UNIVERSIDAD POLITÉCNICA DE MADRID

FACULTAD DE CIENCIAS DE LA ACTIVIDAD FÍSICA Y DEL DEPORTE (INEF)

**EFFECTO DE LAS ESTRATEGIAS COGNITIVAS DE ASOCIACIÓN Y DISOCIACIÓN
SOBRE LA PERCEPCIÓN SUBJETIVA DE ESFUERZO, EL CONSUMO DE
OXÍGENO Y LA ACTIVACIÓN NERVIOSA CENTRAL: UN ESTUDIO
EXPERIMENTAL EN CORREDORES DE FONDO**

TESIS DOCTORAL

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*“if it doesn’t come bursting out of you
in spite of everything,
don’t do it.”*

Charles Bukowski

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“To strive, to seek, to find, and not to yield”

Alfred Lord Tennyson

ABBREVIATIONS

CFF: Critical Flicker Fusion frequency

CNS: Central nervous system

ECG: Electrocardiogram

FF: Flicker frequency

HR: Heart Rate

Hz: Hertz

h: Hour

Km: Kilometer

m: Meter

min: Minute

RPE: Rating of perceived exertion

RQ: Respiratory exchange ratio

SD: Standard deviation

VO₂: Oxygen consumption

VO₂max: Maximum oxygen consumption

VF: Fusion frequency

VT1: Ventilatory threshold

GLOSSARY

Cognitive strategy of association: is regarded as an internal attentional style, where athletes seek to monitor sensory inputs to adjust their running pace accordingly.

Cognitive strategy of dissociation: is referred to any thought that serves to distract attention away from internal sensations to avoid fatigue.

Attention: is the cognitive process of selectively concentrating on a discrete aspect of information, whether deemed subjective or objective, while ignoring other perceivable information.

Oxygen consumption: is the amount of oxygen taken up and utilized by the body per minute.

Perceived exertion: the individual's perception of exertion during physical work.

Central nervous activation: is the physiological and psychological state of being awoken or of sense organs stimulated to a point of perception.

Long distance running: is a form of continuous running over distances of at least three kilometres.

Marathon: is a long-distance running race with an official distance of 42.195 kilometres.

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RESUMEN

Hasta ahora, los estudios sobre los efectos de las estrategias cognitivas de asociación y disociación sobre el rendimiento en carreras de fondo han mostrado resultados controvertidos, especialmente derivados de las limitaciones metodológicas de utilizadas en su estudio. Recientes investigaciones han observado que el uso de la estrategia asociativa, centrando la atención en la respiración, aumenta el consumo de oxígeno del corredor, disminuyendo así la economía de carrera y afectando al rendimiento. Tras 39 años de investigación acerca de los beneficios del uso de estas estrategias en la gestión del esfuerzo de los corredores, en los estudios realizados hasta la fecha no se ha controlado de forma efectiva el uso de un foco atencional concreto. El objetivo de esta investigación se centra en analizar los posibles efectos del uso de las estrategias cognitivas de asociación y disociación sobre la percepción subjetiva de esfuerzo, el consumo de oxígeno y la activación nerviosa central mediante un diseño que ofreciera la posibilidad de una comparación intrasujeto, en dónde por primera vez se controla el uso de estas estrategias cognitivas y la intensidad del ejercicio. Un total de 30 corredores de larga distancia, con edades de 18 a 50 años participaron en la investigación. Se empleó un diseño intrasujeto para la realización del protocolo de estudio, realizado en tres sesiones: (1) prueba de esfuerzo basal para detectar el umbral aeróbico y controlar la intensidad de carrera en las sesiones posteriores; (2) uso de una estrategia cognitiva asociativa; y (3) uso de una estrategia cognitiva disociativa. El orden de las sesiones 2 y 3 fue aleatorizado.

Durante las sesiones 2 y 3, los participantes realizaron 55 minutos de carrera a una intensidad moderada. Mediante el uso de una aplicación móvil y un mando inalámbrico fue posible controlar, en tiempo real, el mantenimiento eficaz del foco atencional- estrategia cognitiva- solicitado durante las sesiones. Los resultados muestran que no

hubo efecto de las estrategias cognitivas empleadas sobre la percepción subjetiva de esfuerzo y el consumo de oxígeno, contradiciendo resultados de investigaciones previas basadas, fundamentalmente, en el uso de autoinformes. Se observó un efecto positivo de las sesiones de estudio sobre la activación nerviosa central y se concluye que, a una intensidad moderada, el uso de estas estrategias no afecta al rendimiento. Por otra parte, la carrera de fondo a una intensidad moderada, influye positivamente en la activación nerviosa central, con lo que el ejercicio realizado se presenta como beneficioso para actividades que requieran una alta concentración. Además, se propone a la metodología utilizada como una opción viable y dinámica para el estudio de las cogniciones en los deportes de resistencia, capaz de superar las limitaciones del enfoque retrospectivo en la investigación de las estrategias cognitivas en la carrera de fondo.

ABSTRACT

Up to now, the effects of cognitive strategies on performance in long distance running have showed controversial results, especially derived from methodological issues. It has been considered that the use of an associative strategy, focus on breathing increase the runner's oxygen consumption, decreasing running economy and affecting the athletes' performance. Nevertheless, none of past studies have controlled if participants maintained the instructed attentional focus. The purpose of the present study was to experimentally assess the effect of cognitive strategies of association and dissociation on perceived exertion, oxygen consumption and central nervous activation. A total of 30 long distance runners, aged range from 18 to 50 years volunteered for the study. The experimental protocol consisted on three sessions (scheduled in three different days): (1) maximal incremental treadmill test, (2) associative task session, and (3) dissociative task session. The order of sessions 2 and 3 was counterbalanced. During sessions 2 and 3, participants performed a 55 min treadmill run at moderate intensity. Though a mobile application and a wireless controller it was possible to control for the first time if participants effectively maintained the requested attentional focus during the sessions. Results showed that there was not effect of cognitive strategies of association and dissociation on perceived exertion and running economy. A positive session effect was observed for the central nervous activation. We conclude that when the workload is controlled at a moderate intensity, runners are free to choose were to focus their attention without affecting their running economy. Moreover, long distance running at a moderate intensity is beneficial for the central nervous activation. In addition, we propose the used methodology as a valid and dynamic option to study cognitions while running in order to overcome the retrospective approach and its limitations.

1. INTRODUCCION

Long distance running is constantly growing in Spain; it is the second most practiced sport activity during the week of the Spanish population (10%) according to the Yearbook of Sport Statistics (2016). This percentage has doubled since 2010 and this growing is presented in all disciplines. One of the most popular long distance running events that has seen tremendous growth during the past decade is marathon running (Allison, 2010) with a distance of 42.195 kilometers is the longest event at the major athletics championships.

Recent marathons have attracted male and female runners of all ages and abilities and often those with little previous athletic involvement. During the 39th edition of Madrid's marathon a total of 33611 runners participated in one of the three races; marathon ($n = 14611$), half marathon ($n = 12000$), 10 k ($n = 7000$), these numbers represented a record since Madrid's marathon first edition in 1978 (Merino, 2016). Only at Madrid's Community every year more than 150 long distance races were performed in 2016. The popularity of long distance running at the Spanish capital is evident with its most important event the San Silvestre Vallecana, a word class 10 km race, which 2016 edition had a participation of 33063 runners. It is worth to mention that 98% of the participants of these events are non-elite runners.

Practicing long distance running regularly has positive effects for physical and mental health (Berger, Pargman, & Weinberg, 2006) and it is a well recommended activity for conditioning the cardiovascular system, regarding age and gender (Högström, Nordström, & Nordström, 2014). As a promoting health sport activity long distance running have a positive impact for the osseous mass density (Ramos, López-Silvarrey, Montoya, Segovia, & Legido, 2006) it is recommended to practice from 3 to 5 times per

week with sessions of 30 to 60 minutes (Kohrt, Bloomfield, Little, Nelson, & Yingling, 2004).

Long distance running is highly demanding and requires months of dedicated training and a high level of commitment especially for the marathon's distance (Hanson, Madaras, Dicke, & Buckworth, 2015). It has been suggested that marathon attracts people of all ages and abilities partly because it's unique ability to satisfy a wide range of needs, both extrinsic and intrinsic (Summers, Machin, & Sargent, 1983).

Successful performance in long distance running is derived from various factors like technical, tactical, physiological, biomechanical and psychological (Hanley, 2016). In addition, factors like footwear and sportswear have evolved to play an important role on athletic performance. Recently, it has been concluded that energy return footwear have a positive effect on oxygen consumption in comparison to conventional shoes (Sinclair, McGrath, Brook, Taylor, & Dillon, 2016). Intelligent fabrics have been developing to regulate athletes' body temperature (Pailes-Friedman, 2016).

Considering as one of the most stressful situations, in which a person participates voluntarily (Eich & Metcalfe, 2009) long distance running requires both physical and psychological abilities. As a leisure activity, long distance running is perceived as a challenge, a test for the individual capabilities. Runners that participate in organized events voluntarily expose themselves to physical and psychological stress while following training schedules and diets (Ogles & Masters, 2000, 2003; Raglin, 2007).

To complete the marathon distance of 42.196 km of marathon, athletes must train in an organized way regardless of their competitive level.

If athletes set their goals to beat personal records or compete for winning or finish at top places, training plans can be fully organized. Strategy while training and competing is

crucial for peak performance. Specifically, strategy while running is related to the running pace (Abbiss & Laursen, 2008; March, Vanderburgh, Titlebaum, & Hoops, 2011; Thiel, Foster, Banzer, & De Koning, 2012) and it has been suggested that using the right pace is crucial for top performances (Angus, 2014). These particularities make long distance running an interesting athletic discipline to study from a psychological perspective.

1.1. A PSYCHOLOGICAL PERSPECTIVE FOR THE STUDY OF LONG DISTANCE RUNNING:

Psychological benefits of long distance running had been widely studied reporting positive results for a general well-being. A positive effect of running has been observed reducing anxiety (Petruzzello, Landers, Hatfield, Kubitz, & Salazar, 1991), depression (North, McCullagh, & Tran, 1990), increasing self-efficacy (Martin & Gill, 1991) and affect (Szabo & Abraham, 2013). In addition, participating in a long distance running event has the capacity to temporarily promote participants' life satisfaction (Sato, Jordan, & Funk, 2015).

Psychological variables as self-esteem (Hulley & Hill, 2001; Shipway & Holloway, 2010), motivation (Ogles & Masters, 2000), goal setting (Krouse, et al., 2011) personality (Deaner, 2013; De la Vega, Rivera, & Ruiz-Barquín, 2011; Solanki, 2008), confidence (Donohue, et al., 2006; Martin & Gill, 1991), affective states (Vasilica, Cristina, Iulian, Georgeta, & Radu, 2013), body image (Karr, et al., 2013), identity during injuries (Allen-Collinson & Hockey, 2007), attentional focus (Brick, MacIntyre, & Campbell, 2014) have been widely examined.

The majority of research findings had shown that runners that scored higher in those variables are more likely to perform better. These results have leaded the interventions

in order to train and increase those abilities for elite competition or as guidelines to promote healthy lifestyles in a wide variety of populations. A range of methodologies have been using including questionnaires, interviews, personal journals, observations, experimental trials. With the exception of the controlled interventions, the majority of the research of psychological variables research involved in long distance running have been used extensively a retrospective approach that can be considered as a methodological limitation, specifically for studying the flow of cognitions while running (Samson, Simpson, Kamphoff, & Langlier, 2017).

The popularity of long distance running, growing worldwide every year, and the adherence of the general population to physical activity, for health and well-being purposes make necessary to continue researching the psychological variables involved in this sport activity. Particularly, long distance running, has been considered as one of the most stressful situations in which a person participates voluntary (Aitchison, Turner, Thompson, Micklewright, & St Clair Gibson, 2013; Eich & Metcalfe, 2009; Sapolsky, 2004), the popularity of this sport and its unique nature make long distance running the dominant sport to study the effect of attentional focus. In addition, as a sport where athletes have long times with their own thoughts, and in a close relation with discomfort, suffering and pain the study of cognitions while running is mandatory for understanding how the attentional focus can influence the long running performance. It must be considered that using a retrospective approach to study athletes' cognitions is not the path to follow since the methodological limitations (see Table 1) and the controversies derived from the conclusions of past studies (Brick et al., 2014). The use of new technologies as measures tools offers an advantage to effectively overcome those limitations.

Table 1. Studies of cognitive strategies in long distance running

Year	Authors	Results	Limitations
1977	Morgan & Pollock	Associative strategy for competing Dissociative strategy for training	Retrospective approach
1980	Russell & Weeks	Perceived exertion is attention dependent	No control of the use of cognitive strategies of association and dissociation
1983	Morgan et al.	No effect on physiologic variables	No control of the use of cognitive strategies of association and dissociation
1985	Okwumabua	Associative strategy for competing Dissociative strategy for training	Retrospective approach
1986	Schomer	11 Categories for classify cognitions while running	Retrospective approach
1989	Padgett & Hill	Perceived exertion is attention dependent	No control of the use of cognitive strategies of association and dissociation
1998	Stevison & Biddle	Associative strategy increase RPE and decrease performance	Retrospective approach No control of exercise workload No control of the use of cognitive strategies of association and dissociation Not an unified conceptual framework about attention and cognitive strategies
1998	Masters & Ogles	20 years systematic review	Retrospective approach Unclear results
2001	Tenenbaum	Perceived exertion is multifactorial, attention is only one factor	No control of the use of cognitive strategies of association and dissociation

Year	Authors	Results	Limitations
2004	Baden et al.	While running at high intensity attention cannot be shifted from internal to external	No control of the use of cognitive strategies of association and dissociation No control of exercise workload
2009	Schücker et al.	Associative strategy increase oxygen consumption and decrease performance	No control of the use of cognitive strategies of association and dissociation
2010	Salmon et al.	30 years systematic review	Retrospective approach No control of the use of cognitive strategies of association and dissociation Not an unified conceptual framework about attention and cognitive strategies New construct: Mindfulness
2013	Schücker et al.	Associative strategy increase oxygen consumption and decrease performance	No control of the use of cognitive strategies of association and dissociation
2014	Brick et al.	34 years systematic review	Retrospective approach No control of the use of cognitive strategies of association and dissociation Not an unified conceptual framework about attention and cognitive strategies New construct: Metacognition

1.2. COGNITIVE STRATEGIES AND PERFORMANCE IN LONG DISTANCE RUNNING

As a general cognitive capacity, attention has been widely studied regarding to motor learning and motor control, researchers have concluded that attentional focus plays a key role on motor performance (Chow, Woo, & Kon, 2014; Wulf, 2013). Studies have tried to answer one of the big issues related to the endurance sport field, where to focus attention to perform at one's best?

Attentional focus in endurance sports have been formally studied for more than 39 years, in 1977 Morgan and Pollock highlighted a distinction between two broad categories of attentional focus, developing the term of cognitive strategies of association and dissociation, which has become a dominant construct linking attention and physical effort derived from long distance running. Association was regarded as an internal attentional style, turning focus inward and toward bodily sensations. Dissociation is an external attentional style, referred to any thought that serves to distract attention away from internal sensations (Brick et al, 2014; Conolly & Tenenbaum, 2010; Masters & Ogles, 1998; Salmon et al., 2010).

Since the pioneer work of Morgan and Pollock (1977) with long distance runners there has not been clear conclusions about the effect of attentional focus on performance. The lack of a clear and unified conceptual framework, methodological limitations such measures and design, have shown contrary results for the past 40 years (Brick et al., 2014). Moreover, the definition of the cognitive process of voluntary directed the attention to stimuli has adopted different names and definitions. From the dichotomy of association and dissociation proposed by Morgan & Pollock to the multi classification of Samson, Simpson, Kamphoff, and Langlier (2017). Since the attentional focus was considered to be spontaneous and not voluntary controlled and therefore not related to a

planned strategy in order to obtain a certain result. The definition of this process has been named differently: cognitive strategies (Morgan & Pollock, 1977; Okwumabua, 1985), attentional strategies (Connolly & Janelle, 2003) cognitive orientation (Acevedo, Dziewaltowski, Gill, & Noble, 1992) or attentional focus (Schücker, Hagemann, Strauss, & Völker, 2009). The need for a conceptual clarity has been highlighted by Brick et al., (2014) to overcome the controversies of past studies. As Gill (1997) discussed, conceptual clarity is the first step to use valid purported measures.

For the present study, we will use the term of cognitive strategies of association and dissociation, since we design two different tasks that required participants to voluntarily direct their attention toward specific stimuli in order to give responses. Moreover, association and dissociation are not synonyms of internal and external attentional focus (Brick et al., 2014; Connolly & Tenenbaum, 2010; Masters & Ogles, 1998; Salmon, Hanneman, & Harwood, 2010; Stevinson & Biddle, 1998).

For our study the association session will be named as associative task and dissociation as dissociative task with clear and objective responses.

One of the big difficulties for the assessment of the attentional process is related to their nature, cognitions are internal and not directly observable (Hutchinson & Tenenbaum, 2007). The research of Quintana, Rivera, De la Vega, and Ruiz (2012) have shown that stream of cognitions while running is dynamic, switching from thoughts to sensations and emotions. Particularly, long distance running, and the accumulated effort of the activity have shown that cognitions cannot maintain a linear direction (Balagué, Hristovski, Aragonés, and Tenenbaum (2012). In order to overcome these limitations it is necessary to design tasks that required participants direct their cognitions toward specific direction: associative or dissociative.

In addition to contrary results obtained in past studies, the explanations haven't offer clear conclusion in order to offer practical implications. Different recommendations have yielded so far, and researchers have shown contrary results about where to focus attention to enhance performance. Throughout non experimental studies, it has been suggested, that associative thoughts was related to a better sport performance. Nevertheless, the criteria of what is considered running performance was not unified, a wide range of variables have been considered as performance parameters (i.e. perceived exertion, running speed, time to exhaustion, distance).

Without a clear definition of what is considered performance, in terms of objective measures, it was difficult to assess the effect of cognitive strategies. Specially, when the suggested effect was directly related to exercise's workload (i.e. perceived exertion, running speed, time to exhaustion, distance) the study protocols have been mainly performed at a self-regulated intensity which may biased the obtained results.

