Model no lineal del focus d'atenció durant l'exercici: criteris pel disseny d'estratègies cognitives

Sergi Garcia Retortillo

Tesi doctoral

INEFC

Generalitat de Catalunya

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Sergi Garcia Retortillo

Complex Systems in Sport

Universitat de Barcelona

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Tesi doctoral presentada per:
Sergi Garcia Retortillo

Dirigida per:
Dra. Natàlia Balagué Serre
Dr. Robert Hristovski

Tutoritzada per:
Dra. Natàlia Balagué Serre

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Als meus pares, Tonyi i Joan, i a la meva parella, Clara,

per acompanyar-me des del primer moment, sense dubtar-ho

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The only place success comes before work is in the dictionary

(Vince Lombardi)

Model no lineal del focus d'atenció durant l'exercici. Criteris pel disseny d'estratègies cognitives

Aquesta tesi per compendi de publicacions està estructurada en 6 capítols. El primer consisteix en una introducció general de la tesi i en la presentació dels objectius de la mateixa. El segueixen els capítols 2, 3 i 4, els quals contenen íntegrament cadascun dels 3 estudis publicats. A continuació, el capítol 5 està dedicat a la discussió general dels resultats obtinguts, futures línies de recerca, limitacions i recomanacions pràctiques. La tesi finalitza amb el capítol 6, que recull les referències dels capítols 2, 3 i 4.

ÍNDEX

RESUM

El focus d'atenció durant l'exercici s'ha vingut estudiant durant els darrers anys com a estratègia cognitiva, però el seu impacte sobre el rendiment, així com els mecanismes que expliquen el seu efecte ergogènic, són encara motiu de controvèrsia. La literatura científica d'aquest camp distingeix principalment 4 categories de pensament: pensaments externs i interns relacionats amb la tasca (TRT-E, TRT-I) i pensaments externs i interns no relacionats amb la tasca (TUT-E, TUT-I; Schomer, 1986). Balagué, Hristovski, Aragonés, i Tenenbaum (2012) van evidenciar que el focus d'atenció no podia considerar-se simplement com una conseqüència de l'activitat volitiva, i van desvetllar un efecte no proporcional del temps d'esforç sobre la dinàmica de pensaments durant un exercici realitzat en cinta rodant fins l'exhauriment. Com a conseqüència d'aquests resultats els autors van proposar un model no lineal del focus d'atenció, que estableix 3 fases de pensament durant l'esforç imposant TUT: una fase inicial estable de TUT, seguida per una fase metaestable (canvis espontanis de TUT a TRT) i finalment, una fase estable de TRT prop de l'exhauriment. Per testar la consistència d'aquest model i aprofundir en la comprensió del rol del focus d'atenció durant l'exercici, els objectius d'aquesta tesi doctoral són: a) testar el model no lineal del focus d'atenció sota diferents protocols d'exercici i de recollida de dades, en diversos tipus de població, b) analitzar la dinàmica del contingut de pensaments, no només respecte a la relació del pensament amb la tasca (TUT/TRT), sinó també respecte a la direcció del seu contingut (intern/extern), i c) establir criteris per a dissenyar estratègies cognitives adequades. Els resultats dels 3 estudis portats a terme van mostrar que es troben les mateixes fases de pensament establertes pel model no lineal del focus d'atenció independentment de la tipologia d'exercici, protocol de recollida de dades, nivell d'entrenament i gènere. Tant la dimensió relació amb la tasca (TUT o TRT) com la direcció (interna o externa) del contingut de pensaments van canviar de forma involuntària en funció de l'esforç acumulat, esdevenint cada cop més associats (TRT) i interns (TRT-I). A l'hora de dissenyar estratègies cognitives, cal tenir en compte que tant els pensaments relacionats com no relacionats amb la tasca poden ser efectius, tot depèn del seu perfil d'estabilitat en cada fase d'esforç. Mentre que a intensitats moderades tant els TUT com els TRT poden ser estables, prop de l'exhauriment només són estables els TRT. Per tant, qualsevol intent de mantenir TUT prop de l'exhauriment podria ser cognitivament exigent i limitar el rendiment.

ABSTRACT

Attention focus during exercise has been studied during last decades as a cognitive strategy, but the mechanisms underlying its ergogenic effect are still unknown. Growing literature centred around 4 categories of thoughts: external and internal task-related thoughts (TRT-E, TRT-I), and external and internal task-unrelated thoughts (TUT-E, TUT-I; Schomer, 1986). Balagué, Hristovski, Aragonés, and Tenenbaum (2012) showed that attention focus cannot be merely volitional and revealed a non-proportional effect of effort accumulation on thought dynamics, during a constant running until exhaustion. As a result the authors proposed a nonlinear model of attention focus which establishes 3 thought phases while imposing TUT: an initial TUT stable phase, followed by a metastable phase (switches between TUT and TRT), and a stable TRT phase near volitional exhaustion. To contribute to the understanding of the role of attention focus during exercise, the purposes of this thesis are: a) to test the nonlinear model of attention focus under different exercises and data collection methods in different populations, b) to analyse task-relatedness (TUT/TRT) and direction (external/internal) of thought content dynamics, and c) to establish criteria to optimize cognitive strategies. Results of the 3 studies within this thesis showed the same thought phases, regardless of the exercise type, data collection method, gender, and fitness level. Both task-relatedness (TUT, TRT) and direction (external, internal) of thought contents involuntarily changed over accumulated effort and became associative (TRT) and internal (TRT-I). In order to optimize cognitive strategies interventions, practitioners and performers should take into account that both task-related and task-unrelated thoughts can be effective depending on their stability profile. While during low and moderate intensities TUT and TRT are stable, approaching volitional exhaustion TRT is the only stable thought category. Therefore, any attempt to keep the focus on thoughts that become predominantly unstable near exhaustion (i.e., TUT) can be cognitively taxing and limit performance.

CAPÍTOL 1: Introducció general

El focus d'atenció ha estat estudiat durant els darrers anys com a estratègia cognitiva d'intervenció psicològica per a millorar el rendiment en esports de resistència. La literatura científica d'aquest camp distingeix principalment quatre categories de pensament: pensaments externs i interns relacionats amb la tasca (TRT-E, TRT-I) i pensaments externs i interns no relacionats amb la tasca (TUT-E, TUT-I; Schomer, 1986; veure Taula 1). Tot i la gran quantitat d'investigacions existents al respecte, tant els efectes del focus d'atenció sobre el rendiment, com els mecanismes que expliquen el seu efecte ergogènic són encara motiu de controvèrsia. Mentre alguns autors consideren més efectiu l'ús dels TUT (Gill & Strom, 1985; Morgan, Horstman, Cymerman, & Stokes, 1983; Pennebaker & Lightner, 1980; Schücker, Hagemann, Strauss, & Völker, 2009), d'altres s'inclinen pels TRT (Connolly & Janelle, 2003; Couture, Jerome, & Tihanyi, 1999; LaCaille, Masters, & Heath, 2004).

Taula 1.

Tres nivells de les categories del contingut de pensament en la classificació de Schomer (1986)

Task-Relatedness	Attentional direction	Schomer's Subcategories	Thoughts
TUT	TUT-I	Reflective activity (R)	Past and future issues related to running
		Personal Problem Solving (PS)	Issues of an intra-personal and inter-personal nature
		Work and Career (W)	Job, work, and career-related issues
	TUT-E	Course Information (I)	Scenery not related to pacing strategy
		Conversational Chatter (CC)	Related to internal dialogue
		Environmental Feedback (E)	Here and now nature feedback related to environment
TRT	TRT-I	Body Monitoring (B)	Here and now nature with specific reference to anatomy and/or physiology-related feedback
		Command and Instruction (CI)	Self-regulatory instruction to specific body parts or to whole body related to running
		Feelings and Affect (FA)	Whole-body sensations
	TRT-E	Pace Monitoring (P)	Verbalized feedback on the current performance related to time, distance, speed, pacing

Nota. TUT-I = Internal Task-Unrelated Thoughts; TUT-E = External Task-Unrelated Thoughts; TRT-I = Internal Task-Related Thoughts; TRT-E = External Task-Related Thoughts.

Cal destacar, però, que els estudis mencionats són purament descriptius i no expliquen perquè ni com emergeixen i canvien els diferents tipus de pensaments durant l'exercici. En general, els pensaments són tractats a la literatura científica com a productes de la volició i, per tant, com a elements susceptibles de ser manipulats a conveniència, o sensibles a la intensitat de la càrrega imposada. Així, el model proposat per Tenenbaum (2001) considera que a càrregues baixes o moderades el focus d'atenció és flexible, però quan les exigències de l'esforç augmenten l'atenció esdevé estreta i associativa (Tenenbaum & Connolly, 2008). Considerant una relació de tipus lineal entre càrrega i pensament, Hutchinson i Tenenbaum (2007) preveuen que a partir del 90% VO2 màxim els pensaments passen a ser principalment associats. Malgrat descriure l'efecte de la intensitat de l'esforç sobre el pensament, aquest model no explica per què es produeix el canvi cap al pensament associatiu, ni tampoc perquè es dóna a una intensitat d'esforç concreta.

Per tal de donar resposta a alguns dels interrogants sobre el focus d'atenció, Balagué, Hristovski, Aragonés, i Tenenbaum (2012) van suggerir estudiar els pensaments durant l'exercici des d'una perspectiva dinàmica i no lineal. Basant-se en el dual intrinsic-intentional paradigm (Kelso, Scholz, & Schoner, 1988), dissenyat inicialment per reconèixer el rol de la intenció en el comportament motor, els autors van proposar un disseny experimental de dues fases: 1) estudiar primerament la condició intrínseca de pensaments (sense imposar cap tipus de pensament) durant un exercici fins a l'exhauriment; 2) seguidament, estudiar la condició intencional manipulant la intenció del participant (imposant qualsevol tipus de TUT durant el mateix exercici), per a observar els canvis espontanis en la dinàmica de pensaments. La seqüència d'aquestes condicions (intrínseca – intencional) no és intercanviable doncs té l'objectiu d'avaluar com la intenció parametritza el perfil d'estabilitat de la condició intrínseca.

