performance (Moore et al 2015) and movement reinvestment caused performance decrements in dart-throwing (Weiss 2011). Therefore, it is predicted that a challenge appraisal, lower levels of movement reinvestment will positively influence dart score. In addition, task cardiac vagal activity and attention towards the task will positively influence psychomotor performance.

There is emerging evidence that coping-related variables including cardiac vagal activity can play a role in performance under pressure (Laborde et al, 2015; Laborde et al, 2015; Laborde et al, 2011). However, current research only examines cognitive tasks thus making it difficult to make comparisons to the sporting domain. Moreover, trait and state CRV have rarely been considered together concerning their influence on psychomotor performance under pressure. Therefore, the aims of this study were 1) to assess the predictive role of CRV (trait emotional intelligence and reinvestment, challenge and threat appraisals) on cardiac vagal activity (derived from heart rate variability), and 2) to investigate the influence of the predictive role of CRV and cardiac vagal activity on a dart throwing task under low and high pressure conditions. Based on previous literature the predictions for the current research are presented in Table 1.

Hypotheses for prediction of cardiac vagal activity by CRV
Tonic cardiac vagal activity at rest will be positively associated to phasic (reactivity) cardiac vagal activity. Trait EI will be positively associated to cardiac vagal activity at rest and during the task. Decision reinvestment would predict negatively cardiac vagal activity during the task. Challenge appraisal will positively affect cardiac vagal activity reactivity.
Hypotheses for prediction of dart throwing task performance
Task cardiac vagal activity and attention directed towards the task will be positively associated to psychomotor performance. Challenge appraisal will positively influence dart score Movement reinvestment will negatively influence dart score.

Table 1: Hypotheses

It is important to note that these predictions branch across both low and high pressure conditions. However, the relationships with the CRV may be more pronounced under high pressure than low pressure given the stronger role of emotion regulation in this case as seen in other studies assessing differences between low and high pressure conditions (Laborde et al, 2015; Geukes, Mesagno, Hanrahan & Kellmann, 2013).

2. Materials and Methods

2.1. Participants

Fifty-one participants (30 male and 21 female; M_{age}=24.9, SD=7.7) took part in the experiment. All participants competed in a variety of sporting disciplines (team sport=36, individual=15) with an average of 11.7 years' experience (SD=8.3). Participants were asked if they had any cardiac disease or if they were taking any medication that could affect the heart, none reported so. The study was approved by the University ethics committee.

2.2. Measures

2.2.1. Personality measures

The Trait Emotional Intelligence Questionnaire (TEIQue) (Petrides, 2009) assesses global trait EI and four main factors: well-being, self-control, emotionality and sociability. It has 153 items which are scored on a seven-point scale from 1 (completely disagree) to 7 (completely agree) (Petrides, 2009) (Original global score α =.89, well-being α =.85, self-control α =.76, emotionality α =.74 and sociability α =.85. Current study; global score α =.81, well-being α =.88, self-control α =.91, emotionality α =.88 and sociability α =.86).

The Movement-Specific Reinvestment Scale (MSRS) (original α = .79, current study α = .81) was used and is a nine item scale which are rated on a five point Likert scale which ranges from 1 strongly agree to 6 strongly agree (Masters and Maxwell 2008).

The Decision-Specific Reinvestment Scale (DSRS) by Kinrade, Jackson, Ashford & Bishop, (2010) was used which consists of 13 item measure (original α = .89, current study α = .81), which is rated on a 5 point Likert scale ranging from 0 not characteristic to 4 very characteristic.

2.2.2. HRV

HRV was measured using the Faros 180° device (Mega Electronics Ltd, Pioneerinkatu, Finland). Two pre-lubricated disposable electrodes (Ambu VLC-00-S/25, Ambu GmbH, Bad Nauheim, Germany) were placed on the body, one just below the right clavicle and one on the left side of the chest below the 12th rib.

2.2.3. Perceived stress intensity

A VAS was used to reflect stress intensity, on which participants placed a cross on a 100mm line on “how stressed they felt as the present moment” which was anchored from “not at all stressed” to “extremely stressed (Lesage, You, Dosseville & Salinas, 2012).

2.2.4. Attention

A VAS was also used to measure the attentional direction of participants. The original suggestion by Tammen (1996) only had one single item to rate from 0 *(attention away from* *task and body)* to 10 *(attention on task and body)*. However, in previous research the suggestion to specify two scales where the attention was directed, either task or self, has been noted (Laborde et al, 2015). Therefore, two separate VAS scales were used in order to differentiate from the task and the self. Participants placed a cross on the line to determine where their attention was focused during the task. The first was anchored by the phrase "towards the task" at the bottom of the line and "away from the task" at the top in order to reflect distraction theory. The second was anchored by the phrases "towards self" at the bottom of the line and "away from self".

2.2.5. Perceived pressure

The pressure/tension subscales were utilised from the intrinsic motivation inventory (Ryan, 1986). Participants rated four items such as "I was anxious while doing the task" on a Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree).