Perceived exertion has been considered as the mayor performance variable (Masters & Ogles, 1998) specially, because long distance running was perceived as a stressful situation. Perceived exertion is one of the key variables in endurance sports (Baden, Warnick-Evans & Lakomy, 2004). It is considered as the cardinal reason to stop exercising and a strong predictor of exercise tolerance (Marcora & Staiano, 2010).

Exertion is defined as the effort expended in performing a physical activity. Individual's perceived exertion is a subjective awareness of parameters from the cardiovascular, respiratory or central and metabolic systems or peripheral (Borg, 1982; Cárdenas, Conde-González, & Perales, 2017; Hampson, St Clair Gibson, Lambert, & Noakes, 2001; Noble & Robertson, 1996; Marcora, 2009, Robertson, 1982). The rating of perceived exertion (RPE) scales have been used as reliable and valid measurements of exercise intensity (Doherty, Smith, Hughes & Collins, 2001) for more than 50 years.

According to Stevinson and Biddle (1998), paying too much attention to physical symptoms, as using an associative strategy, can contribute to magnifying them and consequently to increasing the discomfort and consequently reducing exercise performance. Perceived exertion was considered mainly as attentional focus dependant for 30 years after Morgan and Pollock's (1977) study (Hutchinson, 2011; Johnson & Siegel, 1992; Padgett & Hill, 1989; Pennebaker & Lightner, 1980; Russell & Weeks, 1994; Schomer, 1986; Tammen, 1996). The reviews of Masters and Ogles (1998) and Salmon et al. (2010) highlighted this issue, showing that this erroneous assumption has showed opposite results. We consider that in order to assess the effect of cognitive strategies on running performance, it is necessary control the exercise intensity.

It has been suggested that attentional focus has a mediating effect over how the perception of effort is integrated, operating as a filter of the physiological inputs derived from physical activity (Baden et al., 2004; Masters & Ogles, 1998; Morgan, Horstman, Cymerman & Stokes, 1983; Salmon et al., 2010; Schomer, 1986; Tammen, 1996). Different models have been processed to understand the relationship between cognitive strategies and perceived exertion.

Adapting the sensory model of pain (Leventhal & Everhart, 1979), Rejeski (1985) developed the parallel processing model for the study of perceived exertion. This model proposes that the information derived from the physical work is organized in a parallel fashion. Rejeski's model (1985) distinguishes perception from focal awareness. Perception refers to all the processed information to which a person can attend, focal awareness represents the particular segment of information to which a person does attend. The corner stone of this flow of information is that attention has a limited

capacity. Considering this, any information which competes with cues arising from physical exertion in terms of occupying attentional focus will reduce perceived exertion (Baden et al., 2004). This model has been used by Brewer and Buman (2006) with unclear conclusions about the role of attention on the perceived exertion response. The social-cognitive model was proposed by Tenenbaum (2001). In this model perceived exertion is determined by different factors as dispositional characteristics, demographic characteristics, task familiarity, exercise workload, performance conditions and the use of cognitive strategies to cope with stress (Tenenbaum, 2001; Tenenbaum & Hutchison, 2007).

None of these models had offered overwhelming explanations about how cognitive strategies mediate the perceived exertion response. Furthermore, those models included more psychological variables that may play also key roles on how exertion is perceived and how the runners can cope with that. The studies that have used those models obtained inconclusive results, as it has been mentioned before, there are design measures limitations that have affected the research protocols. Consequently, in order to establish a relation between cognitions and long distance running performance new approaches have been suggested as the mindfulness approach (Salmon et al., 2010) or the metacognitive perspective (Brick et al., 2014). Nevertheless, these new proposed models, instead of offer simple explanations, complicated even more the theoretical framework of cognitive strategies.

The mindfulness approach suggests that the non-judgemental direction of attention to the present-moment can reduce the emotional interpretation of painful stimuli, as referred by Leventhal and Everhart (1979) minimising the perception of effort. No study have used this model, it is not only more complex than the dichotomy of associative and

dissociative strategies, but if attentional focus is difficult to assess, mindfulness is even more complex, with almost none observable responses. In addition, this model also considers other psychological constructs that are not related to the proposed mediator effect such as Csikszentmihalyi's (2002) flow state (Gardner & Moore, 2004). This model has just presented a hypothetical linkage, with a minimum of possibilities of been used in experimental studies, we consider that this approaches are not the path to follow if researchers want to overcome the lack of controversial results.

Metacognitive perspective, suggest that since the main interaction between metacognition and self-regulation is to control strategies in order to meet goals (Tarricone, 2011) it's application in endurance exercise research can be interesting. For Brick et al (2014) some of the metacognitive processes as the self-monitoring, self-instruction, self-evaluation, and relaxation can be part of the natural content of cognitions while running. However, the same as with the mindfulness approach, no study have used this model and its potential benefit is only hypothetical. The conceptual frameworks used so far had proposed different explanations, but have not effectively offered clear arguments to discuss the obtained results along the variety of studies of cognitive strategies and perceived exertion, and some of them are far from what Morgan & Pollock (1977) proposed as cognitive strategies of association and dissociation.

Morgan et al. (1983) conducted a laboratory research in which they set the exercise intensity as a control variable and concluded that during a treadmill run performed at 80% of maximum aerobic capacity, physiological parameters are similar regardless of the cognitive strategy used, these findings has been supported by Connolly and Tenenbaum (2010).

Nonetheless, those conclusions were obtained from correlation methodologies and do not offer an overwhelming explanation, without an objective performance parameter, results should be interpreted with caution.

None of the studies before 2009 have assessed the effect of cognitive strategies on physiological performance parameters throughout experimental approaches. In order to avoid the controversies and the lack of overwhelming explanations of the non-experimental studies, the approach proposed by Schücker et al. (2009), using the objective performance parameter of running economy.

Defined as the steady-state oxygen consumption (VO_2) at a set speed, running economy has been considered as a valid performance criterion and an important factor in determining success for distance runners (Daniels, 1985; Morgan, Baldini, Martin & Kohrt, 1989; Sawyer, Blessinger, Irving, Weltman, Patrie, & Gaesser, 2010).

Performance in long distance running is intrinsically related to the individual capacity to use and transport oxygen (O_2). A good running economy allows athletes to use less O_2 at the same speed comparing with athletes with poor running economy (Thomas, Fernhall, & Grant, 1999). Studies have shown that long distance running performance is strongly associated with improved running economy (Anderson, 1996; Saunders, Pyne, Telford, & Hawley, 2004). In order to study the effect of cognitive strategies on running performance, running economy can be considered as an objective performance parameter, whereas time to exhaustion and speed can be affected by the person's motivation, running economy cannot be influenced by motivation (Schücker et al., 2009; Saunders et al., Pyne, 2004).

Table 2. Studies of cognitive strategies and oxygen consumption

Study	Participants (N)	Experimental sessions	Exercise Duration (minutes)	Attentional focus manipulation	Exercise Intensity	Physiological Measures	Attentional focus manipulation control	Results
Schücker et al. 2009	Trained long distance runners (24) 6 woman, 18 men Age (M = 30,8, SD = 8,9)	2: one for setting the workload, one experimental	30 10-min for each task (90-s break)	a)internal focus: running movement condition b)internal focus: breathing condition c)external focus: focus on a video	75%VO ₂ Max	-Oxygen consumption VO ₂ -Respiratory Rate -Respiratory minute volume -Respiratory quotient -Heart Rate -Blood lactate	Retrospective Questionnaire % of time using the required attentional focus	External focus generated the lowest oxygen consumption. p < .01
Ziv et al. 2012	Basketball players (17) all male Age (M = 15,1 SD = ,6)	1	30 10-min warm up 10 min for each task	a)internal focus: leg movement b)external focus: focus on a video	60% HRR	- VO ₂ Oxygen consumption -Ventilation - Respiratory Rate -Respiratory exchange ratio -Rating of perceived exertion (1-10 scale)	None	No significant differences in any of the physiological variables between conditions p > .05 No differences in RPE between conditions
Schücker et al. 2013	Trained long distance runners (20)	2: one for setting the workload, one experimental	30 10-min for each task (90-s break)	a)internal focus: breathing condition b)external focus: focus on a video c)control: no instructed focus	85%VO ₂ Max	-Oxygen consumption Vo ₂ -Heart Rate -Blood lactate-Rating of perceived exertion (6-20 scale)	Retrospective Questionnaire % of time using the required attentional focus	External focus generated the lowest oxygen consumption. p < .01
Ziv et al. 2013	Physical education Students (20) all male Age (M = 26,5 SD = 4,04)	1	20 10-min for each task +8-min warmup	a)internal focus: leg movement b)external focus: focus on a video	9,6 km·hr ⁻¹	- VO ₂ -Ventilation -Respiratory Rate -Rating of perceived exertion (1-10 scale)	Retrospective Open-ended strategy check Questionnaire	No significant differences in any of the physiological variables between conditions p > .05 No differences in RPE between conditions
Schücker et al. 2014	Active long distance runners (32) 14 woman, 18 men Age (M = 30,7, SD = 10)	1	24 6-min for each condition (2-min break)	a) internal breathing b) internal movement c) internal feeling of the body d) control: no instructed focus	Speed at 60% of the personal's 1000 m time	- VO ₂ - Respiratory Rate - Respiratory minute volume -Ventilation -Respiratory quotient -Heart Rate -Energy expenditure -Rating of perceived exertion (6-20 scale)	Retrospective Questionnaire % of time using the required attentional focus	Internal breathing and internal movements conditions required higher VO ₂ than internal feeling of the body and control conditions p < .01 No differences in RPE between conditions

Experimental studies have shown different results (see Table 2) using running economy as a dependant variable. Studies that have focused on the effects of cognitive strategies on running economy (Schücker et al., 2009; Schücker, Anheier, Strauss, Hagemann, & Völker, 2013; Schücker, Knopf, Strauss, & Hagemann, 2014) have concluded that dissociative strategy improves running economy by reducing the oxygen consumption at a set running speed. Contrary internal attentional focus increased oxygen consumption and consequently decrease running economy. Since exercise workload was equal for all conditions (internal breathing, internal movement and external) Schücker et al. (2009) argued that changes in oxygen consumption, was due to cognitive strategies. Their results showed that during the focus on breathing condition the respiratory rate decrease and simultaneously the respiratory volume increase. Participants breathed more slowly and deeper; this data itself could explain why internal conditions were less economical and supports that for practical purposes, the common recommendation to focus on breathing while running is not effective. For Schücker et al. (2009) those results can be attributed to attentional focus manipulation of the runners towards the breathing process.

Breathing is a highly automatic process and it works more effectively while running, if is not subjected to conscious control (Bernasconi, Bürki, Bühner, Koller, & Kohl, 1995). Schücker et al. (2009) discussed that their results can be explained within the movement control theories (Chow et al., 2014; Wulf, 2013) establishing that conscious control breaks the natural movement down and decreases performance. Schücker et al. (2009) concluded that the internal condition (focusing on breathing) disrupt the natural and automatic breathing cycle. These results were confirmed in subsequent studies (Schücker et al., 2013; Schücker et al., 2014) suggesting that focus on breathing could decrease running performance in terms of running economy.

Through a similar methodology, regarding to the attentional focus instructions Ziv, Meckel, Lidor, and Rotstein, (2012); Ziv, Rotstein, Lidor and Meckel (2013) observed that attentional focus did not had an effect in oxygen consumption. In their studies, these authors did not use the internal condition of focus on breathing instead they used the attentional condition of focus on movement, the same condition used by Schücker et al. (2009), Schücker et al. (2013) but with different results. It is interesting to highlight that it is possible that the attentional focus condition of focus on breathing has a decisive role on the oxygen consumption. Those results could be partially attributed to the external condition, it has been discussed that the video using for the external condition allowed runners to adjust their pace accordingly, throughout a visual speed feedback, and consequently this lead to the improved running economy (Ziv et al., 2013). In order to avoid this biased effect, these authors used the video during all experimental conditions, including the associative task. Since the germinal study of Morgan & Pollock (1977) and even when running performance has been directed to objective measures as oxygen consumption, results regarding to the effect of cognitive strategies and performance remain controversial. Although the same attentional tasks have been performed, opposed results have been obtained. Participants are different in almost all the studies from trained runners to basketball players (see Table 2).

Regardless on the giant steps reached with the use of objective parameters to assess the effect of attentional focus on running performance, it is still unclear which strategy is more beneficial for endurance sport performance.

Recently, the research of De la Vega, Rivera, Ruiz-Barquin, Ramos and Segovia (2016), which is part of the present doctoral thesis, had showed different results, on their study, these authors designed two attentional tasks that required the use of both cognitive strategies of association and dissociation throughout an experimental design, where they

can assess task adherence. Their results showed that when runners direct their attention to their breathing, with the task of counting set of 7 exhalations, oxygen consumption did not increase while performing a 55 min long distance run at moderate intensity (70% VO_2max).

In order to analyse if running economy was affected by the attentional focus during high intensity exercise, Schücker et al. (2013) performed a study setting a workload speed related to the 85% of the maximum oxygen consumption (VO_2max), while runners had to perform two attentional tasks. Using the same associative task of Schücker et al. (2009), focus on the breathing in and out, their results showed that an external focus improved running economy. Until this research, exercise workload have been always set at moderate intensities when running economy was used as a performance indicator (Schücker et al., 2009; Ziv et al., 2012; Ziv et al., 2013). Setting the speed at moderate intensity has not been an arbitrary decision, based on Tenenbaum's (2001) model, which established that when are working hard in terms of perceived effort, their thoughts naturally become narrow and internal, mainly associative. Under high intensity exercise it could not be possible to distract attention away from internal stimuli.

Different studies have obtain similar results to Tenenbaum's (2001) model, where attention couldn't be switched to external stimuli under high intensity exercise bouts (Baden et al., 2004; Hutchinson, 2011; Hutchinson & Tenenbaum, 2007; Tenenbaum & Connolly, 2008). Contrary, in a low-intensity condition, attention can be shifted voluntarily from external to internal focus (Ekkekakis, 2003), thus moderate intensity is seems to be the appropriate workload for the study of cognitive strategies. Specially, considering the methodological limitations that researchers have faced so far, compromising the ability to freely choose and maintain a certain cognitive strategy will

derive in more unclear conclusions. It has been suggested that during a low or moderate intensity dissociative strategy dominated, as the workload increases the use of association also does (Hutchinson & Tenenbaum, 2007). Nevertheless, the assessment of the attentional process is inherently difficult because cognitions are internal and not directly observable (Brick et al., 2014).

Tenenbaum's (2001) model has not been studied using fully experimental protocols, attentional focus has been considered as workload dependant. Based on previous results, were focusing on breathing alters the natural cycle, increasing oxygen consumption (decreasing running economy) Schücker et al. (2014) analysed the effect of attentional focus on three different internal conditions. In addition to the two common used conditions, focus on breathing and focus on movement, they included a third condition: focus on the feeling of the body. Results showed that even between internal conditions oxygen consumption varied, so it was discussed that focusing on the feeling of the body generated the lower oxygen consumption compared with the other conditions. Thus, it was concluded that not all the internal conditions decrease running economy. Schücker et al. (2014) highlighted that is not the internal or external condition by itself, but if the attention is directed to an internal automatic process like breathing and movement what affects running economy. Nevertheless, in despite of this important conclusion, they did not include an external or a control condition. It is necessary to clarify that even if the respiratory rate decrease and the tidal volume increased during the sessions, these results do not imply that cognitive strategies can improve running economy. Recent studies about strategies to improve running economy (Barnes & Kilding, 2015) have showed that training had an influence on running economy, uphill training and high intensity level-ground interval training are commonly prescribed as training forms to enhance running economy. In addition, plyometric training, altitude acclimatization, and

nutritional interventions have also showed positive effects on running economy. Nevertheless, no study suggested that not focusing on breathing process will increase running economy, or can be considered as training strategies to enhance running performance. Is this lack of conclusive practical implications what makes really interesting to keep studying the role of cognitive strategies in long distance running.

For almost 39 years controversies about the effect cognitive strategies of association and dissociation on running performance have been presented in the scientific literature (Brick et al., 2014; Conolly & Tenenbaum, 2010; Masters & Ogles, 1998; Salmon et al., 2010; Stevinson & Biddle, 1998). Despite the advances in the research designs, some issues remain unclear. Specifically, one of the biggest limitations so far has been the attentional focus assessment. Since the use of a particular cognitive strategy, that implies the voluntary direction of the attentional focus towards specific internal, active or external cognitions (Brick et al., 2014), had not been measured directly and it could be possible that during several of past studies participants followed differently the attentional focus instructions (Ziv, et al., 2013). Furthermore, there is not an objective measure that confirms how many of the participants of such studies actually used the required attentional focus (task adherence) and how effectively the task were performed during study sessions. We consider that the same as using an objective performance variable as running economy had shown to be the right the path to follow for future researches the use of an objective method to assess the participants' cognitions while running is necessary.

While oxygen consumption (dependent variable) is measured by a breath by breath procedure through precise tools, cognitive strategies of association and dissociation (independent variable) have been widely measured by interviews, post exercise

questionnaires, thought classification systems as the Running Styles Questionnaire (Silva & Appelbaum, 1989), the Attentional Focus Questionnaire (Wrisberg & Pein, 1990), the Thoughts During Running Scale (Goode & Roth, 1993), the Thinking Styles Questionnaire (Ogles et al., 1993-1994) and the Attentional Focusing Questionnaire (Brewer, Van Raalte, & Linder, 1996), and tape recorded systems (Schomer, 1986), talk-aloud protocol (Samson et al., 2017). Such tools imply a strong retrospective approach and other limitations that may have distorted the findings of past studies (Brick et al., 2014). Furthermore, retrospective recall of thoughts can be biased, and is not as reliable as knowing the thought content during the activity, especially if the task is longer than 10 seconds (Ericsson & Simon, 1993). It would be difficult for the athletes to remember their cognitions during a long distance run (Schomer, 1986), and the thought classification could be biased (Masters & Ogles, 1998) by the simple action of asking participants what they were thinking. As Quintana et al. (2012) reported, the stream of cognitions while running is wide and varied, and can easily shift to images, emotions, sensations, and thoughts pleasant or unpleasant, accordingly, the use of a retrospective approach must be avoided.