En aquest estudi els autors van desvetllar un efecte no proporcional del temps d'esforç sobre la dinàmica de pensaments en un exercici en cinta rodant, realitzat a una velocitat constant al 80% de la freqüència cardíaca màxima i fins l'exhauriment. Específicament, un increment mínim en el temps de carrera va provocar un canvi abrupte en el focus d'atenció, mentre que un increment gran en el temps de carrera no va provocar cap canvi. A més, els autors van evidenciar com el focus d'atenció no pot considerar-se simplement com una conseqüència de l'activitat volitiva; és a dir, a causa de l'esforç acumulat fou impossible mantenir un TUT imposat inicialment com a estratègia cognitiva, ja que finalment s'acabà imposant-se un TRT no voluntari. Segons els autors aquest procés, que es caracteritza per la seva dinàmica no lineal, planteja dos i tres fases de pensament en les condicions intrínseca i intencional, respectivament. Concretament, en la condició intrínseca es va detectar una fase mestaestable inicial, seguida per una fase estable de TRT prop de l'exhauriment. En la condició intencional, però, s'observà una fase estable de TUT inicial, seguida per una fase metaestable i finalment, una fase estable de TRT, tal com mostra el model no lineal del focus d'atenció (Figura 1). Cal destacar que les fases estables de TUT i TRT es caracteritzen per contenir exclusivament TUT o TRT, mentre que la fase mestaestable està marcada per una tendència a canviar el seu curs entre les dues categories de pensament (TUT i TRT). Cal precisar que en la condició intencional la metastabilitat ve donada per la competició entre el pensament imposat intencionalment (TUT) i el pensament que emergeix de forma espontània (TRT). A diferencia del model proposat per Tenenbaum (2001), el model no lineal del focus d'atenció no fixa els canvis de pensament a un temps de durada de l'esforç determinat. Malgrat que les fases es troben en tots els individus testats, aquestes es produeixen a diferents valors relatius del temps de cursa.

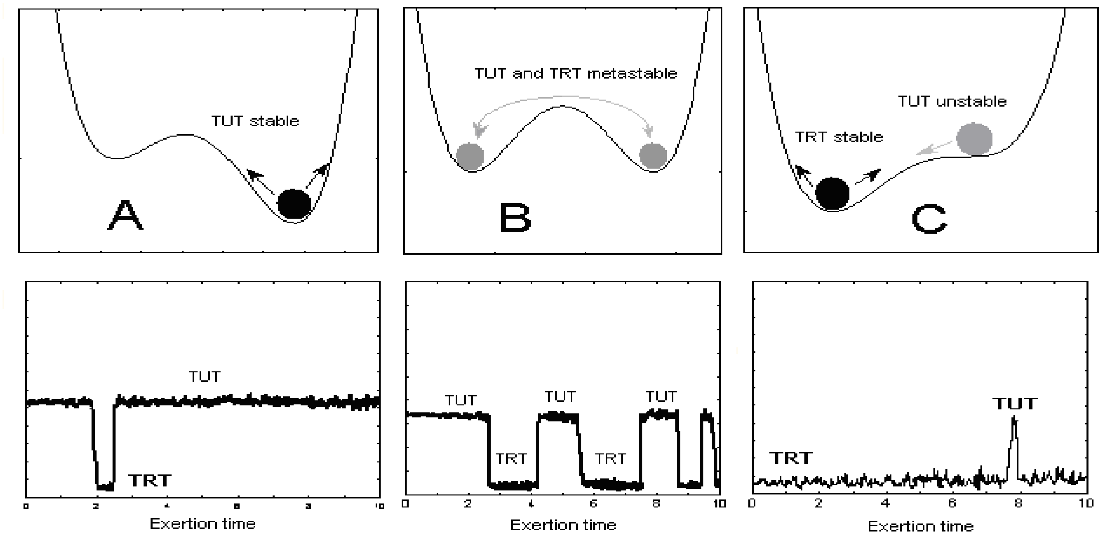

Figura 1. Previsió del perfil d'estabilitat dels pensaments relacionats (TRT) i no relacionats (TUT) amb la tasca durant l'exercici

A diferència de les metodologies de recollida de dades utilitzades pels estudis descriptius previs (qüestionaris retrospectius, recopilació de dades intermitent, recopilació de dades concurrents a intervals regulars durant l'exercici), el model no lineal del focus d'atenció proposa utilitzar: a) un protocol d'auto-monitoratge i d'auto-informe dels canvis de pensament on-line, basant-se en metodologies pròpies de la ciència cognitiva (Giambra, 1995; Smallwood & Schooler, 2006), i b) una tasca portada fins l'exhauriment. Aquesta nova metodologia pretén obtenir informació sobre els canvis de pensament en temps real, evitant la tendència a oblidar o no reportar pensaments (Tenenbaum & Elran, 2003), a generalitzar o reportar només els pensaments més recents (Kirkby, 1996) i a reportar menys TUT (Ericsson & Simon, 1980). D'altra banda, la utilització del dual intrinsic-intentional paradigm va permetre als autors desvetllar l'origen (espontani o volitiu) dels pensaments durant l'exercici.

Per contribuir a la comprensió del rol del focus d'atenció durant l'exercici i establir criteris per al disseny d'estratègies cognitives adequades, els objectius d'aquesta tesi doctoral són:

(1) Testar la consistència del model no lineal del focus d'atenció (Balagué et al., 2012):

(1a) Aplicant diferents protocols d'exercici i diferents protocols de recollida de dades.

(1b) Administrant els test a diferents tipus de població (homes-dones, esportistes experimentats-novells).

2) Testar la dinàmica del contingut de pensaments, no només respecte al seu focus associatiu o dissociatiu (TRT/TUT), sinó també respecte a la direcció (interna/externa).

3) Proposar criteris per al disseny d'estratègies cognitives eficaces i eficients en esforços portats fins a l'exhauriment.

1.1.Justificació i presentació dels articles de la tesi

En el següent apartat es presenten breument els tres estudis que formen aquesta tesi doctoral, així com la seva relació amb els objectius específics de la tesi.

Estudi I: El foco de atención emerge espontáneamente durante el ejercicio progresivo y máximo

Balagué, N., Hristovski, R., Aragonés, D., García, S., & Tenenbaum, G. (2014). El foco de atención emerge espontáneamente durante el ejercicio progresivo y máximo. *Revista de Psicología del Deporte*, *1*, 57-63.

En el primer estudi es van testar les prediccions del model no lineal del focus d'atenció sobre una modalitat d'exercici, protocol d'esforç i protocol de recollida de dades diferents als proposats per Balagué et al. (2012). Concretament, es va testar:

a) Durant un exercici en cicloergòmetre en comptes de en cinta rodant.

b) Amb un protocol de càrrega incremental en comptes de constant.

c) Recollint informació sobre els pensaments a intervals regulars (cada 30 s) i a petició de l'administrador, en comptes de a través de l'auto-informe online.

d) Analitzant les possibles diferències en els resultats respecte al gènere.

Estudi II: Dynamic stability of task-related thoughts in trained runners

García, S., Razon, S., Hristovski, R., Balagué, N., & Tenenbaum, G. (2015). Dynamic stability of task-related thoughts in trained runners. *The Sport Psychologist*, *29*, 302-309. doi:10.1123/tsp.2014-0094

En el segon estudi es van estudiar les prediccions del model no lineal del focus d'atenció en corredors entrenats i no entrenats. Concretament, es van testar:

a) Durant un exercici en cinta rodant.

b) Amb un protocol de càrrega incremental en comptes de constant.

c) En corredors entrenats i no entrenats, estudiant les diferències respecte al contingut de pensaments en funció del nivell d'entrenament.

d) Analitzant les possibles diferències en els resultats respecte al gènere.

Estudi III: Intentional thought dynamics during exercise performed until volitional exhaustion

Balagué, N., Hristovski, R., García, S., Aragonés, D., Razon, S., & Tenenbaum, G. (2014). Intentional thought dynamics during exercise performed until volitional exhaustion. *Journal of Sport Sciences*, *33*, 48-57. doi: 10.1080/02640414.2014.921833

En el tercer estudi es va examinar específicament la condició intencional del contingut de pensaments:

a) En un exercici en cicloergòmetre en comptes de en cinta rodant.

b) Amb un protocol de càrrega constant al 80% de la càrrega màxima.

c) Requerint als participants que reportin els canvis en el contingut dels seus pensaments utilitzant una *paraula clau*, en comptes d'informar únicament sobre la categoria de pensament mitjançant senyals amb els dits (com proposa Balagué et al., 2012).

d) No només respecte a la relació del pensament amb la tasca (TUT/TRT), sinó també respecte a la direcció del seu *contingut* (intern-extern).

e) Analitzant les possibles diferències en el resultat respecte al gènere.

CAPÍTOL 2: Estudi I

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DPSSEC@ps.uib.es, DPSSEC@uib.es
Universitat de les Illes Balears
España

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El foco de atención emerge espontáneamente durante el ejercicio progresivo y máximo[1]

Natàlia Balagué*, Daniel Aragonés*, Robert Hristovski, Sergi García* y Gershon Tenenbaum*****

ATTENTION BECOMES SPONTANEOUSLY FOCUSED DURING PROGRESSIVE AND MAXIMUM EXERCISE

KEYWORDS: Dissociative thinking, Associative thinking, Non-linear model, Emergence, Progressive exercise.

ABSTRACT: The objective of this study was to test a non-linear focus-of-attention model, with the imposition and non-imposition of dissociative thinking during a progressive and maximum bicycle ergometer test. Twelve students who were familiar with experimental procedures performed a progressive and maximum bicycle ergometer test twice under two different conditions: first so as to encourage the emergence of intrinsic dynamics, without imposing any type of thinking and, second, imposing dissociative thinking (DT). During the test, through previously agreed signals, the participants reported on their type of thinking every 30 seconds (DT or AT – dissociative or associative thinking). The individual series were divided into 10 temporary intervals of increasing intensity and the percentage of DT and AT in each one of them was calculated. The median percentage of AT was significantly higher from the 6th interval of intensity onwards in the non-imposed DT test (NIDT) (χ^2 (12, 9) = 39.75; $p < .001$) and from the 8th interval onwards in the imposed DT test (IDT) (χ^2 (12, 9) = 70.65; $p < .001$). The percentage of PD was higher in the PDI test in 6 of the 10 intervals of intensity ($p < .05$). The results demonstrate the spontaneous emergence of PA during a progressive and maximum cycling exercise, confirming the non-linear focus-of-attention model.