2.2.6. Cognitive appraisal

Challenge and threat appraisals were assessed using the cognitive appraisal ratio (Tomaka, Blascovich, Kelsey & Leitten, 1993). Participants were asked "How demanding did you feel the task was?" and "How able were you to cope with the demands of the task?" and were rated on a 6 point Likert scale rated from 1 (not at all) and 6 (extremely).

2.2.7. Motivation and effort

Participants completed a single item indicating "How motivated were you to perform to your best in this task?" on a 6 point Likert scale from 0 (not at all) to 5 (very much so).

2.2.8. Dart throwing experience

Participants were asked about their previous dart throwing experience on a 4 point Likert scale which ranged from 1 "none at all (I have never thrown a dart)" to 4 "very experienced (I play competitively)", which is in line with previous research (Cumming, Nordin, Horton & Reynolds, 2006).

2.2.9. Dart throwing performance

A Dunlop Sport Tournament size dart board (d= 0.46m) was used with a concentric rings of equal size, the outside ring was scored 1 leading to a 12mm red bulls eye in the centre, which scored 10, a miss scored zero. The dart board was positioned at official competitions distances (2.37m directly in front of the participants with the bulls eye positioned 1.73m above the participants' feet). Participants received the same set of instructions for basic dart throwing technique to standardize performance (see supplementary material). The participants had to gain the best possible reduction from a set total (1234) in 5 minutes.

2.2.9.1. Mental stressor (secondary task)

Participants also had to subtract the dart scores from the set total after each consecutive dart throw and the answers were said out loud. If the answer was correct the participant continued to throw the next dart. However, if a mistake was made in the calculation the participant was notified by the experimenter and the score reverted back to the beginning (1234) and they started again. Furthermore, in the high pressure condition if participants took too long to answer they were prompted to speed up. Mental performance was measured by the number of mistakes made over the 5 minute time period.

2.3. Procedures

2.3.1. Pre-performance procedures

Participants were recruited through advertisements and emails aimed at actively competing athletes. Once recruited, participants read the information sheet, provided written informed consent and completed the battery of online questionnaires (which include the TEIQue, MSRS, DSRS). The participant was then invited to the first lab session. Participants were asked to refrain from heavy exercise 24 hours before attending the lab session and to avoid consuming caffeine and food two hours before the session, as this can affect HRV (Quintana, Guastella, McGregor, Hickie & Kemp, 2013). Participants attended two lab sessions; one in low pressure and one in high pressure, which were counterbalanced. Upon arrival to the practical pressure test participants were prompted to re-read the participant information sheet, after which, individuals had the Faros 180° device attached and activated. Once the participant was comfortable a resting HRV measurement was taken for five minutes. The resting measure was completed in a standing position in order to replicate the experimental task, directly after the first stress VAS was completed.

2.3.2. Performance

Before commencing the dart throwing task, participants were given basic instructions on how to throw a dart (see supplementary material) and allowed 24 practice shots in order to familiarize themselves with the task. Participants were informed of the competitive rules and the number subtraction task. They then listened to a pre-recorded high or low pressure script which contained pressure manipulations such as being placed on a leader board and gaining monetary incentives for successful performance. Participants commenced the five minute task under low or high pressure conditions. Specifically, within the high pressure condition additional pressure was added through the participants being filmed, social comparison (scores compared to a professional dart player), and a second experimenter was present who actively made notes on "behavioural reactions" throughout the task. Experimenter behaviour was kept consistent across the testing. Upon task completion participants completed the second stress VAS and a recovery HRV period was completed and recorded. Finally, the final set of subjective measures were taken including the final stress VAS, pressure VAS, cognitive appraisal ratio, pressure/tension scale and motivation scale. The participants were thanked, debriefed and notified about their second visit to the lab, which was completed within a week of the first task in accordance with similar literature (Laborde et al, 2015).

2.4. Data preparation

Personality scores were coded accordingly and the challenge and threat ratio was determined by dividing demands from resources (Moore et al, 2013). Secondly, heart rate variability data were processed for artefacts and indicators of cardiac vagal activity were extracted. In this study high frequency absolute power was used, which is deemed a reliable measure for cardiac vagal activity (Laborde et al 2017). Data were then checked for normality visually via histograms and boxplots. If any outliers existed, they were winzorized for (mean + 2x standard deviations). For HRV variables, which were not normally distributed, a log10 transform was applied. After these processes, the data were checked again and was considered to be normally distributed.

2.5. Data analysis

To check the dart throwing task was successful in inducing pressure a repeated-measures MANOVA was used with condition (low pressure vs. high pressure) set as the within subject factor and the subjective stress variables (Stress VAS after the task, pressure and tension subscales) as dependent variables. A pressure task would be evident by higher ratings of stress after the task, higher ratings of pressure and lower ratings of relaxation in high pressure when compared to low pressure. To explore the contribution of coping-related variables to cardiac vagal activity (resting, task, post task, reactivity and recovery) bivariate correlations were run followed by stepwise linear regression analyses. Stepwise linear regression was further used to explore the contribution of coping related variables and cardiac vagal activity on dart throwing performance under pressure.