For the assessment during running, common methods have been the one question scale (Tammen, 1996), or the Tenenbaum and Connolly (2008) 10-point scale ranging from 0 (external) to 10 (internal), the recording of thoughts with micro-cassette recorders; with their posterior classification (Schomer's classification system, 1986), the talk-aloud protocol (Samson et al., 2017) based on Ericsson and Simon (1980), such tools can be considered more accurate than the used retrospective questionnaires, nevertheless, some of these tasks interrupted the habitual attention patterns (Brick et al., 2014).

The logical next step was the design of specific attentional tasks, in which participants were required to use cognitive strategies while running (De la Vega et al., 2016;

Schücker et al., 2009; Schücker et al., 2013; Schücker et al., 2014), this approach can overcome the inherent limitation of attentional process assessment (Hutchinson & Tenenbaum, 2007). Cognitions are internal and not directly observable, so through the answers of specific attentional task, that are not only observable but measured too it is possible to increase the experimental control. Nevertheless, is worth to mention that during past studies, with the exception of De la Vega et al. (2016), the use of cognitive strategies was not measured directly and there is not objective measure that confirms how many of the participants really used the attentional focus. The used attentional manipulation check has used a retrospective approach, with percentages of task adherence of 85% focus on breathing and 90% external focus (Schücker et al., 2009), 79% focus on breathing Schücker, et al., 2014), and total session task adherence of 78% (Ziv et al., 2013) it is not possible to affirm that a high experimental control has been achieved.

Since controversial results have been presented, it is necessary to use an objective attentional focus tasks, that imply the volitional direction of attention toward internal of external stimuli. Only through this is possible to assess, not only the use of the attentional focus, but the athletes capacity to use that strategy while running, especially for a long period of time, which is organic related to long distance running, where trained athletes run 10 k for periods of 40 min. Moreover, it is necessary to control the performance of that those tasks in real time. Research using experimental designs, with dynamic manipulation checks for the use of cognitive strategies is needed (Brick et al., 2014; Blanchard, Rodgers, & Gauvin, 2004; LaCaille, Masters, & Heath, 2004).

1.3. COGNITIVE STRATEGIES AND CENTRAL NERVOUS ACTIVATION

The research of cognitive strategies and their effect on exercise performance has been widely studied (Brick et al., 2014). Nevertheless, the effect of exercise on the cognitive process required to perform these cognitive tasks, has not been integrated on the study protocols. Since both strategies, associative and dissociative implies several cognitive functions, it is necessary to research about the effect of physical exercise on this process. Associative and dissociative strategies require a cognitive process of stimuli recognition, voluntary inhibition, and short time memory. Turning focus inward bodily sensations or to any thought that serves to distract attention to those internal sensations imply the volitional direction of attention and different cognitive processes depended on the nature of the cognitions. On the contrary, dissociative strategies will imply cognitive processes as visual recognition, stimuli discrimination, self-regulation, motor behaviour, response inhibition.

Based on Tenenbaum's (2001) model, in which attention can be voluntary focus inward or outside bodily sensations only at moderate intensities. It is necessary to study the effect of exercise over the cognitive process while running. The relation of cognitive activity and exercise has been widely studied. Moderate physical exercise has the potential to improve cognitive performance (Audiffren & André, 2015; Brisswalter, Collardeau, & Arcelin, 2002; Davey, 1973; Chmura, Nazar, & Kaciuba-Uscilko, 1994; Kamijo et al., 2006; Kashiara, Maruyama, Murota, & Nakahara, 2009; Lambourne & Tomporowski, 2010; McMorris & Keen, 1994). In addition, acute physical exercise has showed small positive effects on cognitive performance (Chan, Labban, Gapin, & Etnier, 2012). Exercise has shown a facilitating effect on information processing if the following conditions are controlled: (1) the intensity and duration of the physical

exercise, (2) the nature of the cognitive task, (3) the time when the psychological test is administrated and (4) the participant's ability at decision making (Davranche & Audiffren, 2004). Tomporowski (2003) concluded that submaximal aerobic exercise facilitate information processing, if the duration was up to 60 minutes, longer periods, or additional high-intensity exercise above the optimal point may lead into dehydration thus compromising information processing and memory functions. The effect of exercise on cognitive functions is based on changes in the peripheral cardiovascular function affecting regional and systemic perfusion (Critchley, Corfield, Chandler, Mathias, & Dolan, 2000). As consequence of a general activation of both motor and cognitive brain functions, increasing central nervous activation (arousal) and sensory sensitivity (Davranche & Pichon, 2005). Moderate intensities, are linked with improvements in cognitive performance, which is also the highly recommended exercise workload to study the effect of cognitive strategies over running performance. Considering, that fatigue can appear by exercise duration and intensity, a long submaximal exercise could decrease information processing and memory functions. As with the associative and dissociative strategies effect over running performance has been using oxygen consumption as an objective measure. In order to assess the effect of exercise on cognitive performance, the critical flicker fusion frequency (CFF) has been widely used to assess sensory sensitivity and cortical arousal also known as central nervous activation, two important processes in every cognitive task (Clemente, 2011; Davranche & Pichon, 2005; Godefroy, Rousseu, Vercruyssen, Cremieux, & Brisswalter, 2002, Ito, Kanbayashi, Takemura, Kondo, Inomata...Nishino, 2007). In long distance running the research of Clemente and Suarez (2010) has been pioneered showing the effectiveness of the critical flicker fusion (CFF) as measure of central nervous activation.

An increase of CFF threshold is indicative of an increase in central nervous activation and sensory sensitivity. Contrary, a decrease of CFF threshold will imply a reduction in the efficiency of the system for processing information (Li, Jiao, Chen, & Wang, 2004). Until now, several studies have shown that physical exercise alters the CFF threshold (Clemente & Suarez, 2010; Davranche & Audiffren, 2004; Davranche & Pichon, 2005; Godefroy et al, 2002; Lambourne & Tomporowski, 2010; Presland, Dowson, & Cairns, 2005). The CFF test assesses central nervous system global integrative ability, namely sensorial information, discriminable ability, (Smith & Misiak, 1976). If a physical exercise leading to exhaustion induces transitory fatigue in the central nervous system there should be a decrease in sensory sensitivity criterion of CFF threshold.

Alternatively, if this type of exercise induces an increase in central nervous activation and sensory sensitivity there should be an increase in CFF threshold. Tomporowski (2003) concluded that aerobic exercise improves the operation of specific stages of information-processing, in special process that are involved in response inhibition. Attention plays a key role in this process, identifying the stimulus, independently of the nature associative or dissociative. If exercise improves the information-processing needed to perform both cognitive strategies it is difficult to consider that the use of an associative strategy will have a negative effect on running performance when the exercise workload is controlled. In Schücker et al. (2009, 2013, 2014) the effect of exercise in cognitive performance was not assessed. In addition, the attentional focus sessions, did not required that participants give a response, and were only designed to change their attentional focus from internal to external stimuli. If the effect of attentional focus on oxygen consumption is related to the internal or external nature of the task, it will be really interesting to assess the same effect indulging the CFF threshold. Central nervous activation is close related to physical process as blood flow

and oxygen transportation. According to the transient hypofrontality theory (Dietrich, 2003, 2006) physical exercise generates a massive neural activation which contributes to the recruitment of motor units, sensory input integration, and regulation of the autonomic systems. Given a limited resource capacity, this huge request induces a competition for resources that would be expected to result in a diminution of the resources allocated to brain structures which are not directly involved in motor control. Cárdenas et al. (2017) reviewed the concept of fatigue through the physical and psychological approaches, and distinguished two types of fatigue, one direct which impacts directly to the neural processes of motor behaviour, and other indirect related to the metabolic cost of the performed task as the proposed hypofrontality theory.

In addition, it has been suggested that cognitive tasks requiring self-regulation (as in the present study) may cause the depletion of central nervous system resources, leading to reduced capacity of the CNS to recruit the working muscles (Bray, Martin Ginis, Hicks, & Woodgate, 2008; Bray, Graham, Martin Ginis, & Hicks, 2012; Martin Ginis & Bray, 2010). For this reason is important to analyse the effect of cognitive strategies on the physiological parameters related with exercise, as heart rate, oxygen consumption and blood lactate concentration.

Self-regulation as defined by Karoly (1993) is the modulation of thought, affect, behaviour, or attention via deliberate or automated use of mechanisms of cognitive control. Researches have shown that performing cognitive tasks requiring self-regulation can lead to impaired performance in both cognitive and physical tasks (Hagger, Wood, Stiff, & Chatzisarantis, 2010) due self-regulation's the limited resource, once depleted leads to impaired self-regulation (Muraven & Baumeister, 2000). This effect has been mainly observed when the cognitive tasks engagement that requires self-regulation for a period of 30 to 90 min impairs endurance performance

during subsequent exercise (Marcora et al., 2009; MacMahon, Schücker, Hagemann, & Strauss, 2014; Pageaux, Lepers, Dietz, & Marcora, 2014). However, no negative effects were found on the physiological system (cardio respiratory and metabolic) supporting endurance exercise, the impairment performance was considered as the effect of mental fatigue. Cognitive tasks requiring a prolonged self-regulation lead into a subjective state on mental fatigue, which increases the perception of effort before endurance exercise, it is possible to consider that the mental fatigue induce a subjective lack of energy (McEwan, Martin Ginis, & Bray, 2013; Pageaux, Marcora, Rozand, & Lepers, 2015). Despite of these findings, we consider that perceived exertion is a modest indicator of mental fatigue. Recently, it has been highlighted that even that scientific literature distinguishes between perceived exertion and fatigue, in practical terms fatigue derived from physical exercise or as consequence of performing a task with a high mental workload, or both on at the same activity, is processed in a parallel way to the perceived exertion response (Cárdenas et al., 2017). Moreover, fatigue can also be the consequence of the mental workload of the activity, affecting decision making, self-regulation processes, and impairing the working memory.

In order to understand the effect of a self-regulation cognitive task on endurance performance, it is necessary to use a reliable mental fatigue measure as the critical flicker fusion frequency. Moreover, past studies have conducted the endurance exercise trial after the cognitive tasks. Parallel, the effect of exercise on cognitive performance has shown that exercise had a positive effect on the cognitive task, when the workload is moderate and the duration is less than 1 h. In previous studies cognitive and endurance tasks have been performed separately. And based on the results of Pageaux et al. (2014) it is possible to consider that this phenomenon is related to the workload (in terms of self-regulation) and duration on the cognitive task.

Considering these opposed results about the interaction of endurance and cognitive performance, it is necessary to design a methodology capable of study this relation as it occurs, assessing the performance of self-regulation cognitive tasks while performing an endurance exercise. Furthermore, aerobic exercise influence the speed of decision making once the information is processed (Alves et al., 2012).

Long distance running and what can be considered as fatigue are close related (Mizrahi, Verbitsky, Isakov, & Daily, 2000). Without a clear definition, some authors consider that fatigue is a conscious sensation rather than a physiological occurrence. This model considers fatigue as a complex emotion affected by factors such as motivation, drive, anger, fear, memories of previous experiences and activities (St Clair Gibson et al., 2003). In addition, fatigue has a purpose protecting the organism from a serious damage (Ament & Verkerke, 2009).

Physical fatigue, defined as the exercise's induced reduction in ability to generate muscle power (Gandevia, 2001) can affect peripheral and central nervous system factors (Meeusen, Watson, Hasegawa, Roelands, & Piacentini, 2007), influencing performance and cognition (Moore, Romine, O'coonor, & Tomporowski, 2012). Some of the physical factors related with fatigue are cardiovascular performance, oxygen and nutrients uptake efficiency, blood lactate levels. In all these processes the central nervous system plays a key role regulating the effort while exercising preventing for a potential damage caused by a physical overexertion (Abbiss & Laursen, 2004). For this reason it is widely consider that fatigue sensation it is also highly influenced the mental workload of the activity. Mental fatigue, defined as the psychobiological state caused by prolonged periods of demanding cognitive activity (Boksem & Tops, 2008) can impact cognitive performance, physical performance (Marcora et al., 2009) and central nervous

activation (Audiffren & André, 2015; Tomporowski, 2003). The sensation of fatigue derived from the mental workload has been the determined element for the time to exhaustion physical performance, and it has been suggested that is not only mediated by cardiorespiratory and musculoenergetic factors. In addition, mental fatigue also had a negative effect on perceived exertion, increasing the RPE response at the same workload when compared with a no mental fatigued condition (Marcora et al., 2009). Fatigue (mental or physical induced) negatively impacts on performance (cognitive of physical). Exercise and task workload play a key role in order to study the effect of exercise on cognitions under controlled conditions. Accordingly, in the present study we will take into account that mental fatigue caused by the attentional task can induce physical fatigue and the fatigue produced by the long distance run may cause an indirect effect on mental process and it can impairs participants' tasks performance. The importance of controlling the attentional task effectiveness in real time and during the session is of great relevance to analyse if the results are biased due to the fatigue effect. Considering that fatigue has a dichotomous approach, at one edge peripheral fatigue affecting muscular fibres due to the concentration of lactate and ammoniac. While on the other edge central fatigue is presented as the disturbance of the processes involved in the motor order and motor cells communication and the central nervous activation (Cárdenas et al., 2017). It is necessary to analyse both, central (with the CFF) and peripheral with blood lactate concentration, hear rate, oxygen consumption and perceived exertion.

Blood lactate concentration is considered as a limitation factor for physical exercise. In addition lactate threshold (the point at which the blood lactate concentration exceeds 4 mm/l) is considered as a predictor of performance and a precise indicator of exercise workload. Lactate concentration increase at high speed once the lactate threshold is

overreached (Heck et al., 1985) thus it is important to measure blood lactate concentration after the experimental sessions.

1.4. Why to study this after 39 years?

Since the pioneer study of Morgan and Pollock (1977), several studies had focus on studying the effect of cognitive strategies on exercise performance. From the first conclusions, where association was related to elite runners and dissociation with novel ones, researchers have expanded these conclusions in two ways. One, clearly focused on the classification of thoughts, with the purpose to clarify what does association and dissociation really mean and because of the dichotomy, highlighted by Morgan and Pollock (1977), was considered too wide and general, researchers transformed it into multi-categorical classifications (Samson et al., 2017; Schomer, 1986; Stevinson & Biddle, 1998) where researchers face the enormous challenge of classifying the whole stream of cognitions while running. Samson et al., (2017) classification included: monitoring pace and distance, strategies to maintain pace, alternating pace, injuries, causes of pain and discomfort, coping with pain, geography and weather, admiration for the environment, wildlife, traffic/others. Schomer's classification (1986) was: feelings and affect, body monitoring, command and instruction, pace monitoring, environmental feedback, reflective activity thoughts, personal problem-solving, work career and management, course information, and talk conversation chatter. Stevinson and Biddle (1998) added to the dichotomous model of association and dissociation the dimension on internal and external.

Recently, the classifications of thoughts returned to a dichotomous model, Balagué et al. (2012) proposed the concepts of task-related and task-unrelated thoughts, this classification, in practical terms, is not different from the proposed by Morgan and

Pollock (1977). Association was regarded as an internal attentional style, where athletes seek to monitor sensory inputs to adjust their running pace accordingly. Dissociation is referred to any thought that serves to distract attention away from internal sensations to avoid fatigue (Masters & Ogles, 1998; Salmon, et al., 2010). The thought classification approach has presented several limitations, the retrospective methodology is inaccurate and some of the measure protocols have biased participants' cognitions into the studied though directions (Brick et al., 2014). Moreover, the effect of those cognitions (classified into different categories) on running performance remains unclear. Until Schücker et al. (2009) no study had really assess an objective effect over an objective performance indicator (running economy).

The other research line is the one related to the effect of exercise on cognitive processes. Considering that the physiological mechanisms of exercise impact the brain functions, researchers have focused in studying the effect of exercise workload in self-regulation tasks (Langner, Steinborn, Chatterjee, Sturm, & Willmes, 2010). The results have shown that exercise and cognitive tasks, at a moderate workload improves cognitive processes by increasing the central nervous activation (Tomprowski, 2003).

Since the cognitive process and central nervous activation plays a key role for exercise performance and cognitive strategies of association and dissociation can be consider as cognitive tasks, it is necessary to integrate both visions and design a study accordingly. In addition, it is mandatory to overcome the methodology limitations of the past years by controlling the use associative and dissociative strategies in real time.

Considering the increase popularity of healthy lifestyles where long distance running is a popular activity in population of all genders, with the particular physical and psychological benefits such as sense of accomplishment, health and fitness, social affiliation (Lee, Sui, Ortega, Kim, Church, & Winett, 2011; Major, 2001; Rendi, Szabo,

Szabó, Velenczei, & Kovács, 2008; Rocheleau, Webster, Bryan, & Fraizer, 2004; Szabo & Ábrahám, 2013) it is necessary to keep studying the role of cognitive strategies in long distance running.

One of the key studies that assessed a real effect of the use of cognitive strategies on performance (Schücker et al., 2009) may be due to the instruction and not as a direct effect of focusing of attention to breathing. Conceptual limitation of what researchers considered as performance was overcome but methodology limitations are still present. In Schücker et al. (2009) study, the instruction of focus on “breathing in and out” may cause the oxygen consumption impairment. Studies directed to analyse the effect of breathing instructions for stress management have shown that attention to breathing significantly reduced respiratory rate and alters the tidal volume (Conrad et al., 2007; Sasaki & Maruyama, 2014). Moreover, physiology studies directed to analyse the control of breathing during exercise have not obtained an overwhelming explanation about how breathing process operates during the exercise. Specifically, there is no complete understanding about how the increase of deep breathing accompanied by an increase in the respiratory rate known as hyperpnea operates during physical exercise (Forster, Haouzi, & Dempsey, 2012; Mateika & Duffin, 1995). Several control mechanisms have been proposed, without having a clear explanation of how the ventilation during constant-load exercise is controlled (Ward, 2014, 2007).