El foco de atención ha sido estudiado durante los últimos años como estrategia cognitiva de intervención psicológica para mejorar el rendimiento deportivo (Wulf, 2007). La literatura científica relacionada con los deportes de resistencia distingue dos categorías de foco de atención: el pensamiento asociado (PA) y el pensamiento disociado (PD). El primero se define por un giro interno del foco de atención hacia sensaciones corporales y el segundo por un giro externo que se aleja de dichas sensaciones (Scott, Scott, Bedic y Dowd, 1999). En general, el PA se relaciona con intensidades altas de esfuerzo y el PD con intensidades moderadas (Ekkekakis, 2003, 2005; Rejeski, 1985; Tenenbaum, 2001). Tenenbaum y Connolly (2008) mantienen que con cargas ligeras el foco de atención es flexible y puede cambiar de forma voluntaria; en cambio, cuando la carga aumenta se vuelve interno y se estrecha. Hutchinson y Tenenbaum (2007) observaron un cambio del PD al PA a medida que se aumentaba la carga (50%, 75%, y 90% del VO2 máx) en un ejercicio cicloergométrico y Baden, McLean, Tucker, Noakes, y St Clair Gibson (2005) encontraron que los PA predominaban cuando la velocidad aumentaba en cinta continua. Sin embargo, los efectos del foco de atención sobre el rendimiento en deportes de resistencia son motivo de controversia. Mientras que algunos autores encuentran más ventajoso el PD (e.g., Gill y Strom, 1985; Morgan, Horstman, Cymerma y Stokes, 1983; Pennebaker y Lightner, 1980; Schücker, Hagemann, Strauss y Völker, 2009) otros se inclinan por el PA (e.g., Connolly y Janelle, 2003; Couture, Jerome, y Tihanyi, 1999; LaCaille, Masters y Heath, 2004). Por su parte los atletas utilizan estrategias diversas para afrontar la competición. En este escenario se hace imprescindible estudiar desde una perspectiva diferente la dinámica del foco de atención durante el ejercicio. En esta línea, Balagué, Hristovski, Aragonés y Tenenbaum (2012) evidenciaron que el foco de atención no puede considerarse simplemente como una consecuencia de la actividad volitiva; es decir, que sería posible seguir con éxito durante el esfuerzo cualquier estrategia cognitiva inicialmente impuesta. Los autores mostraron que a consecuencia de la fatiga era imposible mantener el PD impuesto inicialmente y que acababa imponiéndose un PA no voluntario. Este proceso, que se caracteriza por su dinámica no lineal, plantea la existencia de tres fases en el esfuerzo constante llevado hasta el agotamiento o fallo. En la primera es posible mantener el PD, en la segunda emergen de forma espontánea PA que compiten con los PD, y en la fase final se imponen dichos PA.

El recientemente propuesto modelo no lineal del foco de atención (Balagué et al., 2012) asume que la función cognitiva tiene propiedades emergentes, y se basa en principios dinámicos (Van Orden, Holden y Turvey, 2003). Por consiguiente, parece que está sujeto a influencias periféricas y/o centrales que pueden desestabilizarlo y conducir a una pérdida espontánea (i.e., no deliberada) de adherencia a una cierta estrategia cognitiva inicialmente impuesta. Esta es una consecuencia típica de las interacciones no lineales entre los componentes en los sistemas

Correspondencia: Natàlia Balagué. INEFC. Universitat de Barcelona. Avda. de l'Estadi, 12-22. 08038, Barcelona. E-mail: nataliabalague@gmail.com
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*INEFC Universitat de Barcelona.
** Univ. St. Cyril and Methodius (Skopje, Macedonia).
*** Florida State University (Florida, USA).
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dinámicos complejos, que dan lugar a la formación, alternancia y disolución espontáneas de diferentes estados; es decir, multiestabilidad y metaestabilidad (Balagué y Torrents, 2011). Mientras que los modelos lineales no predicen ningún tipo de alternancia o cambio de dinámica espontáneo entre las categorías del foco de atención, el modelo no lineal predice la formación espontánea de dinámicas metaestables o estables en función del contexto dinámico que acompaña al esfuerzo.

El objetivo de este estudio fue testar las predicciones del modelo no lineal del foco de atención (Balagué et al., 2012) sobre una modalidad de ejercicio, protocolo de esfuerzo y metodología de obtención de datos diferentes de la investigadas hasta el momento. Concretamente, se pretendió testarlo en cicloergómetro en lugar de tapiz rodante, con cargas progresivas hasta llegar al máximo en lugar con una única carga constante, y con una metodología de recogida de información impuesta por el administrador (cada 30s) en lugar de autorregulada por el participante. Las hipótesis de trabajo fueron las siguientes:

1) Los PA emergen espontáneamente, tanto durante un ejercicio sin imponer ningún tipo de pensamiento, como imponiendo PD;

2) Todos los participantes presentarán 2 fases de esfuerzo (alternancia entre PD y PA y estabilidad de PA), durante el ejercicio realizado sin imponer ningún tipo de pensamiento;

3) Todos los participantes presentarán las 3 fases de esfuerzo postuladas por el modelo no lineal del foco de atención, i.e., 1) estabilidad del PD, 2) alternancia entre PD y PA, 3) estabilidad de PA, durante el ejercicio realizado imponiendo PD.

Método

Participantes

Doce estudiantes de educación física caucásicos (6 varones y 6 hembras; M = 22.83 años de edad; DE = 3.04), practicantes regulares de ejercicio pero sin una especialización deportiva destacable, participaron voluntariamente en el estudio. Todos ellos fueron previamente familiarizados con las tareas motoras y cognitivas del experimento, así como con los procedimientos de automonitorización y autoinforme requeridos. Después de leer la descripción y los riesgos del estudio todos ellos firmaron un consentimiento informado. Todos los procedimientos experimentales fueron aprobados por el comité local de ética de la investigación y se realizaron según las pautas éticas de la declaración de Helsinki.

Procedimiento

Después de un proceso de familiarización los participantes pedalearon dos veces en un período de 2 semanas realizando la misma tarea motora pero con dos tipos distintos de instrucciones relativas a su foco de atención. En el primer test no se impuso ningún tipo de pensamiento (pensamiento disociado no impuesto, PDNI) y tuvo como objetivo establecer la dinámica intrínseca de los participantes respecto a su foco de atención. El segundo test se realizó imponiendo PD (pensamiento disociado impuesto, PDI) y tuvo como objetivo testar el modelo no lineal del foco de atención (Balagué et al., 2012) cambiando la modalidad del ejercicio (pedaleo en lugar de carrera), la administración de cargas (progresiva en lugar de continua), y la metodología de obtención de datos (impuesta por el administrador y regular en el tiempo en lugar de autorregulada por parte del participante). Todos los procedimientos (descritos más abajo) se llevaron a cabo en el plazo de 3 semanas.

Familiarización

Una semana antes de realizar los test se describieron verbalmente a los participantes las diferencias entre PD y PA (de acuerdo con la clasificación de Schomer, 1986) y se pusieron ejemplos. Los ejemplos de los pensamientos asociados incluyeron "mantengo el ritmo… respiro," y "me concentro en mi tiempo parcial", mientras que los ejemplos de pensamientos disociados incluyeron "miro el entorno", y "pienso en mis deberes de esta noche" (Balagué et al., 2012; Tenenbaum y Connolly, 2008). Después de exhibir competencias en la discriminación de PD y PA, practicaron 1 prueba simulada que consistió en pedalear hasta que reportaron correctamente la aparición de 3 PD o PA a través de señales del dedo pulgar (Balagué et al., 2012). Las instrucciones de señalización se acompañaron de una demostración visual. Un ensayo fue suficiente para que todos los participantes se sintiesen seguros de su uso antes del test.

Tarea motriz

La tarea motriz fue realizada en un cicloergómetro (*Sport Excalibur* 925900) y consistió en un ejercicio incremental realizado hasta el agotamiento. Los participantes comenzaron a pedalear a una potencia de 20W, que aumentó 20W/min, hasta que no pudieron mantener la cadencia de pedaleo (70 rpm) durante más de 15s. La prueba fue filmada en vídeo para comprobar los datos obtenidos.

Test PDNI

Para detectar la dinámica intrínseca del foco de atención durante la tarea motriz se pidió a los participantes que monitorizasen e informasen de su categoría de pensamientos cada 30s. Se optó por señales del dedo pulgar visibles, distinguibles y previamente convenidas (pulgar hacia arriba si tenían un PD, y pulgar abajo si tenían un PA) (Balagué et al., 2012). Al final de la prueba, los participantes fueron entrevistados sobre el contenido de sus PD y PA para confirmar que realizaron una distinción apropiada del tipo de pensamiento, y para recopilar información cualitativa adicional. Específicamente respondieron a la pregunta: "¿Podrías, por favor, expresar cronológicamente el contenido de tus PD y PA durante el pedaleo?"

Test PDI

El test PDI consistió en imponer conscientemente desde el principio cualquier clase de PD que los participantes eligiesen, sin importar su contenido (para reducir al mínimo el esfuerzo cognitivo), y que lo mantuviesen intencionalmente durante la prueba. Comenzando con el PD impuesto se les pidió que señalizaran (igual que en el test PDNI) cada 30s su categoría de foco de atención en aquel momento. Al final de la prueba también fueron entrevistados respecto al contenido de sus PD y PA.