2.6. Preliminary checks

In order to ensure all participants had comparable levels of dart throwing experience a one item measure on a 4 point Likert scale which ranged from 1 “none at all (I have never thrown a dart)” to 4 “very experienced (I play competitively)” was used. Participants all reported little or no dart throwing experience (*M*=2.05, *SD*=0.46). In addition to check if participants were motivated in the tasks a single item measure was used that asked “How motivated were you to perform to your best in this task?" on a 6 point Likert scale from 0 (not at all) to 5 (very much so). The participants appeared to be motivated in both the low pressure condition (M=4.11, SD=0.79) and the high pressure condition (M=4.15, SD=0.94). A paired sample t-test confirmed there was no difference between motivation in both conditions $t(50)=.405$, $p=.687$, $d = 0.05$.

3. Results

Descriptive data are shown in Table 2, correlation matrixes are displayed Tables 3 and 5.

3.1. Descriptive statistics

	M	SD		
Age	24.96	7.75		
Trait Variables				
DSRS	28.19	9.18		
MSRS	26.35	9.09		
Trait EI - Well-Being	5.53	0.69		
Trait EI - Self-Control	4.45	0.80		
Trait EI - Emotionality	5.05	0.75		
Trait EI - Sociability	4.85	0.64		
Trait EI - Global Score	4.92	0.55		
Performance Variables	*High Pressure*		*Low Pressure*	
	M	SD	M	SD
Remaining Dart Score	1136.39	75.56	1124.33	67.48
Math Errors	4.00	2.32	2.92	2.31
Attention Towards Task	14.23	17.27	13.49	14.01
Attention Towards Self	44.65	33.30	42.98	33.03
Perceived Demands	4.24	1.39	3.61	1.27
Perceived Resources	3.59	1.27	3.76	1.12
Demand/Resource Ratio	-0.65	2.11	0.16	1.82
Resting CVA	2.41	0.39	2.45	0.43
Task CVA	2.54	0.33	2.56	0.33
Post task CVA	2.52	0.55	2.57	0.46
Reactivity CVA	.12	0.43	-.009	0.38
Recovery CVA	-.01	0.46	.009	0.38
Perceived Stress Post Task	50.92	27.64	42.31	21.59
Perceived Pressure Post Task	5.31	1.50	4.73	1.60
Perceived Relaxation Post Task	2.76	1.74	3.65	1.57
Motivation to Compete	4.16	0.95	4.12	0.79

Note: DSRS = Decision reinvestment total score; MSRS = Movement reinvestment total score; Trait EI = Trait Emotional Intelligence; CVA = Cardiac Vagal Reactivity

Table 2 - Descriptive Statistics

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	18
1. DSRS	-															
2. MSRS	.77**	-														
3. Trait EI - Well-Being	-.35*	-.29*	-													
4. Trait EI - Self-Control	-.23	-.27	.58**	-												
5. Trait EI - Emotionality	-.29*	-.20	.62**	.54**	-											
6. Trait EI - Sociability	-.17	-.23	.38**	.20	.44**	-										
7. Trait EI - Global Score	-.36**	-.35*	.83**	.76**	.85**	.61**	-									
8. Attention Towards Task	.01	.09	.00	-.17	-.06	-.28*	-.17	-								
9. Attention Towards Self	.11	.17	-.20	-.37**	-.12	-.00	-.26	-.08	-							
10. Demand/Resource Ratio	-.06	-.00	-.06	.12	.00	-.00	.01	-.06	-.15	-						
11. Resting CVA	-.14	-.04	.15	-.11	.07	.04	.07	.11	.17	-.08	-					
12. Task CVA	.22	.14	-.07	-.21	-.10	.02	-.11	.21	.25	-.13	.55**	-				
13. Post task CVA	.01	.07	.05	-.10	.09	-.05	.02	.16	.29*	-.00	.69**	.56**	-			
14. Reactivity CVA	.22	.24	-.10	.04	.01	.09	.02	-.04	.20	-.10	.27	.73**	.22	-		
15. Recovery CVA	-.09	.02	-.36	-.44*	-.02	-.07	-.26	.05	.50**	-.07	.00	.34	.76**	.45	-	
16. Math Errors	-.18	-.20	.00	-.02	-.23	-.18	-.12	.25	-.00	-.10	-.20	-.16	-.18	-.09	.16	-
17. Dart Score	-.12	-.15	.08	.02	.03	-.06	.02	.26	-.24	-.16	-.17	-.13	-.14	-.20	.17	.64**

*$p < .05$; ***$p < .01$

Note: DSRS = Decision reinvestment total score; MSRS = Movement reinvestment total score; Trait EI = Trait Emotional Intelligence; CVA = Cardiac Vagal Reactivity