Since my personal background as psychologist and long distance runner the daily coexistence with several thoughts while training and competing attracted me towards the study of the psychological processes involved in long distance running. Of the whole range of variable none of them seemed as relevant as the cognitive strategies of association and dissociation. During races of ultra-running, which are races where athletes need to cover distances longer than marathon the flow of cognitions is huge, but

when the pain starts and during races of 100 kilometers pain will be present at some point, this flow of cognitions become narrow and directed toward specific stimuli like the feelings of the legs, the track and sometimes the view. These unique moments of endurance sports, especially in long distance running offered me an interesting field for study cognitions. In addition, when we start searching about the effects of cognitive strategies of association and dissociation we find that it was a topic full of controversies. I started this project with the intention of answer the question: where to focus attention to perform at one's best? After more than 39 years of research, one of the big issues regarding to sport psychology still remains unclear.

2. PURPOSES AND HYPOTHESIS

General purpose

The general purpose of the present study was to experimentally assess the effect of cognitive strategies of association and dissociation in long distance runners. Since no study had control the direction of the attention in real time, it is necessary to control exercise workload and task adherence.

Past studies had observed that attentional focus impairs oxygen consumption (Schücker et al., 2009), when runners focus on their breathing the respiration rate decreases and tidal volume increase. Nevertheless the fact that task adherence was not controlled in real time, do not offer solid arguments. If the breathing pattern while exercising at the same workload is affected by the cognitive strategies, more research is needed because will not only be a step forward in the sport psychology research but also in the physiology' field.

Hypothesis 1

We hypothesize that an associative task that request runners to focus their attention on breathing will increase oxygen consumption and consequently reduce running economy. Past studies did not controlled task adherence in real time and exercise workload which one of the key variables related to exertion response. Consequently, results and conclusions obtained are based on researches with methodological limitations. Considering Rejeski's parallel processing model (1985), where attention has a limited capacity and any information which competes with physical exertion cues may reduce perceived exertion (Baden et al., 2004; Brewer & Buman, 2006).

Hypothesis 2

We hypothesize that if both cognitive strategies require runners to focus their attention constantly toward the attentional tasks perceived exertion there will be no differences in perceived exertion values.

Exercise induces an increase in central nervous activation (Clemente & Suarez, 2010; Davranche & Audiffren, 2003; Davranche & Pichon, 2005; Tomporowski, 2003) if the exercise duration and workload are controlled. In addition, fatigue derived from a sustained cognitive task can lead into physical fatigue (Bray et al., 2008, 2012; Martin et al., 2010; Pageaux et al., 2014). Transient hypofrontality theory (Dietrich, 2003) establishes that exercise recruits a huge amount the resources and consequently it is expected a reduction of the resources allocated to brain structures that are not directly involved in motor control. Although there may be an important relation between exercise, cognitive function, fatigue and central nervous activation none of the past cognitive strategies' studies had include this effect on their research protocols.

Hypothesis 3

We hypothesize that the sessions (exercise and attentional task) will increase the central nervous activation (CFF threshold), considering that exercise duration (less than 1 h) and workload are controlled (at moderate intensity). Consequently, we hypothesize that the exercise bout will not affect task effectiveness, contrary to the transient hypofrontality theory (Dietrich, 2003).

We designed two attentional tasks, one associative and other dissociative, in which participants were required to maintain their attentional focus intentionally throughout the session while controlling exercise workload was at a moderate intensity. Using dynamic tools as the mobile phone application and the wireless controller was possible to control in real time, if participants effectively performed the assigned cognitive

strategies without using verbalization or retrospective approach with the purpose to overcome methodology limitations. Through this experimental design we will be able to work on specific purposes.

Objective 1

Analyze the effect of association and dissociation tasks on oxygen consumption.

Objective 2

Assess the effect of cognitive strategies on perceived exertion when the workload is controlled.

Objective 3

Assess if using the cognitive strategies of association and dissociation while running affect the central nervous activation.

Objective 4

Since, the present study will control the use of the cognitive strategies in real time; we also want to analyze task effectiveness as an indicator of the effect of physical exercise on cognitive processes.

3. METHOD

3.1. PARTICIPANTS

The sample for this study included thirty (eight women) long distance runners members of the “Agrupación Deportiva Maratón” a club with a history of more than 55 years. Aged range from 18 to 50 years ($M = 32.87$, $SD = 8.15$). Participants maximum oxygen consumption ($M = 53.90$, $SD = 7.51$ ml/kg/min), they were experienced runners with an average of 10.93, $SD = 8.21$ years of formal practicing long distance running. All participants trained under the guidance and control of professional trainers at their club, they were competing at local and national level.

Long distance runners were defined as those who regularly run more than 10 km (Benyo & Herderson, 2002). The inclusion criteria required that participants trained regularly at least two times per week and compete in 10 km (50% of participants), half marathon (33%) and marathon (17%) distances, being free of any disease, and not taking any medication that can influence nervous system functions, and had a normal or corrected to normal vision. In order to keep a strict control, participants were excluded from the study if they did not complete the three experimental sessions over a time period of ten days.

Figure 1. Flow chart of study participants.

Flow-chart for the 30 participants is presented in Figure 1, the complexity of the design with three sessions in different days caused an experimental mortality of eight runners from session 1 to session 3.

The research was conducted at the Complutense University of Madrid Physical Education and Sports Medicine School's Exercise Physiology Laboratory with the valuable help of the Senior and Junior medical staff.

The study was conducted in accordance with the code of ethics on human experimentation established by the declaration of Helsinki (1964) and amended in Seoul (2008). All participants provided written informed consent before participating in the study.

Sample size was calculated using the study of Schücker et al., (2009) as reference, we use the same variable of oxygen consumption (VO_2) during both conditions their results were: internal focus ($M = 39.19$, $SD = 4.38$ ml/kg/min) and external focus ($M = 42.80$, $SD = 5.16$ ml/kg/min) using the equation $n = 2(Z\alpha + Z\beta)^2 \cdot (S1^2 + S2^2)/d^2$. Result was $n = 29.48$.

3.2. DESIGN

We used a within-subjects design that allows us to experimentally analyse the effect of cognitive strategies on oxygen consumption, perceived exertion and central nervous activation. With this design it was possible to reduce the variance error of individual differences.

In order to overcome the design limitations of past studies (Brick et al., 2014), where participants had to perform associative: focus on breathing and focus on movement and dissociative: focus on a video) at the same session (Schücker et al., 2009, 2013) we

conducted two sessions at different days. One session for the associative strategy and one session for the dissociative, the order of the session was counterbalanced.

Considering that exercise duration and intensity play a key role on the effect of central nervous activation (Davranche & Audiffren, 2004; Tomporowski, 2003) and taking into account the results of previous experimental studies and with the purpose to obtain valid data we set the duration of the session at 55 min and the workload at a moderate intensity calculated by the ventilatory threshold. At this speed, participants will be able to run during the whole session. In addition, 55 min run can be considered as natural for trained long distance runners (Benyo & Henderson, 2002). In order to assess the effect, with an experimental approach, of cognitive strategies and oxygen consumption, we consider that it was necessary to increase the session duration time to obtain more data. The current design differs from previous studies in three key elements. First, it was conducted during three different days. Second the duration of each session was higher than any of the previous studies (Brick et al., 2014) and third, based on previous studies was possible to calculate the study sample size.

3.2.1. MEASURES

Background, preferred cognitive strategy and demographic interview:

This interview was designed specifically for this study to obtain qualitative data (see Appendix I and II). We included information related to their running background (preferred distance, coming races, injuries, and personal records), coming competition goals, last's week training workload, and the preferred cognitive strategy while running.

Post session interview:

At the end of each experimental session, participants completed an interview tapping their subjective assessment of the session (see Appendix III). This questionnaire included questions on the implementation and perceived difficulty of using the

requested cognitive strategies. We used this information to complete the data we will obtain with other tools. One of these questions was “I have difficulties using the associative/dissociative strategy”. Another question asked: “Rate the level of performance you consider you had achieve using the associative/dissociative strategy”. The answers were made on a scale ranging from 1 (“very low”) to 5 (“very high”). Although not an objective measure, it was considered useful to make a subjective indication of how well the attentional tasks were performed. Another part of the questionnaire assessed the subjective perception of how participants consider that using an associative/dissociative strategy help them to obtain a better running performance. Or if they consider that the attentional task had affect their natural style for running.

Central nervous activation:

The flicker-fusion frequency is regarded, next to other criteria (e.g. electroencephalogram, skin conductance responses) as an indicator for this central-nervous function capacity (Görtelmeyer & Wiemann, 1982). For this study we use the test form S1 (Schuhfried, 2001), which consists of the increasing and decreasing measuring modes. The two light diodes (58 cd/m^2), one for the left eye and one for the right, were presented simultaneously in the Flicker Fusion unit, the light stimulus are separated by 2.75 cm (center to center) with distance to eye of 15 cm and a viewing angle of 1.2 degrees. The flicker frequency increment (0.1 Hz/sec) changed in two ways: first, it increased from 10 to 80 Hz until the participant perceived fusion, which is call the Fusion Frequency (VF), and then decreased from 80 to 10 Hz until Flicker Frequency (FF) was detected. After a fovea binocular fixation, participants were required to respond by pressing a button on the Flicker Fusion Unit (SCHUHFRIED GmbH, Moedling, Austria) upon identifying the visual flicker (descending frequency)

and the fusion (ascending frequency) thresholds (Davranche & Pichon, 2005). They performed for practicing three alternately trials of each test, ascending (VF) and descending (FF), immediately they must perform eight trials for each test. The average of eight values, in hertz was used as an overall response using the Flicker/Fusion Frequency (FLIM) Software (SCHUHFRIED GmbH, Moedling, Austria).

Perceived exertion:

The Rating of Perceived Exertion (RPE; Borg, 1998,1982) was used as a measure of central (cardiorespiratory) and peripheral (local-muscular, metabolic) exertion during the exercise (Bolgar, Baker, Goss, Nagle, & Robertson, 2010; Cárdenas et al., 2017; Pandolf, Billings, Drolet, Pimental, & Sawka, 1984; Pandolf, 1982). The RPE is a 15 point category-ratio scale (see Appendix IV).; the odd numbered categories have verbal anchors. Beginning at 6, “no exertion at all,” and goes up to 20, “maximal exertion.”

Before testing, subjects were instructed on the use of the RPE scale (Noble & Robertson 1996, pp.77–81). Participants had to: (1) Understand the definition of RPE. (2)

“Anchor” the top and bottom perceptual ratings to previously experienced sensations of the easiest and most difficult exercise encountered. (3) Understand the subjective nature of the RPE scale; that there are no “right” or “wrong” responses.

We use the scale with the clear differentiation between central as peripheral perceived exertion following the recommendations of the medical staff and under the guideline of Borg (1982) for applied studies.

Oxygen consumption:

The steady-state oxygen consumption (VO_2) was measured continuously using a breath by breath procedure with a Vmax29c bxb metabolic & pulmonary analysis system (Sensormedics Corporation, California, USA). This automated device was calibrated

before each session using certified gases of known concentration (11.5% O₂ and 5.1% CO₂) and a 3.0 liters calibration syringe.

Heart rate:

Participants' heart rate was measured with an electrocardiogram (ECG) continuously during the whole session. For the present study, we only used the ECG recordings at every 5-min interval (Quest 12-lead ECGs, Quest BURDICK, INC. Milton, USA).

Figure 6 shows participants' heart rate evolution across the sessions.

Blood lactate concentration:

In the present study the Dr. Lange miniphotometer LP8+ (Dr. Bruno Lange GmbH; Berlin, Germany) was used to analyse the blood lactate concentration, this protocol requires that the blood must be hemolyzed in a reagent solution (Goodwin, Harris, Hernández, & Gladden, 2007).

Cognitive strategies:

For the associative task, participants were instructed to focus on the breathing process; this internal direction of attention has been effectively used by Schücker et al., (2009, 2013, 2014). Nevertheless, our task was different from the past studies, we asked participant to direct their attention towards the breathing process by counting sets of seven exhalations. When one set was completed they had to make a double click on the button A using the Zeemote controller. Throughout the gas analyser monitor, researchers were able to monitor each exhalation and check in real time if the task was been performed effectively. In addition, since every click made with the controller and every exhalation was recorded, it was possible to analyse the task effectiveness after each session. Dissociative task required that participants maintained an external attentional focus. In order to control if participants were effectively focusing on an external input, they were asked to focus on a color-word interference presentation that

was projected on a LCD screen (17 inches, AOC Monitors, Illinois, USA.) located at a 1.60 m height, in front of the treadmill (see Image 1).

Figure 2. Laboratory layout

We use four words (yellow, green, blue, red) written in four colors (yellow, green, blue, red). All runners were given the target word yellow written in red color letters. A total of 165 targets appeared three times per minute in no specific order. During the 55 min session 825 Words (4-s interval) were presented. Participants were instructed to make a double click (button A) with the Zeemote controller every time the target word appears during the presentation. This task was based on the Stoop Test (MacLeod, 1991);

however, we did not request to verbalize the color of the word as the test does.

Both, associative and dissociative tasks responses were monitoring and recording in real time through dynamic measure tools: MindFocus® mobile phone application

(O3WellBeing Solutions, Spain), this application was designed to registered clicks, with an exact time reference. In addition, the application offers the functionality of create new sessions and control those session by time, from 1 min to 60 minutes, through 5 min interval. Installed on a mobile phone (Nokia N95, 8GB, Nokia Corporation,

Helsinki, Finland) and synchronized with the wireless controller (Zeemote JS1®, Zeemote Technology Inc., United Kingdom) that served as a response device. The MindFocus® application allowed us to overcome the tools limitations of past studies (Brick et al., 2014). As Quintana et al., (2012) suggested using the MindFocus® application with the hand held controller showed to be effective tools for real time measuring of cognitions while running.

Figure 3. Zeemote JS1®

3.3. PROCEDURE

Assessment took place in three sessions: (1) incremental test to record the maximum oxygen consumption, (2) associative task, and (3) dissociative task. Sessions two and three were counterbalanced. All sessions were performed on different days at approximately the same time of the day. In order to avoid biased effects related to physical fatigue a severe inclusion criterion was established, if participants had competed or performed high intensity training during the 48 hours previous to the session, they were rescheduled for another day, within the 10 days period.

The first session served to record maximum oxygen consumption ($\text{VO}_{2\text{max}}$) which was used to compute the target speed at the ventilatory threshold (VT_1) for sessions two and three.

This threshold represents the point where acid lactate starts to increase above the rest level but does not exceed 2 millimoles per liter at a certain exercise workload (Orr, Greenn, Hughson, & Bennett, 1982). VT_1 can be considered valid indicator of a moderate workload (Jones & Carter, 2000; Tjelta & Enoksen, 2001). During this first session participants completed one incremental test, which consisted of a run to exhaustion to assess peak treadmill running speed. Before start running, participants completed the mandatory questionnaire of the exercise physiology laboratory. The purpose of this questionnaire was to obtain participants clinical history.

Following a brief warm-up, participants began running on a horizontal treadmill at 11 $\text{km}\cdot\text{hr}^{-1}$. Speed was increased by one kilometer per hour every minute until they were unable to continue.

Blood lactate concentration was measure immediately after the participants stop running. For this research we use the h/p/ Cosmos treadmill (h/p/Cosmos sports & medical GMBH, Traunstein, Germany).

In addition, during this session participants familiarized with the Rating of Perceived Exertion scale (RPE; Borg, 1998, 1982) and the physiological measure devices such as the gas analyzer mask and the heart rate electrodes. The schedule of the two experimental sessions was organized after this session. Since it was mandatory to avoid participating in competitions and perform high intensity training sessions before session two and three, if participants request it we re-schedule. The study was carried out for a period of 12 months, a total of 122 sessions were performed.

The critical flicker fusion test was carried out before and after sessions 2 and 3 in an office next to the laboratory. After the pre session interview, participants sat in front of the Flicker Fusion Unit (SCHUHFRIED GmbH, Moedling, Austria). The testing time is around ten minutes.

Before Session 2 and 3, before participants start to run, they completed the pre session questionnaire, special attention was directed to last week training sessions and if it was some impediment to match with the inclusion criteria. Participants were also briefed about the definition of cognitive strategies of association and dissociation, the questionnaire included questions related to their preferred strategies while running. Since some authors have suggested that if runners are forced to use a different strategy of what their normal use can affect perceived exertion (Masters & Ogles, 1998; Salmon et al., 2010) we want to consider every detail that can explain the obtained results, and reduce the methodological limitations.

In addition to this questionnaire, we assured that the rating of perceived exertion before running was 6 (not exertion at all).

The researcher team was formed by at least 3 members during all sessions, two Senior sport medicine experts, at least one Junior sport medicine expert and the sport psychologist. Each member of the team had specific tasks during the sessions. In order to reduce at the minimum the interaction with the participants while they were performing the attentional task, which imply a distraction, the research team was aware of comment the minimum.

Once at the exercise physiology laboratory, the medical team proceeded to prepare every runner for the session, heart rate electrodes and the oxygen consumption mask were collocated and all the tools were checked before the start of the session.

MindFocus® application and Zeemote® controller were synchronized. All sessions were recorded at the mobile phone memory for further analysis. Participants were informed of the exact exercise duration and the workload speed before each session. Due to the stricter requirements of the experimental protocol we informed that the session cannot be interrupted, and each participant must complete the 55 min protocol. Only one of the participants (none of the 30 study participants) was not able to complete one of the experimental sessions.

During Sessions 2 and 3, participants performed a 55 min treadmill run at a speed corresponding to their ventilatory threshold plus a 3 min warming up at 3km•h⁻¹ lower than the target workload speed and a 3 min active cool down. Blood lactate concentration was measured four times, immediately after participants stop running, and at 3, 6 and 9 min after the 55 min protocol was completing.

In order to assess the effect of cognitive strategies on central nervous activation we set the warm-up duration in 3 minutes, sufficient time to stabilize the physiological parameters (Hagberg, Giese, & Schneider, 1978). RPE values (central and peripheral) were obtained every 5 min.