Análisis de los datos

Se registraron las series temporales del foco de atención de cada participante en los dos test para mostrar la dinámica de sus PD-PA. Las series individuales se dividieron en 10 intervalos temporales iguales y de intensidad creciente, para obtener los porcentajes de PD de todos los participantes en cada uno de ellos. Se obtuvo una mediana en cada intervalo a partir de dichos porcentajes. La hipótesis nula de una mediana constante (sin diferencias significativas) a lo largo del tiempo se testó a través de la prueba no paramétrica de medidas repetidas Friedman ANOVA. Se llevó a cabo el test de Wilcoxon para comprobar si había diferencias significativas entre las parejas de intervalos 1,5, y 10 en la condición PDNI y en la condición PDI, respectivamente; igualmente se comprobaron todas las parejas de intervalos (e.g., 1-1, 2-2, 3-3) correspondientes a ambas condiciones (PDNI-PDI). Para controlar posibles diferencias relacionadas con el género se compararon las medianas obtenidas en cada intervalo de intensidad por el grupo de chicas y chicos, respectivamente, a través de la prueba U de Mann-Whitney. El nivel de significación se fijó en $p = .05$. Los tamaños del efecto se calcularon como medidas *PS*dep (Grissom y Kim, 2012).

Resultados

La carga máxima alcanzada por los participantes en el test PDNI fue $M = 263.3$W; $DE = 58,3$ y en el test PDI, $M = 268.33$W; $DE = 56.86$. En las Figuras 1 y 2 se pueden observar las medianas de los porcentajes de PD en los diferentes intervalos de intensidad de esfuerzo, en los test PDNI y PDI, respectivamente. La Friedman ANOVA de medidas repetidas aplicada a los 10 intervalos ($N = 12$, $df = 9$) mostró un efecto significativo, $\chi2$ (12, 9) = 39.75; $p < .001$, del esfuerzo incremental sobre los porcentajes de PD en el test PDNI y también en el test PDI ($\chi2$ (12, 9) = 70.65; $p < .001$). En la condición PDNI el test de Wilcoxon mostró diferencias estadísticamente significativas ($p = .011$) entre los intervalos de intensidad 1 y 10; 5 y 10. Como muestra la Figura 1, el porcentaje de PD correspondiente a la mediana osciló entre 32% y 58% en los 4 primeros intervalos de intensidad. A partir del 4° intervalo empezó a descender progresivamente hasta ser de un 0% en los 4 últimos intervalos (del 7 al 10). En cambio, en la condición PDI el test de Wilcoxon indicó diferencias significativas entre los intervalos de intensidad 1 y 5 ($p = .043$); 1 y 10 ($p = .002$); 5 y 10 ($p = .003$). Como muestra la Figura 2, el porcentaje de PD correspondiente a la mediana empezó siendo del 100% en la primera mitad de los intervalos de intensidad, cayó a un 60% en los intervalos 6, 7, 8, y al 0% en los dos últimos intervalos. Los valores *PS*dep para diferencias de porcentajes intragrupales entre los intervalos de intensidad 5 y 1, 10 y 1 y 10 y 5 fueron, respectivamente, 0.16; 0.66; y 0.66 en el test PDNI y 0.41; 1.00; y 0.91 en el test PDI.

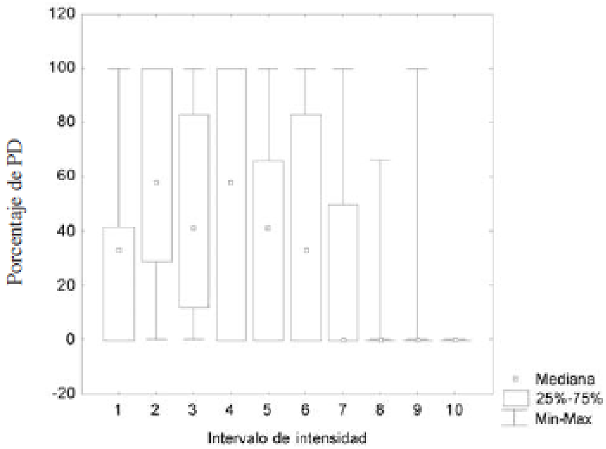

Figura 1. Medianas de los porcentajes de PD en los 10 intervalos de intensidad de esfuerzo en los test PDNI (pensamiento disociado no impuesto). PD = pensamiento disociado.

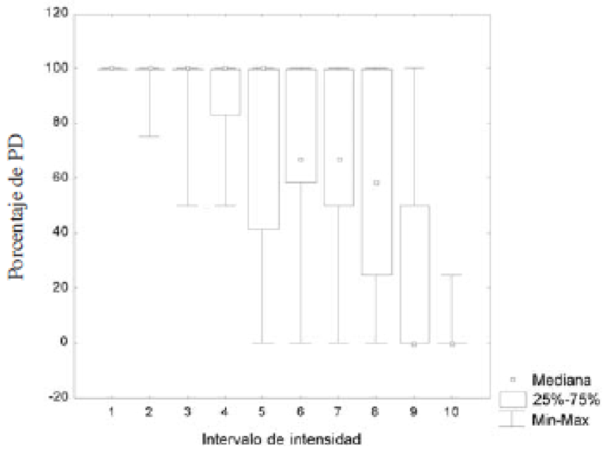

Figura 2. Medianas de los porcentajes de PD en los 10 intervalos de intensidad de esfuerzo en los test PDI (pensamiento disociado impuesto). PD = pensamiento disociado.

Como muestra la Tabla 1 los porcentajes de PD fueron significativamente superiores en el test PDI respecto al test PDNI en los primeros 4 intervalos de ejercicio y en los intervalos 7 y 8 ($p < .05$). En cambio, no se encontraron diferencias significativas en el resto de intervalos temporales. No se encontraron diferencias entre los resultados obtenidos por los chicos y las chicas en ninguno de los intervalos de intensidad de los dos test ($p = 1$).

Par de variables	*T*	*Z*	*p*-nivel	PS_{dep} [a]
1PDNI y 1PDI	0.00	2.93	**<.01**	.91
2PDNI y 2PDI	1.00	2.20	**.02**	.58
3PDNI y 3PDI	3.50	2.45	**.01**	.75
4PDNI y 4PDI	7.50	2.04	**.04**	.75
5PDNI y 5PDI	13.50	1.73	.08	.58
6PDNI y 6PDI	11.50	1.91	.05	.75
7PDNI y 7PDI	13.00	2.04	**.04**	.83
8PDNI y 8PDI	7.50	2.27	**.02**	.75
9PDNI y 9PDI	4.50	0.81	.41	.33
10PDNI y 10PDI	0.00	—	—	.08

Nota. $p < .05$ están en negrita. PDNI = pensamiento disociado no impuesto; PDI = pensamiento disociado impuesto; PS_{dep} = probabilidad de superioridad para grupos dependientes.
[a]Según Grissom y Kim (2012).

Tabla 1. Valores del Test de Wilcoxon (T, Z, p-nivel) y del Tamaño del Efecto (PSdep) Para los Pares de Variables PDNI y PDI.

Discusión

Los resultados obtenidos corroboran las predicciones del modelo no lineal del foco de atención en el ejercicio llevado hasta el agotamiento a través de una modalidad de esfuerzo y una metodología de obtención de datos distinta de la testada hasta el momento (Balagué et al., 2012; Hutchinson y Tenenbaum, 2007). Un ejercicio de pedaleo incremental y progresivo reemplazó al esfuerzo realizado a velocidad constante sobre tapiz rodante y la metodología de recogida de datos fue impuesta de forma regular por parte del administrador en lugar de ser autorregulada de forma espontánea por parte del participante.

Se deduce de los resultados obtenidos que el cerebro no puede imponer deliberadamente cualquier clase de pensamiento con la misma eficacia durante un esfuerzo con aplicación progresiva de cargas. Si la adherencia al foco de atención fuese totalmente arbitraria (e.g., sujeta a un control deliberado), el test PDI hubiese estado dominado por PD hasta el final. ¿Cómo se podría explicar desde una concepción volitiva que los PA dominaron totalmente el foco de atención a intervalos de intensidad superiores a 8 en el test PDI? Sin duda necesitaríamos añadir algunas explicaciones *ad hoc* para comprenderlo. Además, los PA dominaron totalmente dicho foco de atención a intervalos de intensidad superiores a 6 en el test PDNI. Por su parte, no sólo los PA sino también los PD emergieron espontáneamente en el test PDNI. A diferencia de los PA, los PD emergentes se registraron hasta el intervalo 6, pero no a intensidades superiores.

El aumento de PA en los intervalos de mayor intensidad, y que comportaron un mayor grado de fatiga, pudo ser simplemente una consecuencia de la mayor estabilidad dinámica de los mismos en dicho contexto. Esto corroboraría la hipótesis del modelo no lineal de regulación dinámica del foco de atención durante el ejercicio constante llevado hasta la extenuación (Balagué et al., 2012). Según dicho modelo los pensamientos emergen de forma espontánea como producto dinámico del entorno psicobiológico cambiante de esfuerzo. Para ello no se precisa de ninguna red neuronal o dispositivo responsable de emitir órdenes deliberadas que explique los cambios en el foco de atención que se producen con la fatiga.

Sin embargo, resultó interesante observar los efectos de la intención sobre la dinámica del foco de atención. Las diferencias en la dinámica de los PD y PA entre el test PDNI y PDI indicaron que la intención fue capaz de modificar el foco de atención a intensidades de ejercicio moderadas pero fue perdiendo progresivamente su estabilidad, tal como sugirieron anteriormente Balagué, Hristovski, y Aragonés (2011); Hristovski y Balagué (2010) y Hutchinson y Tenenbaum (2007).

En el test PDI se distinguieron 3 fases de esfuerzo coincidiendo con las propuestas por Balagué et al. (2012): estabilidad del PD impuesto intencionalmente, emergencia espontánea del PA, cambiando intermitentemente a PD y, por último, PA estable. En cambio, en el test PDNI se detectaron sólo dos fases, de acuerdo con las propuestas anteriormente por Tenenbaum y Connolly (2008): con cargas ligeras el foco de atención es flexible y emergen tanto PD como PA; en cambio, cuando la carga aumenta el foco de atención se estrecha dando lugar únicamente a PA. Sería conveniente estudiar en un futuro la correspondencia de dichas fases con las establecidas por umbrales fisiológicos.