Table 3: Correlation Matrix for all Variables (Low Pressure Condition)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. DSRS	-															
2. MSRS	.77**	-														
3. Trait EI - Well-Being	-.35*	-.29*	-													
4. Trait EI - Self-Control	-.23	-.2	.58**	-												
5. Trait EI - Emotionality	-.29*	-.20	.62**	.54**	-											
6. Trait EI - Sociability	-.17	-.23	.38**	.20	.44**	-										
7. Trait EI - Global Score	-.36**	-.35*	.83**	.76**	.85**	.61**	-									
8. Attention Towards Task	.31*	.39**	-.17	-.18	-.11	-.09	-.20	-								
9. Attention Towards Self	.03	.05	-.23	-.34*	-.16	-.07	-.27*	-.01	-							
10. Demand/Resource Ratio	-.14	-.13	-.13	-.07	-.25	-.24	-.21	-.09	.05	-						
11. Resting CVA	-.05	.01	.07	-.09	.10	.12	.08	.25	.03	-.20	-					
12. Task CVA	-.02	-.059	.02	.06	.09	.11	.11	.01	.01	.08	.28*	-				
13. Post task CVA	.22	.22	-.01	-.09	.03	-.02	-.01	.27*	.23	-.23	.60**	.32*	-			
14. Reactivity CVA	-.34	-.39*	.11	.29	.17	.32	.30	-.20	-.31	-.13	-.03	.75**	-.13	-		
15. Recovery CVA	.08	.02	-.00	-.05	-.07	-.30	-.12	.29	.09	.02	.10	.56**	.90**	-.05	-	
16. Math Errors	.00	.05	-.09	.01	-.20	-.05	-.11	.34*	.13	-.02	-.01	-.01	-.11	.13	.28	-
17. Dart Score	-.03	-.02	.10	.15	.21	.03	.16	.26	-.03	-.15	-.04	-.07	-.01	.30	.35	.61**

*$p < .05$; **$p < .01$

Note: DSRS = Decision reinvestment total score; MSRS = Movement reinvestment total score; Trait EI = Trait Emotional Intelligence; CVA = Cardiac Vagal Reactivity

Table 5: Correlation Matrix for all Variables (High Pressure Condition)

3.2. Pressure manipulation checks

The MANOVA showed a significant main effect for condition $F(3, 48) = 5.05$, $p = .004$, $\eta^2 = .14$. Follow up ANOVA's showed a main effect for stress rating after the task with a significant increase in stress following high pressure when compared to low pressure conditions $F(3,48) = 8.68$, $p = .005$, $\eta^2 = .14$, this was also found for pressure ratings $F(3,48) = 4.63$, $p = .036$, $\eta^2 = .08$. A main effect for feelings of relaxation was also found with a significant decrease in relaxation when competing in high pressure when compared to low pressure $F(3,48) = 11.59$, $p < .001$, $\eta^2 = .18$. Results indicate that the pressure manipulations were successful in creating low and high pressure conditions.

3.3. The predictive ability of coping-related variables to cardiac vagal activity in low pressure

Correlations between all variables are reported in Table 3. As study variables were intercorrelated a series of stepwise regressions were performed to identify salient predictors (Table 4). Each regression specifies the predictor variables that were entered at each point. For resting cardiac vagal activity all trait variable were entered and no predictors were found. For task cardiac vagal activity all trait, state and resting cardiac vagal activity were entered at this stage. The first factor extracted was the level of cardiac vagal activity at rest (adjusted $R^2 = .29$, $p < .001$). The second factor extracted was DSRS (adjusted $R^2 = .08$, $p < .001$). The two factors together predicted 37% of the variance in cardiac vagal activity at task. For post task all trait, state and resting and task cardiac vagal activity variables were entered at this stage. The first factor extracted was cardiac vagal activity at rest (adjusted $R^2 = .46$, $p < .001$). The second factor extracted was the cardiac vagal activity at task (adjusted $R^2 = .04$, $p < .001$). Taken together the two factors combined explained 50% of the total residual variance stage. For cardiac vagal reactivity trait and state variables were entered at this stage. Other cardiac vagal activity variables were excluded at this stage as reactivity is derived from the tonic cardiac vagal activity variables, there were no predictors found. For cardiac vagal recovery trait and state variables were entered at this stage and other cardiac vagal activity variables were excluded at this stage as reactivity is derived from the tonic cardiac vagal activity variables. The first (and only) predictor extracted was attention towards the self (adjusted $R^2 = .22$, $p = .006$).

Model	**Unstandardized coefficients**		**Standardized coefficients**	***t***
	B	Std Error	β	
Task CVA				
1 Resting CVA	.42	.09	.55	4.64**
2 Resting CVA	.46	.08	.59	5.27**
DSRS	.01	.00	.30	2.70**
Post task CVA				
1 Resting CVA	.74	.11	.69	6.69**
2 Resting CVA	.59	.12	.54	4.57**
Task CVA	.37	.16	.26	2.20**
Recovery CVA				
1 Attention to Self	.07	.02	.71	3.43**
Math error				
1 Attention away from task	.07	.02	.71	3.43**
Dart Score				
1 Reactivity CVA	-85.70	23.94	-.73	-3.58**
2 Reactivity CVA	-105.65	20.61	-.90	-5.12**
Trait EI (wellbeing)	-31.36	11.78	-.47	-2.66*
3 Reactivity CVA	-102.96	16.73	-.88	-6.15**
Trait EI (wellbeing)	-26.93	9.70	-.40	-2.77*
Attention away from task	.68	.27	.33	2.498*

***$p < .05$; **$p < .01$**
Note: CVA = Cardiac Vagal Activity, DSRS = Decision reinvestment score, Trait EI = Trait Emotional Intelligence
If regressions had no predictors they were excluded from the table.