Before Session 2 and 3, participants completed the background questionnaire to verify the inclusion criteria reporting their last training sessions. After that, participants stand at the treadmill; all were instructed about the attentional task they were going to perform. Immediately prior to the start of the session, they were trained to operate the controller, which was used as a response device. For both sessions a task trial was performed, this trial also served to confirm that the controller and the MindFocus® application were effectively connected. Trials were not recorded. All athletes were briefed in the use of the RPE scale, and all indicated that they felt confident with its use

prior to the run. For the present research we used a RPE scale that was printed on a wood board of 40 x 70 cm.

While all the runners were standing on the treadmill, the following instructions were given: “every 5 min you will be asked to provide a measure of the perceived exertion, you only have to point to the number which represents how you are feeling, the first number is for central exertion and the second number is for peripheral.” “If at any point of the session you feel that you cannot run any longer let us know by saying the word, stop.” Our first assessment was at minute 5, after participants achieved a metabolic steady state (after ~4 min; Doherty, Smith, Hughes & Collins, 2001; Noble & Robertson, 1996). In addition to the task trial, for sessions 2 and 3, during the warm-up of 3 min a general practice of both attentional tasks was carried out. All medical devices were checked during this warm-up. Immediately after this general session trial, the researcher proceeded to set the timer (55 min) on the mobile application. Once the timer was set, the sport psychologist give the instruction to start, and the treadmill started to work at the VT1 workload speed. Oxygen consumption (VO_2) was measured during both sessions as an indicator of running economy (Sawyer et al., 2010). Heart rate was measured continuously during both sessions. Participants were informed of the fact that the task will be monitored. The mobile phone was located at left arm of the treadmill, since it was synchronized with the controller by Bluetooth® technology it was necessary that both devices were not placed far away from each other. Participants were not able to see the mobile phone’s monitor. In addition, they did not receive any feedback about the task effectiveness or running outputs (e.g. speed, VO_2 or time). During the session, the only researcher-participant interaction was for the RPE measures. The researcher took the RPE table and presented it in front of every participant. They only have to point out the number on the scale one for central one for

peripheral. To confirm the RPE measures researcher said the numbers aloud. During the RPE measurement, participants keep running at the session speed only the attentional task was interrupted. RPE measurement required less than 30 sec. In order to avoid disturbing the attentional tasks, researchers did not speak or commented anything that was not extremely necessary. With high precision tools as the ECG device that detects the minimal heart rate variability it was necessary to avoid any extra-protocol stressful situation (Appelhans & Luecken, 2006). With a controlled workload speed at a VT1, it was expected that the HR was stable during the session, any variability will showed valuable data about the relationship between the cognitive strategies and the central nervous activation (Acharya, Joseph, Kannathal, Lim & Suri 2006).

The MindFocus® application timer alarm sounded when the 55 min were completed, the last RPE measure was carried out. Immediately, the medical team proceed to the 6 min cool down protocol, reducing the speed gradually one kilometer per hour every minute. The researcher picked up the controller and proceeded to save the session at the MindFocus® application memory for posterior analysis. The cool down was not included at the attentional task protocol, and once completed the medical team proceeded to retire the ECG electrodes and the oxygen consumption mask. Participants immediately performed the post session Flicker Fusion test and the post session questionnaire. Only after the end of the questionnaire participants were allowed to eat and drink. The full session time was approximately of 1 h 30 min. We used a strict protocol that was only possible to be carry out at a full featured exercise physiology laboratory with the help of a medical team. In addition, it was very important that participants were trained long distance runners. Appendix V describes the briefing interview. The sessions' protocol is presented in Appendix VI.

4. RESULTS

4.1. Data Analysis

In order to analyse if participants were using the requested cognitive strategy, a percentage of task effectiveness was calculated. For the associative task, we compare participants' responses (total clicks) recorded with the MindFocus® mobile application, with the objective sets of seven exhalations recorded with the gas analyser (synchronizing with the controller at first double click). Dissociative task effectiveness was obtained comparing the number of targets recorded (total clicks per minute) with the total number of targets (per minute) during the presentation. Figure 2 shows participants' recorded and control responses across the sessions.

Average oxygen consumption (VO_2), perceived exertion (central & peripheral) and heart rate values from minutes 6-55 were calculated. Shapiro and Wilk's W test for normality was calculated for oxygen consumption (VO_2) for both associative and dissociative sessions, as well as in three different intervals (T1: minutes 6-20, T2 minutes 21-40, T3 minutes 41-55).

Wilcoxon Rank-Sum Test was used for statistical comparison of oxygen consumption (VO_2) during the associative and dissociative sessions, as well as intra session along three different moments (T1, T2, T3). Paired samples t-test was used to analyse differences between the RPE (central & peripheral) values inter experimental sessions. In addition to analyse the effect of the experimental session a paired samples t-test was used to compare the central nervous activation pre-post for both, flicker and fusion frequency. Cohen's effect sizes (d) were calculated when significant differences were observed. A one-way ANOVA was performed to analyse the effect of time on perceived exertion and participants' heart rate during both experimental sessions.

Alpha level was established at $p = .05$.

Blood lactate concentration after the experimental sessions was not including for the analysis. Considering the samples results, and under the advice of the Senior medical staff, whom determined that the obtained blood lactate concentration was not valid in most of the cases. Descriptive means and standard deviations are presented for all variables.

4.2. Task effectiveness:

During the associative session a mean of 225.50 ($SD = 47.33$) sets of seven exhalations were registered. Participants focused on an average of 1578.50 ($SD = 332$) exhalations. A total of 825 words (165 targets) were displayed during the dissociative session. The results showed that a mean of 158.70 ($SD = 5.97$) targets were registered. Sessions' task effectiveness percentages are presented in Table 3.

Figure 4. Registered and control responses across the sessions.

Table 3. Average task effectiveness, perceived exertion related to cognitive strategies

Variables	Cognitive Strategies	
	<i>M (SD)</i>	
	Associative	Dissociative
Task Effectiveness (%)	94.47 (5.00)	96.18 (3.53)
RPE Central	10.58 (2.13)	10.65 (2.33)
RPE Peripheral	10.65 (2.33)	10.79 (2.17)

Note. $N = 30$; RPE = rating of perceived exertion.

With tasks effectiveness higher than 94% for a 55 min run it is possible to consider that participants' attention was effectively directed to the attentional task for every session. Those percentages represent a task adherence of more than 51 min for each session. The protocol used to control the use of cognitive strategies has shown to be effective in order to assess and control the task adherence while running. The present study showed that cognitive performance was efficient in both attentional tasks, despite the moderate exercise intensity performed for 55 min.

4.3. Oxygen consumption

Due to an error caused by the gas analyser that registered oxygen consumption values that were considered totally out the normal range of values for that participant, and as recommended by the Senior medical staff, one runner was excluded from the analysis. Average oxygen consumption during the sessions (total and for three time intervals) are presented in Table 3. Shapiro and Wilk's W test for normality showed that oxygen consumption during associative session was not normally distributed ($p = .04$), the same

result was found on that session during T1 ($p = .04$). Dissociative values of oxygen consumption and intra session associative T2 and T3 were normally distributed ($p > .05$).

Figure 5. Evolution of oxygen consumption values across the sessions.

Wilcoxon Rank-Sum Test for two samples (associative and dissociative conditions) showed no differences in oxygen consumption between the two experimental sessions see Table 4. During the sessions, participants' oxygen consumption was stable. These results confirm that the exercise workload was effectively controlled at VT1 intensity. Moreover, since no differences were found between the sessions, it is clear that an associative task of focusing on breathing (exhalations) did not modified the natural breath cycle. Consequently, none of the cognitive strategies affected participants' running economy. Figure 3 illustrated the course of oxygen consumption during both sessions.

Table 4. Average oxygen consumption during the experimental sessions and Wilcoxon Rank-Sum Test results

Oxygen consumption ^a				
Time Intervals	<i>M (SD)</i>		<i>Z</i>	<i>p</i>
	Associative	Dissociative		
T1 (minutes 6 to 20)	37.49 (4.65)	38.06 (4.41)	.00	1.00
T2 (minutes 21 to 40)	38.04 (4.70)	38.84 (3.48)	-.61	.53
T3 (minutes 41 to 55)	38.46 (5.08)	39.05 (3.82)	-.09	.92
Total (minutes 6 to 55)	38.00 (4.69)	38.65 (3.63)	-.52	.60

Note. $N = 29$; ^a = ml/kg/min.

4.4. Perceived Exertion

Shapiro and Wilk's W test showed a normal distribution for RPE values in both associative (central, $p = .91$, peripheral, $p = .42$) and dissociative conditions (central, $p = .50$, peripheral, $p = .61$). Perceived exertion values (central & peripheral) for minutes 5 to 55 are presented in Table 2. The paired samples t-test reveals that there were no differences in RPE values between the associative and the dissociative sessions (central, $t = -.53$, $p = .59$; peripheral, $t = -.40$, $p = .68$). The use of cognitive strategies of association (focus on breathing) and dissociation (focus on a color-word interference

presentation) did not affect participants' perceived exertion values. Figure 6 and 7 illustrated the course of the participants' perceived exertion during both conditions. RPE values increased over the session; this resulting time effect on perceived exertion could be due an accumulated session's fatigue. In order to analyse this effect a one-way ANOVA was performed. We established three time intervals T1 (minutes 5 to 20), T2 (minutes 21 to 40), T3 (minutes 41 to 55) for each of the RPE measures, in both conditions. Alpha level was set at $p = .05$.

There was a statistically significant differences along the three time intervals as determined by one-way ANOVA for the Associative task: RPE central ($F_{(2,87)} = 11.36, p = .000$) and RPE peripheral ($F_{(2,87)} = 9.79, p = .000$). A Tukey post hoc test revealed that central and peripheral perceived exertion increased over associative session T2 (central $10.87 \pm 2.26, p = .01$, peripheral $10.93 \pm 2.55, p = .03$) and T3 (central $12.09 \pm 2.93, p = .000$, peripheral $12.15 \pm 2.97, p = .000$) compared with T1 (central $9.15 \pm 1.88, p = .01$, peripheral $9.26 \pm 1.98, p = .03$). There was no statistically significant difference between T2 and T3 (central $p = .12$, peripheral $p = .15$).

For the Dissociative task the one-way ANOVA revealed significant time effect. RPE central ($F_{(2,87)} = 10.70, p = .000$) and RPE peripheral ($F_{(2,87)} = 11.24, p = .000$). Tukey post hoc test revealed that central and peripheral perceived exertion increased over dissociative session T2 (central $11.00 \pm 2.48, p = .01$, peripheral $11.00 \pm 2.42, p = .03$) and T3 (central $12.11 \pm 2.86, p = .000$, peripheral $12.36 \pm 2.86, p = .000$) compared with T1 (central $9.20 \pm 1.93, p = .01$, peripheral $9.26 \pm 1.98, p = .03$). There was no statistically significant difference between T2 and T3 (central $p = .19$, peripheral $p = .08$).

Figure 6. Evolution of central perceived exertion values across the sessions.

Figure 7. Evolution of peripheral perceived exertion values across the sessions.

Figure 8 shows the evolution of participants' heart rate, it is interesting that heart rate increases over time despite the session workload was at the same speed. Moreover, oxygen consumption did not change across the session. In order to analyse if the cognitive task had an effect on heart rate we compare participants' heart rate at each of the two sessions, at three time intervals, as with oxygen consumption, T1 (minutes 5 to 20), T2 (minutes 21 to 40), T3 (minutes 41 to 55) for heart rate, in both conditions.

Alpha level was set at $p = .05$.

The Kolmogorov-Smirnov's test showed a normal distribution for heart rate values in both associative (T1, $p = .88$, T2, $p = .45$, T3 $p = .39$) and dissociative tasks (T1, $p = .89$, T2, $p = .97$, T3 $p = .81$). The paired samples t-test reveal that there were no differences in heart rate values between the associative and the dissociative sessions during the same time interval T1 ($t = .12$, $p = .90$), T2 ($t = .88$, $p = .38$), T3 ($t = -.22$, $p = .82$). Using the same workload for both sessions, there were no differences on heart rate and oxygen consumption, these results let us consider that the exercise workload was effectively controlled. Nevertheless, Figure 6 suggests a time effect on participants' heart rate, due to the importance of fatigue on the cognitive process and central activation we analyse this data with a one-way ANOVA.

The one-way ANOVA analysis showed a time effect on participants' heart rate during both experimental conditions. Associative session ($F_{(2,87)} = 12.83$, $p = .000$), Dissociative session ($F_{(2,87)} = 11.07$, $p = .000$). A Tukey post hoc test revealed that heart rate increased across the time intervals during both sessions T2 (associative 156.59 ± 9.95 beats, $p = .00$, dissociative 155.63 ± 11.82 beats, $p = .01$) and T3 (associative 160.46 ± 11.28 beats, $p = .00$, dissociative 160.81 ± 11.02 beats, $p = .000$) compared with T1 (associative 147.19 ± 9.99 beats, $p = .00$, dissociative 147.03 ± 11.52 beats, $p =$

.01) There was no statistically significant difference between T2 and T3 (associative $p = .32$, dissociative $p = .19$).

Figure 8. Evolution of participants' heart rate across the sessions.

4.5. Central Nervous Activation

The Kolmogorov-Smirnov's test showed a normal distribution for CFF values in both associative (VF Pre, $p = .89$, VF Post, $p = .72$, FF Pre, $p = .75$, FF Post, $p = .46$) and dissociative sessions (VF Pre, $p = .63$, VF Post, $p = .82$, FF Pre, $p = .59$, FF Post, $p = .44$). CFF values (Fusion & Flicker) are presented in Table 5. After the session, an increase of Fusion and Flicker frequencies for both associative and dissociative conditions were observed (see Figure 9 & 10). The paired sample t-test reveals the effect of the exercise-attentional task, specifically, an increase on the dissociative' Fusion frequency ($p < .005$) (from 37.39 ± 2.57 Hz to 38.16 ± 2.65 Hz), and on the associative ($p = .03$) Flicker frequency, increasing from 38.78 ± 3.11 Hz to 39.36 ± 2.86 Hz. No significant effect was observed for associative' Fusion frequency ($p = .08$) and

dissociative' Flicker frequency ($p = .41$). Based on Cohen's (1977) criteria, where less than .50 is considered small (Brand, Bradley, Best, & Stoica, 2008) Cohen's effect sizes showed small effects for these differences in CFF (VF Associative, Pre vs. Post, $d = .18$; VF, Pre vs. Post, $d = .30$; FF Associative, Pre vs. Post, $d = .19$; FF Dissociative, Pre vs. Post, $d = .17$). These results showed that the CFF base-line was the same before both sessions. Consequently, is possible to argue that participants had the same central nervous activation, before each session. As the session order was counterbalanced there was not an order effect, but a session effect. In addition, as the CFF threshold did not decrease after the sessions, the results showed that there was not a session induced central fatigue. It is interesting that RPE values increased over time for both sessions, despite that oxygen consumption and central nervous activation was stable and did not significant change across and pre-post the sessions.

Table 5. Critical flicker fusion test values, pre-post for associative and dissociative sessions.

Time Intervals	CFF Test		t	p
	<i>M (SD)</i>			
	Pre	Post		
VF Associative	37.67 (2.74)	38.15 (2.55)	-1.80	.08
VF Dissociative	37.39 (2.47)	38.16 (2.65)	-3.43	.002
FF Associative	38.78 (3.11)	39.36 (2.86)	-2.26	.03
FF Dissociative	39.34 (3.60)	39.93 (3.18)	-.83	.41

VF = Fusion frequency, FF = Flicker frequency

Figure 9. Pre and post sessions Fusion frequency values.

Figure 10. Pre and post sessions Flicker frequency values.

Accordingly the 55 min run can be consider as a valid protocol for the study of cognitive strategies, perceived exertion, running economy and central nervous activation. Furthermore, when performed at the same time, a cognitive task and a moderate workload run, the CFF showed an increased central nervous activation.

5. DISCUSSION

The general purpose of the present study was to experimentally assess the effect of cognitive strategies of association and dissociation in long distance runners. Since no study had control the direction of the attention in real time we designed two attentional tasks, one associative and other dissociative, in which participants were required to maintain their attentional focus intentionally throughout the session while they run at a controlled moderate speed.

Using dynamic measure tools was possible to control in real time, if participants effectively performed the assigned cognitive strategies, without using verbalization or retrospective approach thus overcoming the methodological limitations of past studies. Through this design we worked on specific purposes: 1) assess the effect of cognitive strategies on perceived exertion, 2) analyze the effect of association and dissociation tasks on oxygen consumption and 3) assess the effect of using the cognitive strategies on central nervous activation. Since, the present study will control the use of the cognitive strategies in real time; we also analyzed task effectiveness as an indicator of the effect of physical exercise on cognitive processes.

5.1. Task effectiveness

Cognitions are internal and not directly observable, the stream of cognitions while running is dynamic switching from thoughts to sensations and emotions (Hutchinson & Tenenbaum, 2007, Quintana et al., 2012). In the present study was possible to control if participants were using the requested associative and dissociative strategy during every session.

Our results showed that participants maintained their cognition's direction despite that perceived effort increased along the session. We demonstrated that at moderate exercise workload, tasks designed to maintain participants' attentional focus toward specific

stimuli that required a motor behaviour was possible during 55 min. Contrary to what Balagué et al. (2012) have proposed, in our study participants effectively maintained the requested attentional focus. For these authors, cognitions stream is affected by the accumulating effort compromising the effectiveness of the attentional tasks.

Nevertheless, previous studies (Balagué et al., 2012; Garcia, Razon, Hristovski, Balagué, & Tenenbaum, 2015) used a retrospective interview to assess the direction of cognitions while running, we consider that this methodology is not as accurately than objective attentional tasks.