La intención (test PDI) mostró tener un papel substancial en la modificación de la dinámica intrínseca (reflejada en el test PDNI) durante la mayor parte del ejercicio progresivo, como se deriva de la valoración del tamaño del efecto (ver Tabla 1). No obstante, durante los últimos intervalos de intensidad el efecto intencional se debilitó hasta prácticamente desaparecer como puede observarse en la Figura 2.

Estos resultados corroboran también los obtenidos con anterioridad por otros autores, quienes atribuyen el foco de atención al nivel de la intensidad de la carga de trabajo (Gammage, Hardy y Hall, 2001; Schomer y Connolly, 2002; Tenenbaum, 2001), regulando ésta el perfil de estabilidad de los dos tipos de pensamiento/estrategia cognitiva (PD y PA). Hutchinson y Tenenbaum (2007) encontraron que los PA dominaban a medida que aumentaba la carga en cicloergómetro: mientras que los PA supusieron un 22% de los pensamientos durante el pedaleo al 50% del VO2 máx, aumentaron a un 61% y a un 93% al 75% y al 90% del VO2 máx, respectivamente. A diferencia del estudio actual, en el que se recogió la información de los participantes a intervalos regulares (30s), dichos autores la registraron de forma continua durante la prueba. Es importante destacar que esta última estrategia, a pesar de ofrecer menor sensibilidad, no afectó a las conclusiones, lo que ayuda a corroborar la consistencia de las mismas.

A diferencia de Balagué et al. (2012), quienes testando la dinámica intrínseca (sin imponer ningún tipo de pensamiento) de una población similar corriendo a una velocidad del 80% de su FC máx, no encontraron PD, en el presente estudio sí que se hallaron a pesar de no estar impuestos (test PDNI). La inclusión de cargas ligeras y moderadas (correspondientes a intervalos de intensidad inferiores a 8) y el aumento progresivo de las mismas, puede explicar los PD encontrados durante el test PDNI. A intensidades superiores al intervalo de intensidad 8 la mayoría de participantes tampoco presentaron ningún PD en nuestro estudio. Sin embargo, en el test PDI los PD registrados se redujeron progresivamente, de la misma manera que observaron Balagué et al. (2012) a medida que aumentó el tiempo de esfuerzo. El dominio de los PA sobre los PD a cargas altas fue superior en el presente estudio probablemente debido a las diferencias metodológicas entre ambos trabajos. Así, mientras que Balagué et al. (2012) calcularon para cada participante los porcentajes de tiempo transcurrido manteniendo PD respecto al tiempo total (tiempo manteniendo PD + tiempo manteniendo PA) en cada uno de los intervalos, en este estudio se calcularon para cada participante los porcentajes de PD registrados respecto al total de pensamientos registrados (PD + PA) para cada intervalo. Esta última estrategia limitó las posibilidades de hallar PD especialmente al final del esfuerzo ya que la duración de dichos PD impuestos se redujo a medida que aumentó la estabilidad de los PA (Balagué et al., 2012).

Los resultados de este estudio suponen un reto para la investigación futura de la integración psicobiológica durante el esfuerzo. Por un lado, el cerebro no puede entenderse como un subsistema encapsulado cuya eficacia no se ve afectada por la periferia, y por el otro, resulta evidente que la periferia constriñe la intención y las propiedades estabilizadoras de la mente, lo que apunta hacia una causalidad circular entre ambas (Balagué, Hristovski y Aragonés, 2011). Además, pueden tener implicaciones importantes en el diseño de intervenciones cognitivas orientadas a la mejora del rendimiento deportivo y en el desarrollo de criterios no-invasivos para el control de las cargas de entrenamiento. Resulta necesario realizar más investigación para comprobar la relación entre variables fisiológicas y las fases dinámicas del foco de atención descritas, especialmente en deportistas de élite. Sería también recomendable investigar el contenido de los PD y de los PA durante el esfuerzo. Como se pudo apreciar en las entrevistas realizadas post-test y tal como sugieren resultados recientes (Balagué, Hristovski, Aragonés, García y Tenenbaum, datos sin publicar), dicho contenido se ve modificado a medida que se acerca la terminación.

En esta línea las intervenciones cognitivas propuestas deberían tener en cuenta que imponer PD puede ser eficiente a intensidades bajas o moderadas, tal como sugieren Schücker et al. (2009); sin embargo, a medida que la intensidad aumenta, y especialmente cuando es máxima, los PA de tipo alentador como "aún puedo aguantar cinco minutos más" pueden ser más recomendables y efectivos, tal como se deduce de los resultados de este trabajo y de las estrategias cognitivas usadas por algunos competidores (Schomer y Connolly, 2002). El esfuerzo por mantener PD a intensidades altas podría resultar poco eficiente y, como se deriva de los resultados de este estudio, también poco eficaz. Hay que resaltar también las posibilidades de aplicación práctica de las fases de esfuerzo detectadas no invasivamente gracias al estudio de la dinámica del foco de atención. Sin embargo, para una adecuada interpretación de estos resultados se debe tener en cuenta las limitaciones asociadas con las metodologías que utilizan autoinformes, reconocidas por la literatura científica que estudia el pensamiento emergente (Christoff, Ream y Gabrieli, 2004; Kam et al., 2011; Smallwood, Riby, Heim y Davies, 2006; Smallwood y Schooler, 2006, 2009). La señalización del tipo de pensamiento a través de posiciones del dedo pulgar, que podría considerarse excesivamente rudimentaria comparada con la utilización de dispositivos electrónicos utilizadas por otros autores en condiciones de reposo, se prefirió en este estudio porque, tal como informaron los participantes, la presión de botones suponía un esfuerzo cognitivo adicional que aumentaba la posibilidades de introducir algún error en la distinción de los pensamientos, especialmente al aplicar cargas cercanas a la terminación del esfuerzo (Balagué et al., 2012). Otra limitación del estudio fue la recogida de información sobre el tipo de pensamiento a intervalos regulares (30s), que no permitió registrar la duración de los PD y de los PA durante los test, impidiendo estudiar sus cambios con el incremento de carga. Sin embargo, su menor sensibilidad sirvió para reforzar la consistencia de los resultados obtenidos.

En conclusión, los PA emergen de forma espontánea durante el ejercicio cicloergométrico progresivo y máximo a medida que aumenta la carga; siendo el foco de atención dominante al aproximarse la extenuación en los dos test (PDNI y PDI). Todos los participantes muestran la existencia de dos fases (alternancia de PD y PA, y dominancia de PA) en el test PDNI y de tres fases en el test PDI (estabilidad de PD, alternancia de PD y PA y estabilidad de PA), lo que confirma la consistencia del modelo no lineal del foco de atención propuesto.

EL FOCO DE ATENCIÓN EMERGE ESPONTÁNEAMENTE DURANTE EL EJERCICIO PROGRESIVO Y MÁXIMO

PALABRAS CLAVE: Pensamiento disociativo, Pensamiento asociativo, Modelo no lineal, Emergencia, Ejercicio incremental.
RESUMEN: El objetivo de este estudio fue testar un modelo no lineal del foco de atención imponiendo y sin imponer un pensamiento disociado durante un test cicloergométrico progresivo y máximo. Doce estudiantes previamente familiarizados con los procedimientos experimentales realizaron dos veces un test progresivo y máximo en cicloergómetro en dos condiciones diferentes: la primera, orientada a establecer su dinámica intrínseca, sin imponer ningún tipo de pensamiento, y la segunda imponiendo un pensamiento disociado (PD). Durante los test los participantes informaron cada 30s sobre su tipo de pensamiento (PD o PA -pensamiento asociado) a través de señales previamente convenidas. Las series individuales se dividieron en 10 intervalos temporales de intensidad creciente y se calcularon los porcentajes de PD y PA en cada una de ellas. Se encontraron porcentajes significativamente superiores de PA a partir del 6° intervalo de intensidad en el test con PD no impuesto (PDNI) (χ^2 (12, 9) = 39.75; $p < .001$) y a partir del 8° intervalo en el test con PD impuesto (PDI) (χ^2 (12, 9) = 70.65; $p < .001$). Los porcentajes de PD fueron superiores en el test PDI en 6 de los 10 intervalos de intensidad ($p < .05$). Los resultados demuestran la emergencia espontánea de PA durante el ejercicio progresivo y máximo confirmando el modelo no lineal del foco de atención.

O FOCO ATENCIONAL EMERGE ESPONTANEAMENTE DURANTE O EXERCÍCIO PROGRESSIVO E MÁXIMO

PALAVRAS-CHAVE: Pensamento dissociativo, Pensamento associativo, Modelo não linear, Emergência, Exercício progressivo.
RESUMO: O objectivo deste estudo foi testar um modelo não linear do foco de atenção impondo e sem impor um pensamento dissociativo durante um teste cicloergométrico progressivo e máximo. Doze estudantes previamente familiarizados com os procedimentos experimentais realizaram duas vezes um teste progressivo e máximo num cicloergómetro em duas condições diferentes: a primeira, orientada para estabelecer a sua dinâmica intrínseca, sem impor nenhum tipo de pensamento, e a segunda impondo um pensamento dissociado (PD). Durante os testes os participantes informaram cada 30s sobre o seu tipo de pensamento (PD ou PA –pensamento associado) através de sinais previamente convencionados. As séries individuais dividiram-se em 10 intervalos temporais de intensidade crescente e foram calculadas as percentagens de PD e PA em cada uma delas. Verificaram-se percentagens significativamente superiores de PA a partir do 6° intervalo de intensidade no teste com PD não imposto (PDNI) (χ^2 (12, 9) = 39.75; $p < .001$) e a partir do 8° intervalo no teste com PD imposto (PDI) (χ^2 (12, 9) = 70.65; $p < .001$). As percentagens de PD foram superiores no teste de PDI em 6 dos 10 intervalos de intensidade ($p < .05$). Os resultados demonstram a emergência espontânea de PA durante o exercício progressivo e máximo, confirmando o modelo não linear do foco atencional.