Table 4 - Multiple (stepwise) Regressions for Cardiac vagal activity in Low Pressure

3.4. The predictive ability of coping-related variables to cardiac vagal activity in high pressure

Correlations between all variables are reported in Table 5. As study variables were intercorrelated a series of stepwise regressions were performed to identify salient predictors (Table 6). Each regression specifies the predictor variables that were entered at each point. For resting cardiac vagal activity all trait variables were entered and no predictors were found. For task cardiac vagal activity all trait, state and resting cardiac vagal activity variables were entered at this stage. The first and only factor extracted was the level of cardiac vagal activity at rest (adjusted $R^2 = .06$, $p = .044$). For post task cardiac vagal activity trait, state and resting and task cardiac vagal activity variables were entered. The first factor extracted was resting cardiac vagal activity (adjusted $R^2 = .35$, $p < .001$). The second factor extracted was decision reinvestment (adjusted $R^2 = .05$, $p < .001$). Taken together the two factors combined explained 40% of the total residual variance in post task cardiac vagal activity. For cardiac vagal reactivity trait, state variables were entered at this stage, other cardiac vagal activity variables were excluded at this stage at reactivity is derived from the tonic cardiac vagal activity variables. For cardiac vagal reactivity the first (and only) factor extracted was movement reinvestment (adjusted $R^2 = .11$, $p = .044$). For recovery no predictors were found.

Model	**Unstandardized coefficients**		**Standardized coefficients**	***t***
	B	Std Error	β	
Task CVA				
1 Resting CVA	.24	.11	.28	2.06*
Post task CVA				
1 Resting CVA	.85	.16	.60	5.30**
2 Resting CVA	.88	.15	.61	5.68**
DSRS	.01	.00	.25	2.36*
Reactivity CVA				
1 MSRS	-.01	.00	-.39	-2.11*
Math error				
1 Attention away from task	.07	.02	.69	2.71*
2 Attention away from task	.08	.02	.76	3.78**
Reactivity CVA	3.2	1.34	.49	2.45*
Dart Score				
1 Reactivity CVA	175.27	54.24	.75	3.23*

***p* < .05; ***p* < .01**

Note: CVA = Cardiac Vagal activity, DSRS = Decision reinvestment score, MSRS = Movement reinvestment score

If regressions had no predictors they were excluded from the table.

Table 6 - Multiple (stepwise) Regressions for Cardiac vagal activity in High Pressure

3.5. The predictive ability of coping-related variables and cardiac vagal activity on dart throwing performance

For performance prediction all trait, state and cardiac vagal activity variables were entered at this stage, regressions can be found in tables 6 and 4. The first regression performed for high pressure was for math error. The first factor extracted was attention to the task (adjusted R^2 = .41, p = .026). The second factor extracted was cardiac vagal reactivity (adjusted R^2 = .23, p = .012). Taken together the predictors accounted for 64% of the variance in math error in the high pressure condition. The second regression performed for high pressure was for dart score. The first (and only) factor extracted was cardiac vagal reactivity (adjusted R^2 = .51, p = .012).

The first regression performed for low pressure was for math error. The first (and only) predictor extracted was attention towards the task (adjusted R^2 = .47, p = .006). The second regression performed for low pressure was for dart score. The first predictor extracted was cardiac vagal activity cardiac vagal reactivity (adjusted R^2 = .49, p = .004). The second predictor extracted was Trait EI (wellbeing) (adjusted R^2 = .18, $p < .001$). The third and final predictor extracted was attention towards the task (adjusted R^2 = .11, $p < .001$). When taken together the three predictors accounted for 78% of the variance in dart score.

4. Discussion

The first aim of this experiment was to assess the predictive role of CRV on cardiac vagal activity (derived from heart rate variability). The second aim was to investigate the influence of CRV (including cardiac vagal activity) on dart throwing task performance under low and high pressure conditions. Firstly, the predictors of cardiac vagal activity will be discussed and secondly the predictors of dart throwing performance.

4.1. Resting Cardiac Vagal Activity

The hypothesis that resting cardiac vagal activity would be positively associated with trait emotional intelligence was not supported. In both high pressure and low pressure conditions trait EI global score and factors did not emerge as predictors for resting cardiac vagal activity. Based on previous research it was postulated that resting would be predicted by trait EI, in particular the subscale of wellbeing as this was found in previous research (Laborde et al, 2015). However, in other previous research there was no association found with trait emotional intelligence and resting cardiac vagal activity (Laborde et al, 2011). It may be that further investigation is needed into this relationship, with longitudinal measures to understand how resting cardiac vagal activity is associated to stable trait predictors.