Our attentional tasks required that participants focused on stimuli that appeared within a few seconds: associative task, one exhalation almost every 2 seconds and dissociative task one visual stimuli every 4 seconds during the 55 minutes of the session. That is 20 minutes more than all the studies so far (see Table 2). Responses for every minute were analysed to obtain task effectiveness, for associative (94%) and dissociative (96%) sessions, it is possible to consider that participants' attention was effectively directed to the attentional task during each session. Those percentages represent a task adherence of more than 51 min per session. The obtained results show that it was possible to design and control two attentional tasks. This methodology can be considered as suitable and effective for analysis of cognitions while running. Since controversies related to methodological issues and taking into account the results of the present study, we consider that the use of pencil paper questionnaires can be a useful complementary tool to get deep conclusions of the results obtained via more accurately tools. It is worth to mention that Morgan and Pollock (1977) performed clinical interviews ranging from 45 minutes to 1 hour. During these interviews the authors asked elite marathon runners to describe what they used to think about during a long distance run, based on the responses these authors were able to distinguish between the two cognitive strategies.

As Gould (2002) has commented, both qualitative and quantitative methods are needed to improve our understanding in sport psychology research.

5.2. Oxygen consumption

The steady-state oxygen consumption (VO_2) at a set speed, known as running economy, has been considered as a valid performance criterion in long distance running (Daniels, 1985; Morgan et al., 1989; Sawyer et al., 2010). From a practical point of view a good running economy allows athletes to use less O_2 at the same speed (Thomas et al., 1999). In addition, oxygen consumption is an objective measure that can be effectively studied at a physiology laboratory through the metabolic and pulmonary analysis system.

We hypothesized, based on past studies conclusions (Schücker et al., 2009), that an associative task that request runners to focus their attention on breathing will increase oxygen consumption and consequently reduce running economy. Our results not support the hypothesis, showing that during the associative and dissociative sessions oxygen consumption was stable. No differences were found between the two attentional tasks. Participants consumed the same amount of oxygen for the set speed at VT1, no matter if their attention was directed on their breathing or on a visual presentation. This lack of differences showed that running economy was not affected by the use of cognitive strategies. These results are opposed to the results of past studies (Schücker et al., 2009, 2013, 2014) where it has been concluded that focusing on the breathing process alters its natural cycle, reducing running economy by increasing oxygen consumption at a set speed. We further assume that some of the controversies about the effects of cognitive strategies and running economy can be explained by the used

methodology so far, which could be the cause of the effects and not the method to analyse the causes.

The breathing process while running is complex (Ward, 2014) and there is not a clear explanation of why the breathing pattern would be affected by the cognitive strategies. Moreover, when the increase in the respiratory rate known as hyperpnea (Foster et al, 2012) naturally occurs during exercise it seems really interesting to understand why Schücker et al. (2009, 2013, 2014) assessed the oxygen consumption impairment due to the focus of attention towards breathing. It seems controversial that the instruction of focus on breathing in an out will have such effect. Only the research of the effect of breathing on stress management had offer an explanation showing that focusing attention on breathing significantly reduce respiratory rate and alters the tidal volume (Conrad et al., 2007; Sasaki & Maruyama, 2014). Nevertheless, Schücker et al. (2009, 2013, 2014) results suggest that attentional focus not only have an effect on running economy but can also alter the natural breathing pattern while exercising. Our data not support this hypothesis. In our study we used a similar exercise workload to Schücker et al. (2009) the big difference was the attentional task instruction. Since past studies instructions required participants to focus on breathing in and out, we considered that selected only one process was needed. First, because it will be more accurately to control task adherence if we only selected one of the two breathing processes. Second, based on our experience, we considered that focused attention on exhalations will be easier for participants since focusing attention on counting sets of inspirations could imply a short pause between each inspiration. Since the measure tools offer us the possibility of using both processes we choose the one we consider more ecological for our purpose. In addition, controversies about the effects of cognitive strategies on long distance running has derived from methodological limitations (Brick et al., 2014) and

specially the lack of control of the attentional focus (see Table 1). In order to overcome those limitations it was needed to control the associative task with the greatest possible accuracy. An ambiguous instruction of focusing on breathing in and out did not offer the control this research needed. Moreover, Schücker et al. (2009, 2013, 2014) discuss that their results showed that focusing on breathing increase oxygen consumption and consequently reduce running economy nevertheless, is not clear if this effect was due to focusing on inspirations or exhalations. Breathing with such clear processes as inspiration and exhalation offers two study directions. We choose to follow the exhalation process while Schücker et al. (2009, 2013, 2014) did not specify which direction they follow. Based on our data we consider that the lack of task adherence control in real time during past studies could bias the obtained results.

In the present study the instructions of focus on breathing by counting sets of 7 exhalations did not increase the oxygen consumption. We consider as positive that our data not support the hypothesis that focusing on breathing increase oxygen consumption because if the breathing pattern while running at a controlled workload is affected by the use of cognitive strategies it would imply a step forward in the exercise physiology' field, challenging conclusions derived from specific studies on breathing dynamics while exercising (Ward, 2007, 2014).

Since Morgan and Pollock interviews (1977), the cognitive strategy of association was related to bodily inputs such sensations and feelings of the legs, but also to the breathing process. Moreover, in their study when comparing marathon runners ($n = 8$) with middle distance runners ($n = 11$) these authors suggested that the marathon runners' oxygen consumption was less compared to middle distance runners when they ran at a speed of 10 miles per hour. This difference was attributed to their associative process while running, directing their attention to their pace and by been consciously focus on

relaxation. Morgan and Pollock (1977) suggested that associative strategy was in part responsible for the better running economy of elite distance runners. Their conclusions were not based on an experimental protocol. However those conclusions are in line with the research of stress management (Conrad et al., 2007; Sasaki & Maruyama, 2014). In our study, the effect of associative strategy on the decrement of running economy was not observed. Moreover, since oxygen consumption was stable during the sessions, even at the end stage of the session (T3), our instruction did not alter the natural breathing response.

There is no doubt that breathing is an automatic process (Forster et al., 2012; Mateika & Duffin, 1995; Sasaki & Maruyama, 2014; Ward, 2014) and asking participants to consciously focus on breathing can alter the natural cycle as Schücker et al., (2009, 2013, 2014) have discussed. Nevertheless, we demonstrated that focus on breathing as an associative strategy has no effect on running performance, when the instruction is to focus on exhalations.

Ziv et al., (2012, 2013) founded that there were no effects on running economy between internal vs. external attentional focus, these authors used a different internal attentional focus condition (focus on movement). In spite of these results, it is necessary to comment the methodological differences. It is not clear if focus on movement can be considered as a purely internal focus instruction (Brick et al., 2014). In addition, Ziv et al., (2012, 2013) participants were not trained long distance runners, they used basketball players ($n = 17$) and physical education students ($n = 20$) which may be not a representative population.

In the studies of Schücker et al. (2009, 2013, 2014) and Ziv et al., (2012, 2013) the intervention was carried out in just one session. Participants had to perform both attentional tasks in an integrated session, this could affect oxygen consumption. Even if

the sessions were counterbalanced it might not be the most accurate protocol. In our study we performed two sessions, one for each cognitive strategy. Moreover, exercise duration was higher during our study in order to assess a possible fatigue effect on oxygen consumption and avoid biased results.

It is worth to mention that during past studies the use of cognitive strategies of association and dissociation was not measured directly and there is not an objective measure that confirms how many of the participants really used the requested strategy during the research sessions. With a task effectiveness of 94.47% for associative condition and 96.18% for dissociative, we were able to assess if participants were really using the requested cognitive strategies. These results are higher than the retrospective attention manipulation checks performed so far. Schücker et al., (2009) manipulation checks revealed a task adherence of 85% of the time for the internal focus: breathing and 90% for external focus: video. Schücker et al., (2014) internal focus: breathing 79%. Ziv et al., (2013) reported that during their study participants followed the attentional instructions 78% of the time. Despite those tasks' adherence values were not considered as limitations, such percentages do not guarantee that the lack of complete task adherence control did not biased the results.

5.3. Perceived Exertion

As an endurance sport, long distance running is an activity where performance is governed by the physical capacities as well by the willingness of the athletes to tolerate the discomfort associated with the physical work (Morgan & Pollock, 1977). Perceived exertion has been considering as the cardinal reason to stop exercising (Marcora & Staiano, 2010).

The effect of cognitive strategies on perceived exertion has shown opposite results (Masters & Ogles, 1998; Salmon et al., 2010). Given the role of attentional focus in how the perception of effort is integrated, it has been suggested that it would operate as a filter of the physiological inputs derived from physical activity (Baden et al., 2004; Masters & Ogles, 1998; Morgan, Horstman, Cymerman & Stokes, 1983; Salmon et al., 2010; Schomer, 1986; Tammen, 1996). Nevertheless, conclusions derived from past studies have not offered an overwhelming explanation of how the use of cognitive strategies can mediate the perceived exertion response under controlled conditions. Particularly, when perceived exertion has been used as a dependent variable, manipulating the attentional focus without control may confound the obtained results (Brewer & Buman, 2006). Three theoretical models have been considered to understand the effect of cognitive strategies on perceived exertion (Brick et al., 2014) but none of them has been tested while controlling the physical variable (exercise workload) and the use of cognitive strategies. Task adherence was controlled mainly with a retrospective approach, and in few cases the use of a particular attentional focus was measured in real time but with high invasive methods as the think-aloud protocol (Ericsson & Simon, 1980; 1993) that can biased the results (Salmon et al., 2010).

We hypothesized that there will be no differences in perceived exertion values if both cognitive strategies required runners to focus their attention constantly toward the attentional tasks. Our results support the hypothesis showing that cognitive strategies did not affected perceived exertion when both exercise workload and the use of association and dissociation were controlled. No differences between the associative and dissociative session were observed in both central and peripheral RPE values (see Table 3). Given the obtained results we consider that is possible that perceived exertion is independent of cognitive strategies. The lack of differences between the two sessions

is contrary to what has been proposed by other authors (Baden et al., 2004; Masters & Ogles, 1998; Morgan et al., 1983; Salmon et al., 2010; Schomer, 1986; Tammen, 1996). Nevertheless, conclusions of past studies did not derive from experimental designs. Our results seemed opposed to the proposal that attentional focus has a mediating effect over how the perception of effort is integrated (Baden et al., 2004; Masters and Ogles, 1998; Morgan et al., 1983; Schomer, 1986; Tammen, 1996). Scientific literature had assumed that attentional focus can serve as a filter of physiological stimuli (Baden et al., 2004; Masters and Ogles, 1998; Morgan et al., 1983; Salmon et al., 2010; Schomer, 1986; Tammen, 1996) and consequently, manipulating attentional focus will improve endurance performance, or increase exercise tolerance by reducing the RPE (Salmon et al., 2010). Rejeski's model (1985) based on Leventhal and Everhart's (1979) parallel processing model of pain, establish that the information which does not occupy the focal awareness would not be part of the perceived exertion response, due to the limited capacity channel. According to Leventhal and Everhart's (1979) model the conscious awareness of pain perception depends of attentional focus, if the attentional channel is occupied by other stimuli effort or pain perception will be processed on a preconscious level, therefore the use of a cognitive strategy will have an impact over the pain or perceived exertion response. This model has been proposed as the most theoretically solid (Brewer & Buman, 2006) and has been used by other authors to explain the suggested effect of cognitive strategies (Baden, McLean, Tucker, Noakes, & St Clair Gibson, 2005; Brick et al., 2014; Rejeski, 1985; Rejeski & Kenney, 1987). Our results showed that participants had a task effectiveness of 94 % during the associative session and 96% for the dissociative. These results showed that participants had a task adherence of more than 51 min per session, thus we can consider that the attentional focus was occupied by the task in hand. As proposed by Rejeski's model (1985) based

on Leventhal and Everhart's (1979) model, both cognitive strategies can be effective for decreasing or increasing the perceived exertion by the amount of attention directed to the attentional task. Presumably, the information which competes with cues arising from physical exertion, in terms of occupying attentional focus, as the attentional tasks in our study, will reduce perceived exertion. Nonetheless, this perspective considers perceived exertion as a static construct. This proposed effect was not demonstrated in our study. Although attentional focus was stable and voluntarily directed to the attentional tasks (associative or dissociative), the rating of perceived exertion did not decrease or increase.

Recent studies (Marcora & Staiano, 2010; Williams et al., 2016) have demonstrated that perceived exertion is a dynamic construct, suggesting that the RPE response is independent of the physiological information and it seems that when the workload is controlled at a moderate intensity perceived exertion response can be also independent from the attentional focus.

Particularly, our results showed that RPE values increased during the sessions in both associative and dissociative (see Figures 6 & 7). It is interesting because the exercise workload was steady and controlled at the VT1 speed along the sessions.

The increase of RPE values (central & peripheral) could be due to an accumulated fatigue or a time effect. It has been suggested that RPE increases as the exercise final point is approaching, no matter if the workload did not change (Baden et al., 2004, Baden et al., 2005; Marcora et al., 2009). Our results are in line with these authors, during our sessions with no changes in exercise workload, with stable oxygen consumption values, participants RPE values increased along the session with the maximum RPE values at the end of the session. It is worth to mention this time effect since on the original studies of perceived exertion (Borg, 1970) RPE increased linearly

with the workload, but the time was not considered. Moreover, heart rate also increased with time (see Figure 8) but it was not directly related to the exercise workload, which remained stable during the sessions. If we consider the high correlation between perceived exertion and heart rate (Borg, 1982; Mihevic, 1981) it is not surprising that these two variables behave the same during the experimental sessions. In addition, to control the sessions' exercise duration and workload, we did not give to participants any feedback related to the session time. Only at the beginning of each session, before starting the run, they were given the RPE instructions. During the sessions briefing all participants were informed that the run will last 55 minutes, and that every 5 min they will request to indicate their central and peripheral RPE values; however during the session none of them received any feedback about the remained time to avoid the final point effect. Our results are in line with those obtained by others researchers (Baden et al., 2004, 2005; Eston, Faulkner, St Clair Gibson, Noakes, & Parfitt, 2007) where RPE increased in a linear manner throughout a constant-load exercise bout and attained the same RPE at the end of exercise, independently of the exercise duration.

Assess the effect of time over perceived exertion was not included in our study purposes. Nevertheless, we consider that is really interesting to mention that instead of having a cognitive strategies effect it was time the variable that increased RPE values. Such effect has not been considered when the Leventhal and Everhart's (1979) parallel processing model of pain was applied to perceived exertion. Considering perceived exertion independently from cognitive strategies it has been suggested that performing cognitive tasks as the ones of our study can lead to a mental fatigue that can impact directly on the RPE (Marcora et al., 2009). In the present study participants focused on stimuli that appeared within a few seconds: associative task, one exhalation almost every 2 seconds and dissociative task one visual stimuli every 4 seconds during the 55

minutes of the session. A cognitive task that required sustained attention and error monitoring may lead into a mental fatigue state, consequently affecting perceived exertion. Nevertheless, research on the mental fatigue effect have used a different methodology, in these studies, mental fatigue was induced before the exercise session, not during. The time effect on perceived exertion and heart rate showed by our results may suggest an accumulating fatigue issue. Nonetheless, with tasks effectiveness values higher than 94% it can be considered that task performance was unaffected during the experimental sessions. We consider that even if our tasks required sustained attention, stimuli discrimination, motor behaviour (for both cognitive strategies) and error monitoring (mainly for the dissociative task) it is not possible to consider a mental fatigue effect on perceived exertion. If mental fatigue would have occurred, the task effectiveness will be lower. We designed both attentional tasks with similar cognitive workload to avoid biased results. Moreover, post session CFF test revealed that the central nervous activation was not negative affected by the sessions. If a mental fatigue effect would be presented the CFF test will reflect it. Post session interview revealed that 93% of participants ($n = 28$) did not perceived difficulties to perform the associative task, for the dissociative task that percentage is 86% ($n = 26$). In addition to the objective task effectiveness, post session interview revealed that 84% of participants ($n = 25$) consider their performance during the associative session as positive, 10% considerer that the performance was very high, only 16% considered their performance as slightly low. Contrary, for the dissociative task 100% of participants considered that their performance was positive, 20% ($n = 6$) reported a very high performance. Participants were not given any feedback about their objective task performance. There is no data in our study that can suggest a cognitive fatigue effect on perceived exertion.

Tenenbaum and Connolly (2008) stated that RPE is not the product of the attentional process but the attentional process, in particular the switch from associative to dissociative, is the product of exercise intensity. The research on this issue has been consistent (Hutchinson, 2011; Tenenbaum, 2001; Tenenbaum & Connolly, 2008). In addition, if intensity plays a key role in the use of cognitive strategies, past researchers that have showed that associative strategy was used mostly during competition (Bachman, Brewer, & Petitpas, 1997; Heffner, 2006; Ungerleider, Golding, Porter, & Foster, 1989) and dissociative for training sessions (Morgan, O'Connor, Ellickson & Bradley, 1988; Okwumabua, 1985; Okwumabua, 1987; Schomer, 1986, Stevinson & Biddle, 1998) had contributed to support Tenenbaum's (2001) model. However these conclusions were obtained from correlational methodologies and do not offer an overwhelming explanation. Post session interviews revealed that 63% of participants ($n = 19$) preferred the associative strategy for competition, in comparison only 20% used it for training sessions. Contrary, 36% ($n = 11$) used dissociation as their preferred strategy for competitions and 80% ($n = 24$) used this strategy for their training sessions. Our results are in line with the ones obtained in past studies (Bachman, Brewer, & Petitpas, 1997); Heffner, 2006, Morgan, O'Connor, Ellickson & Bradley, 1988; Okwumabua, 1985; Okwumabua, 1987; Schomer, 1986, Stevinson & Biddle, 1998; Ungerleider, Golding, Porter, & Foster, 1989). Morgan and Pollock (1977) interviewed marathon runners, this landmark study served as the base of the dichotomous model of cognitive strategies. One implied monitoring sensory input and the other referred to directing attention away from sensory input to external stimuli. They concluded that the preference for using both strategies was related to the competitor's level while elite runners used mostly association novice runners with less qualification preferred the dissociative strategy.