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CAPÍTOL 3: Estudi II

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Human Kinetics
APPLIED RESEARCH

Dynamic Stability of Task-Related Thoughts in Trained Runners

Sergi García
University of Barcelona

Selen Razon
Ball State University

Robert Hristovski
Ss. Cyril and Methodius University

Natàlia Balagué
University of Barcelona

Gershon Tenenbaum
Florida State University

Drawing upon the nonlinear model of attention focus, the purpose of this study was to compare the intrinsic and intentional dynamics of task-related thoughts (TRT) in trained runners and nonrunners during an incremental maximal test. Fourteen trained runners and 14 nonrunners were assigned to 2 conditions: intrinsic (nonimposed thoughts) and intentional (imposed, task-unrelated thoughts; TUT). A significant effect of running velocity over TUT/TRT dynamics in both groups and conditions was observed ($p < .001$). Although, all participants received instructions to keep TUT for the entire duration of the test, an initially stable TUT phase was followed by a metastable phase (i.e., switches between TUT and TRT) and a final stable TRT phase nearing volitional exhaustion. The stable TRT phase lasted longer in runners group ($p < .05$) and included higher probabilities in pace monitoring thoughts subcategory ($p < .05$). The results revealed that trained runners seem to use TRT (i.e., pace monitoring) to maximize performance, and confirm the nonlinear model of attention focus during incremental maximal run in trained runners and nonrunners.

Keywords: runners, task-related thoughts, nonlinear dynamic systems approach

Appropriate attention focus is crucial to high athletic performance in endurance events such as long distance running (see Hutchinson & Karageorghis, 2013). Nonetheless, the underlying mechanisms accounting for the ergogenic effects of appropriate attention focus in runners are rather unknown. Two main categories of attention focus prevail while engaging in physical effort; namely, association and dissociation (Morgan & Pollock, 1977). Association refers to focusing on task-relevant information including pace or distance completed or the body's internal cues including muscle tension and breathing. Dissociation refers to focusing on task-irrelevant cues including problem solving, or listening to music, and distracting from the sensory information stemming from the body (Hutchinson & Karageorghis, 2013; Hutchinson & Tenenbaum, 2007; Razon et al., 2011).

It was recently argued, however, that the associative/dissociative dichotomy may not be sufficiently comprehensive for capturing the dynamic complexities of thought processes (Brick, MacIntyre, & Campbell, 2014). Alternative to this attentional dichotomy, Schomer (1986) had initially proposed four thought-related categories: external and internal task-related thoughts (TRT-E, TRT-I), and external and internal task-unrelated thoughts (TUT-E, TUT-I; see Table 1).

Research findings revealed a more frequent use of TRT in experienced runners (e.g., Masters & Lambert, 1989; Silva & Appelbaum, 1989; Tammen, 1996; Tenenbaum, 2002), compared with their less experienced counterparts (e.g., Padget & Hill, 1989; Pennebaker & Lightner, 1980; Wrisberg & Pein, 1990). However, it is unknown whether the more frequent use of TRT reflects a spontaneous thought flow developed and stabilized through training, or a volitional strategy. Specifically, research has not yet sufficiently investigated dynamics of thoughts, and their stability profile, informing which thought categories among others are persistent.

García and Balagué are with the National Institute of Physical Education of Catalonia, University Barcelona, Barcelona, Spain. Razon is with the School of PE, Sport and Exercise Science, Ball State University, Muncie, IN. Hristovski is with the Ss. Cyril and Methodius University, Skopje, Macedonia. Tenenbaum is with the Dept. of Educational Psychology and Learning Systems, Florida State University, Tallahassee, FL. Address author correspondence to Natàlia Balagué at nataliabalague@gmail.com.

Table 1 Three Levels of Thought Contents Categories in Schomer's (1986) Classification

Task-relatedness	Attentional Direction	Schomer's Subcategories	Thoughts
TUT	I	Reflective activity (R)	Past and future issues related to running
		Personal Problem Solving (PS)	Issues of an intrapersonal and interpersonal nature
		Work and Career (W)	Job, work, and career-related issues
	E	Course Information (I)	Scenery not related to pacing strategy
		Conversational Chatter (CC)	Related to internal dialogue
		Environmental Feedback (E)	Here and now nature feedback related to environment
TRT	I	Body Monitoring (B)	Here and now nature with specific reference to anatomical and/or physiological-related feedback
		Command and Instruction (CI)	Self-regulatory instruction to specific body parts or to whole body related to running
		Feelings and Affect (FA)	Whole-body sensations
	E	Pace Monitoring (P)	Verbalized feedback on the current performance related to time, distance, speed, pacing

Note. TUT-I = Internal Task-Unrelated Thoughts; TUT-E = External Task-Unrelated Thoughts; TRT-I = Internal Task-Related Thoughts; TRT-E = External Task-Related Thoughts.

The nonlinear dynamical systems theory (NDST) is a mathematical theory which helps describe the brain behavior dynamics (Kelso, 1995) and in particular its cognitive functions (Kello, Beltz, Holden, & Van Orden, 2007). Recent research has used the theory to study attention focus and thoughts processes during effort expenditure (Balagué, Aragonés, Hristovski, García, & Tenenbaum, 2014a). To distinguish between spontaneous and volitional conditions, the NDST suggests the use of a dual intrinsic-intentional paradigm (Kelso, Scholz, & Schoner, 1988). According to this paradigm, the intrinsic spontaneous dynamics (i.e., without imposing any type of thought) is initially established. Then the intention of the participant is manipulated (i.e., imposing any type of TUT; external or internal) to test for any spontaneous dynamics change. Specifically, the sequence of conditions (intrinsic/intentional) aims at evaluating how intention parameterizes the stability profile of the intrinsic dynamics. As opposed to more frequently used methodologies (i.e., retrospective questionnaires, intermittent data collection, concurrent data collection at regular intervals), studies within the NDST use continuous self-monitoring and self-reporting protocol of thought changes during task performance up to volitional exhaustion (Balagué, Hristovski, Aragonés, & Tenenbaum, 2012; Balagué, Hristovski, García, Aragonés, Razon, & Tenenbaum, 2014b). Findings from those studies revealed a nonproportional effect of effort accumulation on thoughts dynamics. Specifically, a minimal increase in constant running time led to an abrupt change in the intended thoughts, while a large increase did not produce any change of thoughts. Furthermore, nearing volitional exhaustion, TUT destabilized while TRT stabilized.

Using the intrinsic and intentional dynamics, researchers have uncovered two and three thought phases (Balagué et al., 2012). Specifically, during the intrinsic condition (i.e., without any imposed thought) an initial metastable phase (i.e., switches between TUT and TRT) was followed by a stable TRT phase approaching volitional exhaustion. However, during the intentional dynamics condition (e.g., imposing a TUT) the initially stable TUT phase was followed by a metastable TUT/TRT phase, and a final stable TRT phase. TRT was not imposed because it was already stable under the intrinsic dynamics condition. It should be noted that TUT and TRT phases were characterized by TUT and TRT thought categories exclusively. The metastable phase, however, was marked by a tendency to switch its course between thought categories (i.e., the imposed TUT and the nonimposed, emergent TRT). In NDST the change in the system's stability profile is due to the change of nonspecific control parameters (Kelso, 1995).These parameters (e.g., time on task, velocity, accumulated effort) are considered nonspecific because they do not explicitly prescribe the state of the system, but rather constrain its behavior.

Of the nonspecific parameters, time on task affects task-relatedness and direction (internal, external) of thought contents (Balagué et al., 2014b). Consequently, it may not be possible to intentionally sustain TUT to the point of volitional exhaustion because the gradual destabilization of internal TUT, external TUT, and external TRT may lead to a singular stable internal TRT. Consistent with these assertions, Jantzen, Steinberg, and Kelso (2009) maintained that more energy is expended when a dynamically unstable pattern is intentionally imposed upon an intrinsically stable one. While researchers have investigated the stability of TUT in physically active individuals (see Balagué et al., 2014b), the concept is yet to be tested in trained individuals. Particularly, it is unknown whether the effort phases recognized under the intrinsic and intentional dynamics by the nonlinear model of attention focus are reproducible in trained individuals. In addition, research has tested the nonlinear model of attention focus during constant running (Balagué et al., 2012), incremental and constant cycling (Balagué et al., 2014a, 2014b), but not during incremental maximal running.

Consequently, adopting the NDST perspective, the purpose of the current study was (a) to test the nonlinear model of attention focus in trained runners, (b) to examine the intrinsic and intentional dynamics of TRT during incremental maximal running in both trained runners and nonrunners, and finally (c) to compare and contrast the differences in the TRT contents of trained runners and nonrunners.

Method

Participants

To determine the sample size for this study a power analysis was conducted using G*Power 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007). Similar studies of thought processes (Balagué et al., 2014b) have reported large effect sizes. Thus, using an effect size of $d = 1.0$, $\alpha < .05$, power $(1—\beta) = .80$, we estimated a sample size = 28 (14 participants in each group). Fourteen trained runners (7 males and 7 females; $M = 20.50$ years old, $SD = 1.51$), and 14 nonrunners (7 males and 7 females; $M = 19$ years old, $SD = 2.51$) completed the study. The runners group included participants recruited from local running and triathlon clubs. They were active runners competing in races for 5.14 years ($SD = 1.35$), and ran an average of 39.32 km/week ($SD = 21.14$). Male runners reported a personal best running time for 10 km races of $M = 38{:}25$ min ($SD = 3{:}20$ min), and females reported a time of $M = 42{:}45$ min, ($SD = 2{:}20$ min). The nonrunners group included participants without running specialization but engaging in a wide range of aerobic activities at least three times a week. Exclusion criteria consisted of (a) current or previous injury against exercise testing, and (b) any other conditions that may prevent the performance of a maximal exercise protocol. No participant was excluded from the current study. The experiment was approved by the local ethical committee, and carried out according to the Helsinki Declaration. Participants read the study's description and risks and signed an informed consent before taking part in the study.