4.2. Task Cardiac Vagal Activity

The hypothesis that trait measures and resting cardiac vagal activity would predict task cardiac vagal activity was partially supported. In the high and low pressure conditions resting cardiac vagal activity was the main predictor of levels of cardiac vagal activity during the task. As suggested by the neurovisceral integration model, higher levels of cardiac vagal activity at rest is associated with positive outcomes in relation to emotions, executive functioning and health (Thayer et al, 2009). Cardiac vagal activity reflects effectiveness of self-regulation of the organism (Thayer et al, 2009; Porges, 2007) and during stress those with high levels of resting cardiac vagal activity display more effective behavioral responses during a task (Hansen, Johnsen & Thayer, 2003) and display adaptive emotional responding (Ruiz-Padial, Sollers, Vila & Thayer, 2003; Thayer et al, 2009). This suggests that higher levels of cardiac vagal activity at rest led to higher levels of cardiac vagal activity available during the task which can promote the aforementioned benefits for regulation and performance. This is also linked to activation of defensive systems when faced with stress

(Thayer et al, 1996), whereby vagal withdrawal serves a protective function against environmental demand and higher resting levels are seen to be adaptive in this process (Beauchaine et al., 2001, 2007; El-Sheikh et al., 2011). Conversely, lower resting cardiac vagal activity is linked to a lack of prefrontal control of subcortical activity, this activity is involved in the control of homeostasis, sensory processing and movement (Thayer et al, 2009). Subsequently this can result in poor functioning of self-regulatory systems (Thayer and Lane, 2000; Thayer et al, 2009).

In the low pressure condition there was a second predictor of decision reinvestment, which suggested that the higher levels of decision reinvestment resulted in higher levels of cardiac vagal activity during the task. This is the contrary in research as findings suggest that higher decision reinvestment leads to reduced cardiac vagal activity during a task under stress (Laborde et al, 2015), which could be linked to the role of decision rumination (Kinrade et al, 2010). However, one has to consider that this finding was only present within the low pressure condition which could be because previous studies have found that the effects of reinvestment are only present within high pressure conditions (Jackson, Ashford & Norsworthy, 2006). As this finding was only found in the low pressure condition, this may reflect the interactionist principle of trait activation where individual differences will have a different impact across different pressure situations (Geukes et al, 2013). Therefore it may be that because the low pressure condition was less demanding that the effects of decision reinvestment went against the predictions of previous research (Laborde et al, 2015: Laborde et al, 2014).

4.3. Post Task Cardiac Vagal Activity

The hypothesis that tonic cardiac vagal activity would positively influence cardiac vagal activity during recovery was supported. Resting cardiac vagal activity predicted for higher levels of cardiac vagal activity during post task in both low and high pressure conditions. In addition to resting cardiac vagal activity, the low pressure condition was also predicted by task cardiac vagal activity. Recovery is a key indicator of the adaptability of the organism as it demonstrates the ability to face a stressful event and then return efficiently to resting level (Stanley, Peake & Buchheit, 2013). In contrast, lower levels of cardiac vagal activity post task reflects the result of poor self-regulation as the individual is not able to recover from the stressful event (Berna, Ott & Nandrino, 2014). Furthermore, if individuals experience stressors and poor coping over time, this may eventually facilitate physical wear of the defensive systems impairing recovery (Park et al 2014). These findings suggest higher levels of cardiac vagal activity at rest fosters more effective recovery due to a greater initial capability to uptake self-regulation resources.

In the high pressure condition the first factor extracted was resting cardiac vagal activity, and this was paired with DSRS as a second predictor. The findings suggested that the higher the levels of DSRS the better the levels of cardiac vagal activity post task. Again this finding would go against the hypothesis for the trait itself, particularly that of decision rumination whereby the individual thinks back to decisions they have made (Kinrade et al, 2010). One explanation could be that as the stressor was removed at the point of recovery which prompted a relief, those higher in decision reinvestment display a higher cardiac vagal activity post task. Although DSRS has not been assessed with cardiac vagal activity post task before and consequently this speculative interpretation should be investigated further in order to shed light on this finding.

4.4. Cardiac Vagal Reactivity

The hypothesis that cardiac vagal reactivity would be predicted by the challenge and threat ratio was not supported. For cardiac vagal reactivity, predictors were only found for the high pressure condition which was the levels of movement reinvestment, a trait that is only supposed to be active with high pressure conditions (Jackson et al, 2006). The higher the levels of trait movement reinvestment, the bigger the decrease in cardiac vagal activity from resting to task. As movement reinvestment is linked to the conscious processing of skills, it may be that the uptake of maladaptive coping strategies is higher and thus represents poor self-regulation under pressure (Masters, 1992). In line with previous research, there has been associations found between decision reinvestment and the level of cardiac vagal activity during the task. When comparing low pressure to high pressure conditions those who had higher levels of decision reinvestment had a larger decrease in cardiac vagal activity in the high pressure condition (Laborde et al, 2014). However, within Laborde and colleagues (2014) work the task was cognitive (decision making) unlike the present task which involved both a cognitive and a motor component (dart throwing). Therefore, the current findings compliment previous findings for reinvestment and subsequently further supports the argument for specificity of the reinvestment components (Kinrade et al, 2010).