Hutchinson and Tenenbaum (2007) concluded during low or moderate exercise intensity; the dissociative strategy dominates, as the workload increases the use of association also does. Our interviews showed that runners preferred strategy for moments of hard intensity, like speed training or competition, is the associative strategy (Baden et al., 2004; Hutchinson, 2011; Hutchinson & Tenenbaum, 2007; Tenenbaum & Connolly, 2008). Post session interviews revealed that 26% of the participants considered that the associative strategy has been very helpful to reach a better performance during the experimental session. Moreover, after the dissociative session participants (40%) reported that the strategy was helpful for performance, only 20% referred that dissociative strategy was very helpful. Despite of the similarities with past studies, a more dynamic method for assessing cognitions while running was needed. Tenenbaum and Connolly (2008) used the one question method, similar to Tammen (1996), which may not be the most accurate tool since it was a 10-point scale, ranging from 0 external thoughts to 10 internal thoughts, both sides of the scale include more than one direction of the attention, important information that was not assess, even if it was not possible to determine if participants directed their attention to daydreaming or to the environment on the external side, or to breathing of running technique on the internal side, this measurement was considered as a reliable tool.

Recently, Samson et al. (2017) used the think-aloud protocol, which was developed by Ericsson and Simon (1980) where participants had to say aloud whatever they think while running at a selected pace, meanwhile they had to record those verbalizations with a voice recorder. Despite the invasive method, and the lack of control of the exercise workload, which has been considered as a key factor for the cognitions stream (Tenenbaum, 2001), these authors considered the think-aloud protocol as a promising methodology to capture the thought processes while running. It might be possible that

the think-aloud protocol is a viable real time measure tool. Nevertheless, we consider that non-invasive techniques can offer an ecological approach. Moreover, as suggested by Brick et al. (2014) a common theoretical model is needed, the studies based on thought classification only open the range of themes, but do not offer any cause-effect information. A descriptive analysis of cognitions while running it is not what is needed to understand the discussed effects on running economy and perceived exertion. In addition, Samson et al. (2017) results are similar to the ones observed by Schomer (1986) with the difference on the verbalization classifications, while Schomer classified 10 mental strategy themes Samson et al. (2017) obtained 9.

It is important to describe a change on the study paradigm, until Tenenbaum (2001) it was assumed that the attentional process was linear and perceived exertion static. Moreover, it was considered without an overwhelming explanation that cognitions altered running pace, perceived exertion and performance. Following Tenenbaum's line, the new approach considers that is the pace or exercise workload the responsible of changing cognitions from task related and un-related thoughts, this is a non-linear perspective proposed by Balagué et al. (2012).

Perceived exertion is a complex construct, with physiological and psychological components, and it is the wide interaction of these components the responsible of the exertion response (Cárdenas et al., 2017). In addition, the afferent information that can influence perceived exertion as heart rate, oxygen consumption, blood lactate concentration, muscle damage, skin temperature, glycogen availability, central temperature is integrated in a non-linear way (Cárdenas et al., 2017). With such a complex construct as perceived exertion, it is difficult to assess the effect of cognitive

strategies as mediators of this response. Given the results of the present study, it is difficult that the conceptual frameworks used so far can be experimentally tested. Even when studies overcome methodological limitations, as in the present study, the obtained results cannot be explained within the conceptual frameworks. Conversely, new frameworks as the mindfulness (Salmon et al. 2010) or the metacognitive (Brick et al., 2014) are introducing even more complex constructs. Since Morgan and Pollock (1977) first study, the effect of cognitive strategies of association and dissociation on perceived exertion has not been experimentally demonstrated. After 39 years it is not possible to offer practical recommendations to help athletes to perform at their best based on cognitive strategies.

Perhaps, we are directing our researches to find an effect between two variables that are not related since Leventhal and Everhart's (1979) parallel processing model cannot be tested effectively.

5.4. Central nervous activation

Moderate workload exercise has the potential to improve cognitive performance (Brisswalter et al., 2002; Davey, 1973; Chmura et al., 1994; Kamijo et al., 2006; Kashiwara et al., 2009; Lambourne & Tomporowski, 2010; McMorris & Keen, 1994) by increasing central nervous activation and sensory sensitivity (Davranche & Pichon, 2005). In order to assess the effect of both associative and dissociative sessions on central nervous activation we used the critical flicker fusion (CFF) frequency test. Given the role of exercise and cognitive tasks in improving cognitive process (Tomporowski, 2003) it was necessary to include the central nervous activation as one of our dependent variables. In addition, since our tasks required a considerable amount of attention, that may cause depletion of central nervous system resources increasing

fatigue and consequently could compromise exercise performance, the CFF frequency test was also helpful providing evidence to support our methodology for studying the role of cognitive strategies in long distance running.

We hypothesized that while controlling exercise duration (less than 1 h) and workload (at moderate intensity) the sessions (exercise and attentional task) will increase the central nervous activation (CFF threshold). Our results support this hypothesis showing that our associative and dissociative sessions increased the central nervous activation, these results are in line with other researchers (Bray et al., 2008; Pageaux, Marcora, & Lepers, 2013, Pageaux et al., 2015) showing evidence that cognitive tasks, did not affect exercise performance. In addition, we also hypothesized that the exercise bout will not affect task effectiveness.

Contrary to the transient hypofrontality theory (Dietrich, 2003), our results showed that moderate exercise did not affect the cognitive process and support the hypothesis, with tasks effectiveness higher than 94% during both sessions we consider these results as evidence that there was not a diminution of the cognitive performance even at the late stages of the session. The hypofrontality theory (Dietrich, 2003) propose that physical exercise will generate a massive neural activation and because there is a limited resource capacity, this huge request induces a competition for resources that would be expected to result in a diminution of the resources directly involved into cognitive tasks.

The results showed an increase on the dissociative' task Fusion frequency and on the associative' task Flicker frequency. Considering that CFF test base-line was the same before both sessions, our results showed that not only the performed tasks did not cause depletion of central nervous system resources but increase the performance of stimuli visual discrimination. This positive effect can be due to a better efficiency of the

peripheral sensorial processes (Davranche, Burle, Audiffren, & Hasbroucq, 2005, 2006) as the flicker fusion test showed. The Flicker Fusion test is mainly focus on visual detection that imply a motor behaviour (reaction time) when the person push the bottom once the flicker or fusion frequency is detected. Nevertheless, is not possible to establish if this positive effect was due to the exercise bout or due to the attentional tasks. Based on Davranche, Brisswalter and Radel (2015) study, that established that the cognitive control required to perform such tasks as the Stroop effect, or visual stimuli reaction time responses as the flicker fusion test, is not affected by the intensity of exercise, this might suggest that exercise will not decrease cognitive performance as we hypothesized.

For our study was key to use trained runners, since one of the mayor effects of exercise on cognitive performance is fitness level (Chang, Chi, Etnier, Wang, Chu, & Zhou, 2014; Hüttermann & Memmert, 2014; Labelle, Bosquet, Makary, & Bherer, 2013) all participants were experienced runners that trained regularly at least two times per week and compete in 10 km (50% of participants), half marathon (33%) and marathon (17%) distances. This could contribute to the stability of the cognitive performance and the positive effect of the session in the flicker fusion test. Even when perceived exertion increased with time, a 55 min run at a moderate intensity for these runners was not at the limit of their regular daily training. Pre session interview revealed that participants ran an average of 44 ($\pm$ 30 km) per week, at intensities ranging from low to high depending of their training plans.

Exercise workload at the ventilatory threshold and time resulted as key factors for every studied variable. For Dietrich and Audiffren (2011) exercise duration would be the predominant factor to account for the effect of exercise on central nervous activation.

The proposed hypothesis is that when exercise duration lasts more than 1 h, the appearance of fatigue symptoms such as an increase in metabolic load, heat stress, the appearance of central and peripheral fatigue and hormonal changes would lead to a decrement of cognitive processes efficacy. Considering the obtained results, our proposed methodology has showed to be effective for the study of exercise and cognitive performance, without causing cognitive deficits. It can be consider that the next logical step is that future studies should be conducted using exercise periods that lasts until exhaustion (more than 1 h) with a continuous monitoring of cognitive performance.

Langner et al. (2010) proposed that decrements on performance due to mental fatigue can be observed during tasks that required the voluntary control of attention, excluding the temporal preparation and reaction time. Since our attentional tasks did not require a reaction time response, it was not possible to directly assess Langner et al. (2010) proposal effect through the cognitive strategies.

Nevertheless, CFF threshold test included reaction time and the results showed that there were not decrements on the CFF threshold and consequently it is possible to consider that there were not any performance decrements in both experimental sessions attributed to mental fatigue, not physical or cognitive. Mental fatigue, is characterized by the observed exhaustion of the resources for the execution of a task, since tasks effectiveness were higher that 94% during both session, cognitive task performance was not affected, so it is not plausible that during the experimental sessions participants experienced mental fatigue. Even when our attentional tasks required a high voluntary control of the attention, with participants focusing on stimuli that appeared within almost every 2 seconds (associative condition) and every 4 seconds (dissociative condition) during the 55 minutes of the session. Considering the nature of these tasks

and the elements of mental fatigue such as maintenance of cognitive effort with a high level of vigilance, selective attention, decision making, motor behaviour (Helton & Warm, 2008; Tomei, Cinti, Cerratti, & Fioravanti, 2006) is worth to mention that the cognitive performance did not impair as consequence of a central nervous fatigue. Furthermore, the dissociative strategy using a Stroop effect like task, required a high cognitive control selecting the target word and inhibit inappropriate responses, any decrease at task effectiveness and the flicker fusion test pre-post will suggest that participants' cognitive process was affected by the experimental session. Our results are in consonance with those obtained by Pageaux et al., (2015), showing that self-regulation cognitive tasks did not affect endurance performance. Even, if the cognitive tasks were longer than 30 min. Given the results of task effectiveness and pre-post CFF threshold test, it is possible to argue that during the experimental sessions mental fatigue indicators were not observed. It is important to highlight these results because we design to attentional tasks that requested a high load of attention and a decrease of central nervous activation or low values of task effectiveness could show that the employed methodology was not effective and the results could be biased due to the fatigue effect. The lack of differences in oxygen consumption, heart rate, and central nervous activation between the sessions showed that the energy required to perform both attentional tasks was similar.

Furthermore, the specific purposes of the present study was to assess the effect of cognitive strategies on perceived exertion, oxygen consumption and central nervous activation, any mental fatigue effect will undermine the obtained results and conclusions. Past studies did not include the central nervous activation as a variable that can explain their results, or not even as a control variable. We consider that including central nervous activation and mental fatigue is necessary for future research.

While reviewing the scientific literature about exercise and cognitions, clearly we have distinguished two approaches. One focused in classifying thoughts, with retrospective approaches by pencil paper questionnaires or in a suggested real time methodology by the think-aloud protocol. The other, focused on the effect of aerobic exercise over cognitive processes, assessed after the exercise was performed. Nevertheless, the processes involved in central nervous activation, needed to perform both physical exercise and cognitive task, occurs at the same time. A research that included both approaches was needed; our results showed that is possible to integrate these constructs within the same design. Some of the controversies emerged during the past 39 years can be attributed to the fact that a physio-psychological phenomena has been researched using a reductionist approach. Such is the case that until now, there is not a common definition for the process involving associative and dissociative strategies as well mentioned by Brick et al. (2014), Salmon et al., (2010), Masters and Ogles (1998).

5.5. Practical implications

Considering the lack of effects of perceived exertion, oxygen consumption and the positive effect on central nervous activation the use of cognitive strategies of association and dissociation do not affect long distance running performance. From a practical view, runners are free to choose the cognitive strategy which is considered the most comfortable based on their personal experience without compromising running economy at a moderate exercise workload.

In order to avoid mental fatigue or a decrease in the central nervous activation due to a high attentional load, performing moderate aerobic exercise should be encouraged. Especially in contexts where high performance must be achieved regarding of physical fatigue and with a high mental workload such as sport or military.

6. CONCLUSIONS

After more than 39 years, researches have not answered the question: where to focus attention to perform at one's best while running?

A NEW METHODOLOGY

Using dynamic tools we controlled if participants effectively were focusing on the cognitive strategies while running. Our methodology represented a step forward in the cognitive strategies research; we used innovative technology as sport psychology measures tools. In addition, we integrated different areas of the sport sciences in one design. We were able to work with sport medicine experts, wellness and health experts, coaches, and athletes. Although it was not possible to solve the question where to focus attention to perform at one's best? the methodology we used was effective for our purposes.

PERCEIVED EXERTION

When the exercise workload and the use of the cognitive strategies are controlled the direction of attention on internal or external stimuli did not influence the perceived exertion response. There is not a mediator effect of cognitive strategies on perceived exertion while running. Unexpectedly, we observed a time effect on perceived exertion and consequently conclude that the perceived exertion values increase along the session independently from the used cognitive strategy. We consider that based on the complexity of perceived exertion' construct and the lack of positive results that can showed a direct relationship between cognitive strategies and exertion response is not possible to demonstrate the supposed attention mediating effect. Since the main effect on perceived exertion is derived from exercise duration and independent from cognitive strategies we doubt that including this variable can offer useful insights.

OXYGEN CONSUMPTION

We have demonstrated that focusing attention on breathing did not increase oxygen consumption when the instruction is to focus on exhalations. Thus, using an associative strategy while running will not affect running performance. In addition, task's instructions play a key role and can alter breathing dynamics while exercising.

CENTRAL NERVOUS ACTIVATION

We demonstrated that endurance exercise performed at a moderate intensity while performing attentional tasks of association and dissociation did not cause fatigue among participants and did not impair the physical and cognitive performance. On the contrary, a positive effect on central nervous activation was assessed. Long distance running at moderate exercise during 55 minutes is positive for performing tasks requiring maintenance of cognitive effort with a high level of vigilance, selective attention, decision making, cognitive control, self-regulation and motor behaviour.

Since 1977 we are the first study that can affirm that our obtained results were not influenced or biased by the lack of control on task adherence or exercise workload. We consider that the study of the effects of cognitive strategies of association and dissociation in long distance running far from finishing is just beginning. The use of technology allowed us to overcome methodological limitations as design and measures. Nevertheless, one of the crucial issues for new research remains unclear. Since the study of Morgan and Pollock (1997) three review studies have been published Masters and Ogles (1998), Salmon et al. (2010) and Brick et al. (2014) there is not a unified conceptual framework regarding attention in long distance running. The effort of past research to classify cognitions into categories have not offer overwhelming explanations

about the effects attention in long distance running performance. We consider that is essential to use a solid framework in order to design future studies.

7. LIMITATIONS

In spite of the contributions of this study, limitations should be taken into consideration for future research. One factor to consider is that the size of the sample was modest with an experimental mortality of eight runners from session 1 to session 3. Nevertheless, due to the experimental design and the complexity of the study protocol a total of 30 participants were useful for our purposes. In total we performed 100 sessions at the laboratory, each session cost around 100 euros, and implied that the medical staff was needed to operate and control the physiological measurement and tools for more than 90 hours during the whole data recollection. Due to the inclusion criteria, and the mentioned complexity for schedule and perform every experimental session we consider that a study similar to this, will imply a huge amount of resources in order to work with a larger sample.

Under the advice of the Senior medical staff, whom determined that the obtained blood lactate concentration was not valid we did not consider that data as part of the results or conclusions. We consider this loss of data as a limitation because blood lactate concentration will provide more information about participants' objective fatigue. Since no differences were observed between the sessions in perceived exertion, heart rate, oxygen consumption, and central nervous activation, lactate concentration analysis could offer overwhelming evidence that cognitive strategies of association and dissociation had no effect on long distance running performance. While exercising whole blood lactate concentration values are on average 70% of the corresponding plasma lactate concentration. When analysing these values it should be taken in

consideration the instrument for measuring and the criterion of the enzymatic method (Goodwin et al., 2007), in case one of these elements is not well controlled the blood lactate sample cannot be considered as valid. In addition some of the controversies related to blood lactate measurements rely on the fact that clinicians can erroneously analyse blood lactate concentration, measured via plasma, using the whole blood parameters, resulting in high lactate values, that can be considered as valid. Future studies must consider this issue as a key factor to consider if the research is going to be conducted with an experimental approach.

In addition, despite that the attentional tasks we used can be considered as non-invasive (counting seven exhalations and recognizing the word yellow written in red letters), these tasks are not 100% ecological; normally runners do not have to focus on those stimuli while training or competing. The range of attentional instructions is wide and consequently, difficult to control and assess. Nevertheless, we have considered that those tasks were the best ones in order to control if participants were really using the instructed cognitive strategy. We designed two tasks that required a constant attentional focus and that goal was successfully achieved.

Morgan and Pollock (1977) developed the concepts of cognitive strategies with a precisely differentiated attentional focus, but also as coping mechanisms against stressors derived from long distance running (Masters & Ogles, 1998). In our study, participants were trained runners, who regularly run at higher speeds than the aerobic threshold VT1. Moreover, the workload and exercise duration used during the experimental sessions can be considered as a non-stressful situation for these participants. We must consider that memories of past experiences affect sensation of fatigue (St Clair Gibson et al., 2003) so well trained and experienced runners have their

own fatigue response, which is different from elite runners (international level) and the general population.

Up to now, no studies have focused on assessing the effect of the attentional focus as a form of coping strategies, but the majority of the research was directed to classifying participants' thoughts while running. It would be interesting to analyse what would be the effect if the exercise bout is perceived as a stressful situation.

Given the obtained results, the effect of cognitive strategies as a mediator of perceived exertion seemed implausible. As our results showed, in order to optimize running performance in terms of perceived exertion and running economy, cognitive strategies do not play a decisive role.

8. LINES FOR FUTURE RESEARCH

Future studies, using our methodology, should seek to explore the impact of maximal exercise workload upon the cognitions stream. It showed a high task adherence control, which has been one of the significant limitations during past studies.

With technology evolving day by day study protocols that use a retrospective approach should be avoided. MindFocus® mobile phone application (O3WellBeing Solutions, Spain) synchronized with the wireless controller (Zeemote JS1®, Zeemote Technology Inc., United Kingdom) allowed us to overcome the measure tools limitations of past studies. Mobile applications are increasing in popularity and its use on psychological assessment and intervention is growing and widely used among clinical psychologists (Morris & Aguilera, 2012). It will be positive for sport psychologists to use these new technologies as research tools. Such instruments provide a dynamic feedback and real time monitoring of task adherence and task effectiveness. Especially, the research directed to analyse cognitions in endurance sports could benefit from these tools.