Intervention and Procedure

Completion of this study took a total of three sessions, each session was scheduled one week apart. During the first week, participants completed a familiarization test. During the second week they performed an incremental and maximal running test with no thought imposed (intrinsic dynamics condition), and in the third week they performed the same running test with TUT imposed (intentional dynamics condition). During both tests, participants' thought contents were monitored and assessed.

Thought Contents Monitoring and Reporting Measures. The participants' thought contents were recorded using the self-caught measurement approach and the experimenter-classified method (Smallwood & Schooler, 2006). The self-caught measurement requires individuals to be aware of the contents of their own thoughts and report them whenever they notice thought changes. In the experimenter-classified method it is the experimenter, not the participant, who classifies the type of thoughts. Thus, participants were not informed about the category of thinking that was investigated.

Participants were asked to self-monitor and self-report their spontaneous and deliberate thought flow using a continuous online protocol (Giambra, 1995). This protocol requires participants to report each change of thought content as it occurs (i.e., instantaneously), using a self-selected single key word to identify it. Some of the key words included "exam" or "velocity". The test administrator collected verbatim the list of the key words and upon test completion the interviewee was asked about the thought content related to each key word and ranked them according to Schomer's classification (see Table 1). An example for TUT was: "thinking about my university exams," and for TRT: "focus on the treadmill's velocity." Then participants completed a manipulation check to assess their adherence to manipulation instructions on an 11-point Likert-type scale (0 = *not at all*, 10 = *greatly*). The entire procedure was audio-recorded to validate the content of the key words and its classification.

Procedure.

Familiarization. Participants practiced on a simulated test consisting of running consecutively at 8, 11, and 14km/h. They had to keep each of these velocities until reporting at least five different key words in every one of them, to ensure they understood the reporting procedure properly. Participants were afterward interviewed (see above thought contents monitoring and reporting measures).

Running Test. The test consisted of an incremental running test performed until volitional exhaustion (adapted from McConnell, 1998) to detect the maximal aerobic velocity. Participants started running at 5km/h and the velocity increased by 1km/h every minute until they could not keep the prescribed velocity. All tests were conducted at between 8am-11am on the same treadmill with the screen covered to avoid seeing any data output. Once the test began, to prevent bias from audience effects upon thought measurements, experimenters stood outside the runner's angle of view, and participants were not exposed to any verbal or other communication interaction.

Following the dual intrinsic/intentional paradigm, the test was performed under two different experimental conditions:

> *Intrinsic dynamics.* Participants were instructed to monitor and report their spontaneous thought flow without imposing any specific thought.

Intentional dynamics. Participants were requested to consciously self-impose any type of free chosen TUT (i.e., external or internal) from the outset, and maintain it intentionally throughout the test. They reported the keyword corresponding to the initial chosen self-imposed TUT before the test.

Data Analysis

The different thought contents obtained in both tests were classified as (a) TUT or TRT, and (b) TUT/TRT subcategories (see Table 1) following the experimenter-classified method (Smallwood & Schooler, 2006). TUT/TRT time series of each runner were registered and divided into 10 equal temporal intervals of increasing velocity. Mean probability values for all the participants were calculated for TUT and TRT separately within each of the 10 velocity intervals (i.e., time lap maintaining since reporting TUT or TRT within the velocity interval divided by the total time of the velocity interval). To test the null hypothesis of a constant median over running velocity, a Friedman ANOVA was performed separately for both TUT and TRT. Effect sizes (Cohen's *d*) were computed to demonstrate means' differences where effects approached $p < .05$ level.

The dynamics of TUT/TRT resulted in different qualitative thought phases (e.g., two and three thought phases in the intrinsic and intentional conditions, respectively; see Figure 1). The duration of each thought phase, defined as the number of velocity intervals containing every phase, was calculated for all the participants. Mann Whitney U matched pairs test was used to contrast in both intrinsic and intentional dynamics (a) the duration of the different thought phases, and (b) mean probability values

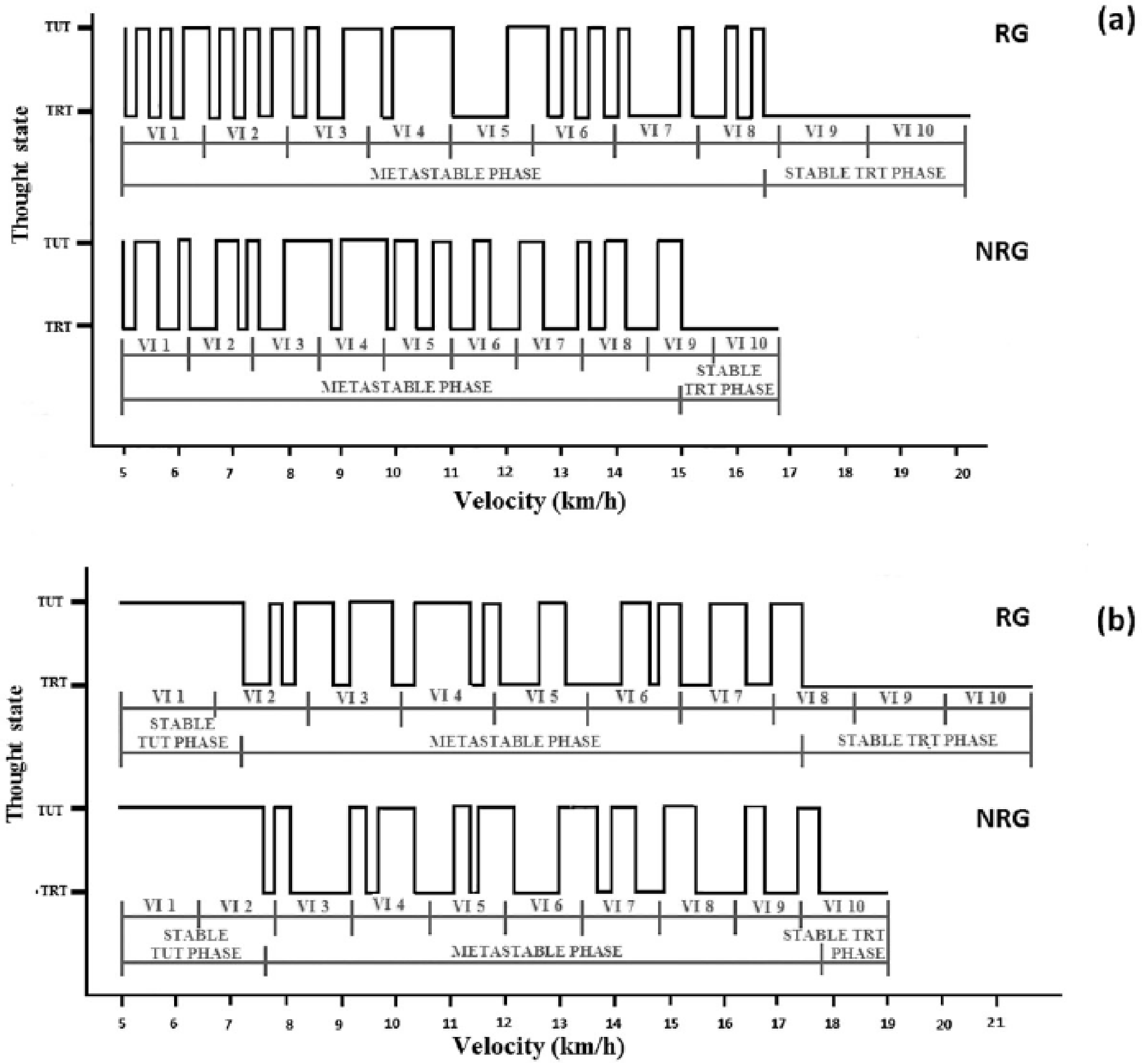

Figure 1 — Examples of two typical individual series of TUT/TRT dynamics in the intrinsic (a) and intentional (b) conditions. RG = runners group; NRG = non-runners group; TUT = task-unrelated thoughts; TRT = task-related thoughts; VI = velocity interval.

obtained for different thought subcategories, within thought phases where significant differences were found in their duration.

Results

Manipulation Check

The manipulation check questionnaire (11 ratings) revealed that both groups showed a high level of adherence. Runners and nonrunners adhered equally to their cognitive instruction during the intrinsic ($M = 9.16$, $SD = 0.75$ in runners group; $M = 9.25$, $SD = 0.96$ in nonrunners group; $t(26) = 0.42$, $p = .69$) and in the intentional dynamics ($M = 9.29$, $SD = 0.51$ in runners group; $M = 9.14$, $SD = 0.96$ in nonrunners group; $t(26) = 0.53$, $p = .47$). The two trained observers classified the key words into the same Schomer's categories and subcategories (see Table 1). Interobserver reliability (Cohen's kappa) was 1.00.

Intrinsic Dynamics

Maximal aerobic velocity in the intrinsic dynamics condition was significantly higher in the runners group than in the nonrunners group: M= 19.93km/h, $SD = 1.19$ vs. $M = 16.64$km/h, $SD = 1.29$ ($t(26) = 4.20$, $p < .001$, $d = 1.59$). Runners group reported $M = 36.88$, $SD = 14.00$, and nonrunners group reported $M = 37.69$, $SD = 16.55$ key words per run ($t(26) = 0.15$, $p = .88$). Figure 1a, displays an example of two typical individual series (TUT/TRT) in the intrinsic dynamics condition. The Friedman ANOVA revealed a significant effect of running velocity over the TUT/TRT dynamics, c^2 (14,9) = 60.7, $p < .001$, with Cohen's d coefficients between the time windows as follows: d(1st vs. 5th velocity intervals) = 0.36, d (1st vs. 10th) = 2.08, d(5th vs. 10th) = 1.48 in runners group, and c^2 (14,9) = 60.47, $p < .001$, d(1st vs. 5th) = 0.15, d (1st –vs. 10th) = 2.29, and d(5th vs. 10th) = 2.79 in nonrunners group, discerning two thought phases: An initial metastable phase characterized by an alternating TUT/TRT pattern followed by a stable TRT phase. The metastable phase ended following the last switch from TUT to TRT.