One consideration worth noting is the role of movement reinvestment in the learning process as the majority of participants had limited dart throwing ability in that the skill may not be autonomous. It has been suggested that movement reinvestment can aid the early stages of learning a skill as the explicit monitoring of movements can help reinforce declarative knowledge (Malhotra, Poolton, Wilson, Omuro & Masters, 2015). Therefore, it may be that the uptake of self-regulation resources, indicated by a reduction in cardiac vagal activity, was greater due the learning effect of dart throwing and thus a decrease in cardiac vagal activity was observed. Although the majority of participants had thrown darts at some point before and task instructions were given, unlike Maholtra et al (2015) who did not use task instructions, therefore further investigation would be needed into this specific area in order to clarify the findings.

4.5. Cardiac Vagal Recovery

Cardiac vagal recovery predictors were only found in the low pressure condition. The more attention the participant paid towards the task and away from their own person the more efficient the recovery from the task. It is more adaptive to have attention directed towards the task at hand rather than a self-focus, as research suggest that a focus on the self during pressurised performance can cause performance decrements (Beilock & Carr, 2001). Additionally, if participants focus on emotionally charged stimuli (for example dwelling on mistakes during recovery) they may have a reduction in cardiac vagal activity (Park et al 2014). This suppression of cardiac vagal activity reflects the activation of the defensive systems (Thayer et al, 1996), which may be reflected in self-focus. Therefore, this could explain the adaptive cardiac vagal recovery pattern when the individuals do not focus on themselves.

4.6. Math errors

The hypothesis that the dart throwing task performance would be affected by attention was partially supported. For both low and high pressure conditions the first predictor extracted for math error was attention away from the task. The more attention that was directed away from the task the more mistakes participants made in the calculations. According to the Attentional Control Theory by Eysenck, Derakshan, Santos & Calvo (2007) anxiety, which often manifests itself within the pressurised environment (Otten, 2009), disrupts attention diverting it away from task-relevant stimuli and towards irrelevant stimuli such as the second experimenter in the high pressure condition.

In addition, in the high pressure condition, cardiac vagal reactivity was the second factor extracted to predict math error. The larger the cardiac vagal activity decrease from resting to task, the fewer math errors were made. It has been suggested that if the situation is stressful then a larger vagal withdrawal is seen to be adaptive as this represents the exertion of self-regulatory effort when exposed to stress (Park et al, 2014; Thayer et al, 2012). This is the opposite when comparing this to tasks that focus heavily on executive functioning as a smaller vagal withdrawal is seen as adaptive, as shown in previous research examining working memory (Laborde et al, 2015). Therefore, within this particular task because of the stressful nature of the high pressure condition and the task not involving executive functioning a larger vagal withdrawal would be seen as adaptive as the organism is recruiting self-regulation resources. This further supports the need to consider the amount of vagal withdrawal to depict self-regulation on a case-by-case basis as the findings suggest that this is dependent on the context of the situational demands (high pressure) and the nature of the task. When examining both predictors together, attention - particularly to emotional stimuli - during tasks is suggested to be modulated by cardiac vagal activity (Park et al, 2014; Park et al, 2013). Therefore, debilitative attentional strategies may have also contributed to poor self-regulation as indexed by a lack of vagal withdrawal in the high pressure condition. This is also reflected in the results from Saus et al (2012) who found cardiac vagal activity (RMSSD) dropped during a navigation task which was significantly mediated by their situation awareness scores. In this sense more mistakes were made when the vagal withdrawal was less within the high pressure condition indicating poor self-regulation. More research into cardiac vagal reactivity and psychomotor tasks is crucial in order to further understand the role of cardiac vagal activity in tasks of this nature.

4.7. Dart score

The hypothesis that the dart throwing performance would be affected by attention was partially supported. Cardiac vagal reactivity was the only factor extracted for the model for high pressure. A larger decrease in cardiac vagal activity during the task was associated with a better dart score. In line with the math error results this may be due to situation having higher stress levels to cope with and a larger vagal withdrawal is seen to be adaptive and shows better self-regulation (Park et al, 2014; Thayer et al, 2012). This withdrawal serves as a protective function against stress and environmental demands when exerting emotion regulation in these situations (Beauchaine et al., 2001, 2007; El-Sheikh et al., 2011). In the high pressure condition when the individual performed badly in the dart task, there was a smaller withdrawal in cardiac vagal activity as they did not meet the demands of the situation, adapting to the situation would have required a large cardiac vagal activity withdrawal in this instance. This reiterates the importance of the effects of context and situational demands on self-regulation indexed by cardiac vagal activity. The opposite finding was discovered in the low pressure condition where the greater the cardiac vagal activity reduction from rest to task the worse the dart score. This suggests that in the low pressure condition, less self-regulatory effort is needed to perform well as shown by a smaller reduction in cardiac vagal activity indicating better the performance. Few findings demonstrate the link between cardiac vagal reactivity and differing situational demands (types of pressure conditions), which further shows the importance of considering cardiac vagal activity as an indicator for self-regulation on a case-by-case basis.