In addition, it would be interesting that future studies directed to analyse the effect of using cognitive strategies of association and dissociation on oxygen consumption with the instruction for the associative task to focus on the inspirations stage, while controlling the attentional focus with a methodology similar to ours. This variable is an objective running performance indicator and can be precise measured by a breath to breath procedure. New research can offer a clear explanation regarding the role of attentional focus and its influence on running economy. And will provide more data to clarify if the attentional task instruction played a key role.

Further studies using a methodology similar to our but increasing the exercise workload is required to examine Tenenbaum (2001) model. Clearly, when one is working at high intensity, distracting attention away of the physical sensations is not helpful to perform the task in hand, and based on Tenenbaum's (2001) model, is not even possible. More research is needed in order to clarify if the use of cognitive strategies influences the athletes' ability to prolong the physical effort while running at a high intensity. It should be interesting also to examine other populations, as non-runners or not experienced runners.

Since central nervous activation increase after the sessions' more research is needed to examine whether these findings are specific to tasks that require visual stimuli reaction time responses as the one we used in the present study or can be generalized across other dissociative tasks.

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10. APPENDIX

APPENDIX I

Entrevista Briefing

Fecha:

Prueba: Día1//Día2

Asocia//Disocia.

Nombre:

Edad:

Sexo: H / M

Lesiones Previas Recientes de Importancia (ultimo año):

1.- ¿Cuántos años tienes como corredor de fondo?

2.- ¿Cuál es la distancia en la que te especializas?

3.- ¿Durante los dos días anteriores a hoy has realizado alguna competencia o algún entrenamiento de mucha intensidad?

<i>Si</i>	<i>No</i>

4.- ¿Te encuentras en actualmente entrenando para alguna competición?, ¿Cuál?

<i>Si</i>	<i>No</i>

5.- ¿Podrás decir cuál ha sido la carga de entrenamiento que has tenido en la última semana?

Volumen Km.:	
Intensidad: % Fc., V02máx.	
Densidad: tiempo(total), series:	

6.- ¿Cuándo corres normalmente en que centras tu atención en las siguientes situaciones (Asociación/Disociación)?

-Entrenamiento:

-Competición:

Observaciones:

7.- De la siguiente escala del 1 al 7 dónde 1 es nunca y 7 es siempre, podrías establecer en que medida empleas la estrategia atencional (As/Ds) en 3 momentos distintos de fatiga.

Fatiga Baja

Asociativa	1	2	3	4	5	6	7	No sabe/no contesta
Disociativa	1	2	3	4	5	6	7	No sabe/no contesta

Fatiga Media

Asociativa	1	2	3	4	5	6	7	No sabe/no contesta
Disociativa	1	2	3	4	5	6	7	No sabe/no contesta

Fatiga Intensa

Asociativa	1	2	3	4	5	6	7	No sabe/no contesta
Disociativa	1	2	3	4	5	6	7	No sabe/no contesta

7.- De la siguiente escala del 1 al 7 dónde 1 es nunca y 7 es siempre, podrías establecer en qué medida empleas la estrategia atencional (As/Ds) cuando te encuentras en un momento táctico importante durante una carrera.

Asociativa	1	2	3	4	5	6	7	No sabe/no contesta
Disociativa	1	2	3	4	5	6	7	No sabe/no contesta

Observaciones Finales:

APPENDIX II

Entrevista Segundo Día

Fecha:

Prueba: Día1//Día2

Asocia//Disocia.

Código:

Edad:

Sexo: H / M

1.- ¿Presentas alguna lesión o enfermedad que te impida correr hoy?

2.- ¿Durante los dos días anteriores a hoy has realizado alguna competencia o algún entrenamiento de mucha intensidad?

<i>Si</i>	<i>No</i>

3.- ¿Podrás decir cuál ha sido la carga de entrenamiento que has tenido en la última semana?

<i>Volumen Km.:</i>	
<i>Intensidad: % Fc., V02máx.</i>	
<i>Densidad: tiempo(total), series:</i>	

Observaciones:

APPENDIX III

ENTREVISTA POSTERIOR

Apellidos y nombre:

Edad:

Fecha:

Prueba realizada: Aso. // Diso.

Indica, en las siguientes cuestiones, cómo te has encontrado en los diferentes momentos de la prueba respondiendo mediante la escala que se te presenta a continuación

Muy en desacuerdo

Muy de acuerdo

1 2 3 4 5

1. He sentido dificultades para utilizar la estrategia _____:
2. He tenido dificultades en el empleo del pulsador:
3. He encontrado dificultades en mi técnica habitual de carrera:
4. He notado que estaba incómodo teniendo que centrar mi atención en la pantalla (en el caso de la estrategia disociativa):
5. Me he sentido incómodo al utilizar el pulsador (con el guante):
6. Indica cuales han sido las dificultades fundamentales que has encontrado durante la prueba:

7. Valora el nivel de rendimiento que consideras que has tenido empleando la estrategia _____ respecto al esfuerzo de dificultad percibida que has tenido en la prueba.

Muy bajo

Muy alto

1 2 3 4 5

8. Trata de describir cómo te has encontrado durante la realización de la prueba partiendo de un análisis en tres periodos: 1/3 de la prueba; 2/3 de la prueba y 3/3 de la prueba

Muy mal

Muy bien

1 2 3 4 5

- 1/3:

- 2/3:

- 3/3:

RPE Börg:

9.- Indica en qué medida consideras que el empleo de esta estrategia _____ te ha ayudado a obtener un mejor rendimiento.

No me ha ayudado en absoluto

Me ha ayudado muchísimo

1 2 3 4 5

¿Cuál ha sido tu impresión general sobre el rendimiento obtenido?

¿Cuál ha sido tu impresión general sobre el estar a gusto/cómodo en la prueba?

APPENDIX IV

ESCALA DE BORG 6-20

PUNTUACIÓN	DESCRIPCIÓN DEL ESFUERZO
6	Nada de esfuerzo
7	Muy, muy ligero
8	
9	Muy ligero
10	
11	Moderado
12	
13	Algo duro
14	
15	Duro
16	
17	Muy duro
18	
19	Muy, muy duro
20	Máximo, extenuante

APPENDIX V

PROTOCOLO BRIEFING SESION ASOCIATIVA

a) Presentación:

Has sido invitado para formar parte de un estudio en carreras de resistencia, tu participación aportará conocimientos nuevos aplicables a las áreas de la psicología del deporte y el rendimiento deportivo.

Como parte del protocolo que el estudio requiere, agradecemos tu presencia voluntaria y te informamos de las actividades que comprenden tu participación.

- Entrevista Introductoria:

Para conocer un poco más sobre ti, uno de los colaboradores te hará unas preguntas acerca de tu experiencia como corredor.

- Antes de iniciar y después de finalizar la tarea realizarás un ejercicio de percepción.

- La escala de Borg.

ESCALA DE ESFUERZO PERCIBIDO	
VALOR	ESFUERZO
6	SIN ESFUERZO
7	MUY, MUY SUAVE
8	
9	MUY SUAVE
10	
11	BASTANTE SUAVE
12	
13	ALGO DURO
14	
15	DURO
16	
17	MUY DURO
18	
19	MUY, MUY DURO
20	ESFUERZO MÁXIMO

Esta es la escala del índice de esfuerzo percibido. El esfuerzo percibido es el esfuerzo global o el malestar de tu cuerpo durante la realización del ejercicio. El número 6 representa el no esfuerzo y el número 20 representa el mayor esfuerzo que puedes experimentar. En varios momentos de la prueba de esfuerzo se te pedirá que indiques de forma verbal el número que corresponda al índice de esfuerzo que percibes para el trabajo respiratorio y para el esfuerzo de las piernas.

- La tarea de hoy consiste que prestes atención al número de respiraciones que realizas mientras corres, después de cada 7 espiraciones tienes que apretar 2 veces el botón del pulsor. Realizarás un calentamiento de 3 minutos de duración para familiarizarte con el pulsador, durante este periodo uno de los colaboradores se colocará a tu lado para sincronizar la transmisión de información.

PROTOCOLO BRIEFING SESION DISOCIATIVA

a) Presentación:

Has sido invitado para formar parte de un estudio en carreras de resistencia, tu participación aportará conocimientos nuevos aplicables a las áreas de la psicología del deporte y el rendimiento deportivo.

Como parte del protocolo que el estudio requiere, agradecemos tu presencia voluntaria y te informamos de las actividades que comprenden tu participación.

- Entrevista Introductoria:

Para conocer un poco más sobre ti, uno de los colaboradores te hará unas preguntas acerca de tu experiencia como corredor.

- Antes de iniciar y después de finalizar la tarea realizarás un ejercicio de percepción.

- La escala de Borg.

ESCALA DE ESFUERZO PERCIBIDO	
VALOR	ESFUERZO
6	SIN ESFUERZO
7	MUY, MUY SUAVE
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Esta es la escala del índice de esfuerzo percibido. El esfuerzo percibido es el esfuerzo global o el malestar de tu cuerpo durante la realización del ejercicio. El número 6 representa el no esfuerzo y el número 20 representa el mayor esfuerzo que puedes experimentar. En varios momentos de la prueba de esfuerzo se te pedirá que indiques de forma verbal el número que corresponda al índice de esfuerzo que percibes para el trabajo respiratorio y para el esfuerzo de las piernas.

- La tarea consiste en que prestes atención a la pantalla, en ella aparecerán distintas palabras, escritas con un color de fondo diferente, por ejemplo:

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uno de los colaboradores te indicará una palabra y un color de fondo específico, cuando veas esa palabra en la pantalla tendrás que apretar dos veces el botón del pulsador. Realizarás un calentamiento de 3 minutos de duración para familiarizarte con el pulsador, durante este periodo uno de los colaboradores se colocará a tu lado para sincronizar la transmisión de información.

APPENDIX VI

PROTOCOLO DE LAS SESIONES DE ESTUDIO

1.- Saludo-bienvenida:

(Saludo breve, sin entablar conversación).

El investigador que recibe al corredor se presenta junto con los otros colaboradores.

2.- Entrega de Protocolo Briefing:

Se le indica al corredor dónde se encuentran los vestuarios para que se prepare y se le entrega la hoja del briefing.

3.- Toma de datos personales:

Antes de comenzar vamos a hacerte unas preguntas:

- a) ¿Cuántos años tienes como corredor de fondo?*
- b) ¿Te encuentras en actualmente entrenando para alguna competencia?, ¿Cuál?*
- c) ¿Podrás decir cuál ha sido la carga de entrenamiento que has tenido en la última semana?*

*Se le da una breve introducción de las estrategias atencionales de asociación-disociación para preguntarle cuál considera que más utiliza cuando entrena y compite.

●*La estrategia de asociación centra la atención a estímulos y molestias que genera la actividad de correr, consiste el monitorear el propio organismo.*

●*La estrategia de disociación centra la atención en factores ajenos a la actividad misma con el fin de distraer la mente de las molestias y la sensación de cansancio que genera el correr.*

- d) ¿Cuál de estas estrategias de atención consideras que más utilizas cuando entrenas y cuando compites?*

4.- Flicker-Fusion: Ejercicio de Fatiga Central, se realizará al inicio de cada sesión y al término de la fase experimental.

- a) Introducen los datos personales para generar un expediente: edad, sexo, nivel de formación).
- b) Se selecciona el test Flicker-Fusion.

c) Se selecciona el protocolo S1.

d) Se introduce el código del día (ASO/DIS + i/ii + dd/mm/aaaa).

e) Instrucciones: *Vas a observar un punto de color rojo que estará parpadeando, tienes que pulsar cualquiera de los dos botones cuando consideres que el punto se queda fijo, el punto estará fijo y tienes que pulsar el cualquiera de los botones cuando consideres que el punto comienza a parpadear. Los 5 primeros de cada uno son de prueba, ¿tienes alguna duda?*

*Se le indica al corredor cuando se encuentra al inicio del 9º de prueba que el siguiente comenzará la fase del test.

5.- Se preparan los instrumentos para realizar la prueba:

-Se introducen los datos personales del corredor en el ordenador ELECTRO

-Se calibra el ordenador para el consumo de gases.

-Se introducen los datos personales para el consumo de oxígeno.

6.- Instrucciones sobre los instrumentos de Medida:

*Uno de los colaboradores, repasa las instrucciones del uso de la escala de percepción subjetiva de esfuerzo.

El número 6 representa el no esfuerzo y el número 20 el mayor esfuerzo, en varios momentos de la prueba se te pedirá que indiques en voz alta 2 números dentro de esta escala, el primero para conocer el esfuerzo a nivel respiratorio y el segundo para el esfuerzo de las piernas. ¿Tienes alguna pregunta?

●Instrucciones para el uso del pulsador para la tarea experimental.

Este aparato funciona como el ratón de un ordenador de forma inalámbrica nos enviará la información al móvil colocado en este punto (señalar la ubicación del móvil), como es necesario que lo utilices a lo largo de toda la prueba y por tu comodidad hemos adaptado este guante que facilita su sujeción (preguntar al corredor si es diestro o zurdo), como puedes sentir el pulsador se adapta cómodamente a tu mano, te pediremos que aprietes dos veces sobre este botón, prueba par que compruebes como funciona.

*(*Se realizan unas pulsaciones de práctica simulando el braceo)*

El corredor conserva el guante puesto y se le quita el pulsador para que los médicos lo preparen para la prueba.

7.- Se prepara al corredor para realizar la prueba:

Los colaboradores de la escuela de la medicina deportiva preparan al corredor para la prueba con:

-Colocación de Electrodo

-Toma de Frecuencia basal (tumbado)

-Toma y Frecuencia en Reposo (de pie)

-Pesado y talla (solo 1º sesión)

-Medida de la Presión arterial (antes de correr, al término (pico, 3, 6, 9).

-Mascarilla para medir el consumo de oxígeno. (Los responsables de colocar la mascarilla se aseguran que la talla sea la correcta y que no existan fugas).

8.- Se prepara el Teléfono Móvil con el que se utilizará el Software MindFocus®:

a) Con el móvil encendido, se va al menú de las aplicaciones.

b) En el menú aplicaciones se selecciona Zeemote®, en dónde se conecta el pulsador.

c) Una vez conectado el pulsador se selecciona la aplicación MindFocus®.

d) En el menú del MindFocus® se accede a la opción realizar ejercicio y se introducen los datos de la sesión, el nombre de usuario se compone de: (iniciales del corredor comenzando por los apellidos + las siglas Aso//Dis dependiendo del protocolo que se vaya a realizar + i // ii según corresponda al orden de situación experimental + fecha dd/mm/aaaa).

e) El protocolo de ejercicio que se utiliza es el de *Counting*.

9.- Periodo de calentamiento/ habituación a la tarea:

*Los colaboradores de medicina deportiva indican las instrucciones para el calentamiento. (velocidad: depende corredor y duración: 3 minutos).

*Se dan las instrucciones para la tarea atencional:

● Tarea Asociativa:

En este periodo de calentamiento haremos un ensayo de la prueba para sincronizar el pulsador y para que te familiarices con la tarea. Mientras corres centra tu atención en la respiración. Cuando realices 7 espiraciones aprietas dos veces el botón del pulsador y así cada 7 espiraciones. Estaré a tu lado un momento para la sincronización con el teléfono móvil.

¿Tienes alguna duda?

●Tarea Disociativa:

*En este periodo de calentamiento haremos un ensayo de la prueba para sincronizar el pulsador y para que te familiarices con la tarea. Mientras corres centra tu atención en la pantalla, donde aparecerá diferentes palabras escritas con un color de fondo diferente, a lo largo de la presentación cada vez que aparezca la palabra **Azul escrita con fondo Verde** debes apretar 2 veces el botón del pulsador. Estaré a tu lado un momento para la sincronización con el teléfono móvil.*

¿Tienes alguna duda?

*Si hubiera dificultades con el uso del pulsador después del calentamiento durante el periodo de 2 minutos (o más si es necesario) se retomarían las instrucciones para la tarea. En la aplicación del Counting se selecciona el periodo de 5 minutos para comprobar que el pulsador funciona correctamente.

10.- Indicaciones previas a la tarea (2 minutos posteriores al calentamiento).

●Tarea Asociativa:

La tarea consiste en que mientras corres centres tu atención en la respiraciones que tienes y, cada 7 espiraciones debes pulsar dos veces el botón, te preguntaran en distintos momentos la percepción de esfuerzo que percibes, debes de dar 2 números indicando el esfuerzo respiratorio y el de las piernas. Estaré a tu lado un momento para la sincronización.

¿Tienes alguna duda?

● Tarea Disociativa:

*Ahora cada vez que aparezca la palabra **Amarillo escrita con fondo Rojo** debes apretar 2 veces el botón del pulsador, te preguntaran en distintos momentos la percepción de esfuerzo que percibes, debes de dar 2 números indicando el esfuerzo respiratorio y el de las piernas. Estaré a tu lado un momento para la sincronización. 3 target por minuto.*

¿Tienes alguna duda?

*Dentro de la opción de Counting se selecciona la duración de 55 minutos. La prueba comienza cuando el responsable del teléfono móvil lo indique.

11.- Durante la tarea:

*Ninguna indicación para las tareas, el único contacto con el corredor será para que indique el número correspondiente a la escala de percepción de esfuerzo de la que se va tomando registro.

12.- La prueba se detiene cuando la cuenta del software MindFocus® llega a 55 minutos el responsable, indica a los demás que se ha completado el protocolo, acto siguiente se le indica al corredor que se sujete de la barandilla del tapiz para detenerlo, se le retira el pulsador, se comienza con las tomas de lactato (mano derecha) y tensión arterial (brazo izquierdo) en los intervalos (pico, y a los minutos: 3, 6, 9), tras la primer toma (pico) se procede a realizar una recuperación caminando (velocidad a petición del corredor) con una duración de 3 minutos, tras concluir este periodo se le retira la mascarilla al corredor.

13.- Flicker-Fusion (final de la situación experimental)

14.- Despedida: Se le agradece al corredor la participación del día y se le recuerda la fecha de su próxima sesión.