Other predictors were extracted for dart score in low pressure were trait EI wellbeing and attention to task. For trait EI wellbeing the higher the amount of wellbeing, the better the dart score. The wellbeing factor reflects a generalised sense of wellbeing that extends from past achievements to future expectations (Petrides, 2009). It is pertinent to note that this finding was only discovered in the low pressure condition, this could suggest that in the high pressure condition the levels of wellbeing of the participants was overridden by the stress of the task. It has been shown in previous research that trait EI has links with cardiac vagal activity, trait EI wellbeing is linked to increased cardiac vagal activity at rest (Laborde et al, 2015) and global trait EI promotes better levels of cardiac vagal activity in stressful situations (Laborde et al, 2011). Similar to findings in math error, attention also played a role on dart score in the low pressure condition, in that the more attention paid away from the task the worse the dart score was. This finding is supported by dart throwing studies examining attention where an external focus towards the dart board (specifically the bull's eye) promoted more accuracy (McKay & Wulf 2012; Marchant, Clough, Crawshaw & Levy, 2009; Radlo, Steinberg, Singer, Barba & Melnikov, 2002). Although anxiety was not tested within the current study it could be linked to the pressure environment and may have promoted poorer aiming towards the dart board and subsequently led to worse scores.

4.8. Limitations

To fully reflect on the main findings of the study it is important to consider some limitations to the study design. Firstly, sample size may be an issue with the number of variables used within the study. Furthermore, the sample was biased towards athletes from team sports and there has been evidence to suggest that personality-trait-like individual differences can differ across team and individual sports (Laborde, Guillén & Mosley, 2016). Some methodological limitations exist in that there was no familiarization of both the cognitive and motor aspects of the task and learning effects may have occurred across the two conditions or across the five minute time period. The timing of errors were not taken into account within this study therefore could be a further limitation. In addition to this, the task was not specific to the athlete's sports and the findings should be checked with dart players. One consideration regarding the measurement of cardiac vagal activity is that there was a small amount of movement involved when the participants threw the dart which may have had an effect on the validity of measurement taken from the cardiac vagal activity reading. It has been stated that in order to gain a valid measure of cardiac vagal activity no movement should take place (Malik, 1996). Although there have been studies that involve movement in the measurement of cardiac vagal activity that link to the current study and have found links to performance (Thomson et al, 2015; Saus et al, 2012). In addition, an effort to control movement was realized through the use of clear instructions to only move the throwing arm and not the whole body (see supplementary material) and extra care was taken when scanning for artefacts in the ECG reading.

5. Conclusion

To conclude, this study has deepened knowledge of how coping related variables can affect dart throwing task performance and how cardiac vagal activity can be affected throughout a pressurised event. We demonstrated that resting tonic cardiac vagal activity can predict cardiac vagal activity at further points within the experiment (task and post task), which strengthens relationship between cardiac vagal activity levels and self-regulation. We also showed that phasic cardiac vagal activity has implications for dart throwing performance as well as the role of attention in aiming tasks. Finally, we found that performance in both cognitive and motor aspects of the task are predicted by different combinations of coping related variables, including trait, state and physiological, depending on the pressure condition experienced. At the theoretical level we have demonstrated that resting cardiac vagal activity influences other tonic phases (i.e. resting cardiac vagal activity positively influences task cardiac vagal activity in both low and high pressure) and phasic cardiac vagal activity is influenced by movement reinvestment in high pressure and attention in low pressure. We have also shown that cardiac vagal reactivity plays a key role in both cognitive (high pressure math error) and motor (low and high pressure dart throwing) performance. This vagal activity linked to self-regulation was shown to differentiate between pressure conditions, which demonstrates a need to consider nature of cardiac vagal reactivity (amount of change, usually withdrawal when under pressure) within the context of situational demands. This further strengthens the need for future research which combines variables in order to get a more holistic view of performance and the use of cardiac vagal activity as an indicator of self-regulatory behaviours pre, during and post task performance. We have also demonstrated that coping related variables are important for dart throwing task performance under both low and high pressure conditions.

At the applied level findings demonstrate the importance of practitioners addressing the role of attention in cognitive aspects of tasks involving secondary aspects to ensure the attention strategy is beneficial for performance. Consultants may also consider the role of cardiac vagal reactivity in aiming tasks as vagal withdrawal appears to have beneficial effects on dart throwing performance. We recommend that future research addresses the role of cardiac vagal activity and coping related variables under pressure. Specifically, the differences between low and high pressure conditions need to be addressed given the performance predictors were different in the current study. In addition, this needs to be explored within ecologically valid performance settings to fully understand the effects in sporting competition.

Supplementary material

Dart throwing instructions

1) Place feet behind the throwing line. You may want to have the corresponding foot to your throwing hand slightly forward.
2) Stand up straight in line with the board.
3) Hold the dart like a pencil and use a light grip.
4) Focus on the area of the dart board as a target
5) Bring the dart back towards your ear in a level position.
6) Throw the dart ensuring your only move your throwing arm. Avoid using a flicking or jerking motion or a great deal of force. Only move your throwing arm and avoid using a whole body action.

Participant proceeds to have 24 familiarization throws.

Adapted from: http://www.wikihow.com/Throw-Darts

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