The duration of the two thought phases in runners and nonrunners groups was contrasted and is presented in Figure 2a. The Mann Whitney U test showed a significantly shorter metastable phase and a significantly longer stable TRT phase in the runners group than in the nonrunners group ($U(26) = 39$, $p = .007$). However, while the time in the metastable phase was similar in both groups ($U(26) = 85$, $p = .55$), the stable TRT phase was significantly longer in the runners group than in the nonrunners group ($U(26) = 27$, $p = .001$, $d = 1.41$).

Pertaining to the TRT subcategories which emerged within the stable TRT phase, "pace monitoring thoughts" were more probable in the runners group than in the nonrunners group, U (26)= 19.50, $p < .001$, $d = 1.74$, with nonsignificant differences in "feeling and affect," $U(26) = 103.5$, $p = .95$, "body monitoring, " $U(26) = 73.5$, $p = .17$, and "command and instruction," $U(26) = 73$, $p = .15$.

Intentional Dynamics

Maximal aerobic velocity in the imposed TUT condition was also significantly higher in the runners group than in the nonrunners group ($M = 18.76$km/h, $SD = 1.23$ vs. $M = 16.3$km/h, $SD = 1.13$), $t(26) = 3.00$, $p = .01$, $d = 1.14$. Runners group reported $M = 42.42$, $SD = 10.25$, and nonrunners group reported $M = 39.92$, $SD = 26.37$ key words per run ($t(26) = 0.31$, $p = .76$). Though any type of intentional TUT (i.e., external or internal) could be selected, all participants self-imposed an internal TUT before the test's outset. They were asked to maintain the imposed internal TUT until volitional exhaustion, but they were unable to maintain it. Figure 1b presents two typical individual series in the intentional thoughts condition. The Friedman ANOVA revealed a significant effect of running velocity over the TUT/TRT dynamics, c^2 (14,9) = 84.54, $p < .001$, with Cohen's d coefficients between the time windows as follows: d(1st vs. 5th velocity intervals) = 0.61, d (1st vs. 10th) = 4.55, d(5th vs. 10th) = 3.06 in runners group, and c^2 (14,9) = 96.35, $p < .001$, d(1st vs. 5th) = 1.18, d(1st vs. 10th) = 5.31, and d(5th vs. 10th) = 0.09 in nonrunners group, discerning three thought phases: an initial intentionally stable TUT phase, a metastable TUT/TRT phase, and a final stable TRT phase. The metastable phase started with the emergence of a sudden shift to a TRT (e.g., whole body sensations such as a feeling of fatigue), and ended up with the last switch from TUT to TRT.

The duration of the three thought phases in the runners and the nonrunners groups were contrasted and are shown in Figure 2b. The Mann Whitney U test applied to the duration of the three thought phases in the imposed TUT condition revealed nonsignificant group differences for the duration of the stable TUT phase, $U(26) = 59$, $p = .07$, and the metastable phase, $U(26) = 65$, $p = .88$, and a longer stable TRT phase in the runners group than in the nonrunners group, $U(26) = 46$, $p = .02$, $d = 0.95$.

Pertaining to the TRT thought subcategories within the stable TRT phase, "pace monitoring thoughts" was more probable in the runners group than in the nonrunners group, $U(26) = 56$, $p < .02$, $d = 0.55$, but nonsignificant probabilities emerged for "feeling and affect," $U(26) = 194$, $p = .68$, "body monitoring," $U(26) = 90$, $p = .71$, and "command and instruction," $U(26) = 203$, $p = 1.0$.

Discussion

The findings of the current study revealed that in both the intrinsic and intentional dynamics conditions runners group were characterized by (1) a longer stable TRT phase than nonrunners group, and (2) higher probabilities in pace monitoring thoughts within the stable TRT phase. The assessment of the intrinsic and intentional thought dynamics revealed two and three thought phases, respectively, in both groups. An initial metastable and final stable TRT phase were observed in the intrinsic dynamics condition. An initial stable TUT phase, followed by a metastable TUT/TRT phase, and a final stable TRT phase was observed in the intentional condition. These findings are consistent with previous results associated with incremental cycling (Balagué, et al., 2014a), and reinforce the notion of a nonlinear attention focus (Balagué et al., 2012) also in trained runners. Although the runners group reached significantly higher maximal aerobic velocity than the nonrunners group, the difference in fitness and skill-level between the groups did not affect the stability of thought phases in either of the conditions. The only difference between the groups was that the runners group showed a longer stable TRT phase in both conditions. This result is consistent with the earlier findings showing that experienced runners tend to focus attention on TRT more frequently than their less experienced counterparts (e.g., Masters & Lambert, 1989; Silva & Appelbaum, 1989; Tammen, 1996; Tenenbaum, 2002) and suggests that the more frequent use of the TRT pattern is likely not merely volitional. Specifically, in the current study, during the intentional condition, TUT was deliberately imposed during the course of the entire trial. Nevertheless, runners were shown to switch involuntarily to TRT that was stabilized during the last velocity interval (see Figure 2). However, additional research ought to determine if indeed TRT is spontaneously stabilized as a consequence of the running practice.

The current research findings also show that only the runners group made higher use of pace monitoring thoughts within the stable TRT phase. This suggests that runners group may have endured longer on test by focusing attention on pace monitoring thoughts (Schomer, 1986), in line with findings suggesting that TRT of technique, cadence, or pacing may extend the running distance or reduce its time in a close loop running (Brick, MacIntyre, & Campbell, 2013; Crews, 1992; Martin, Craib, & Mitchell, 1995). Most of the reported TRT in our study pertained specifically to pacing (e.g., rhythm). Although Schomer (1986) classifies pacing as external TRT, thoughts of pacing can also be classified as internal TRT (Brick, MacIntyre, & Campbell, 2014), which seemed to be the case in the current study. The incremental velocity imposed by the treadmill task herein could promote the pace monitoring focus and distract attention from the psychosomatic sensations of fatigue (i.e., feelings and affect subcategory) that typically characterize thoughts nearing volitional exhaustion

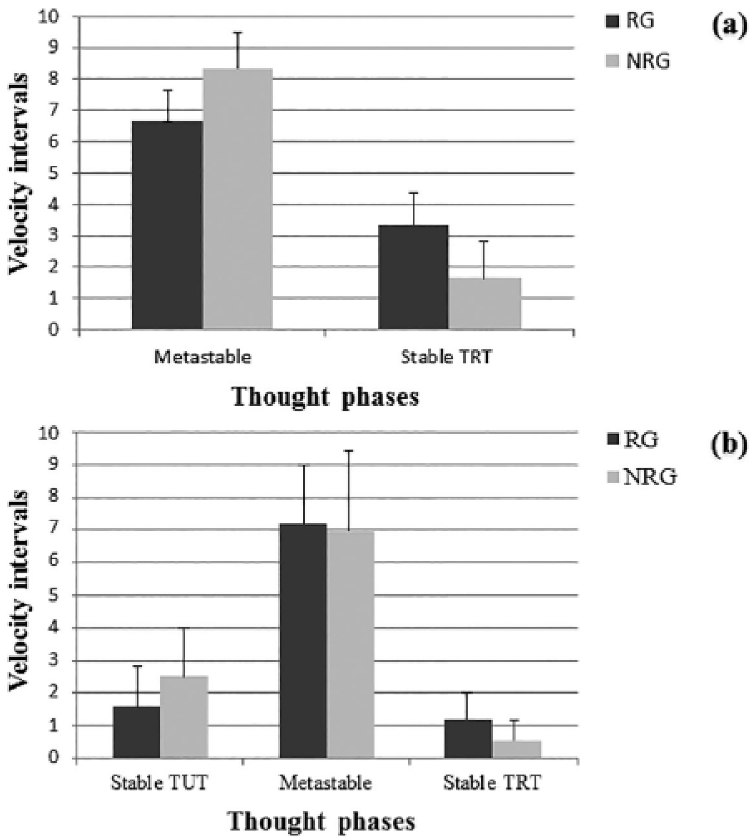

Figure 2 — Comparison of the duration (i.e., number of velocity intervals) in the different thought phases. (a) = intrinsic dynamics condition; (b) Intentional dynamics condition; TUT = task-unrelated thoughts; TRT = task-related thoughts; RG = runners groups; NRG = non-runners group.

(Balagué et al., 2014b). In support of this claim, previous work has shown that TUT stability at low and moderate intensities was compromised when approaching volitional exhaustion due to its competition with the dynamically more stable TRT patterns (Balagué et al., 2014a). In contrast, Schücker, Anheier, Hagemann, Strauss, and Völker (2013) have indicated that during a high-intensity (i.e., 85% VO_{2max})10min running protocol, the running economy increased as a result of adopting external TUT (i.e., watching video) patterns over internal TRT (i.e., breathing control) or pre instructed focus. Given that external TUT is typically more stable than internal TUT in the course of effort expenditure (Balagué et al., 2014b), it is plausible that in the current study, external TUT was more easily volitionally stabilized during the 10min run at 85% intensity.

Similarly to Schücker et al. (2013), other researchers have also reported significantly less than 100% adherence to imposed attention focus (Okwumabua, Meyers, & Santille, 1983; Weinberg, Smith, Jackson, & Gould, 1984). Nevertheless, these studies failed to consider the dynamics of thought changes. As presently shown, the adherence to TUT could further decline in the course of tasks performed until volitional exhaustion because close to this state volition weakens and the imposed TUT focus cannot be stabilized.

Although TRT seem to emerge spontaneously, further study must delineate the effects of psychological intervention programs imposing unstable thought patterns (e.g., TUT) on the intrinsic dynamics of runners and nonrunners. In fact, researchers have already reported changes in the spontaneous stability profile of motor patterns as a result of imposing unstable patterns in early research (Zanone & Kelso, 1992). Consequently, from a practical standpoint, to increase their maximal aerobic velocity, experienced runners may benefit from using the spontaneously stabilized TRT patterns, with particular use of pace monitoring thoughts. To that end, nearing volitional exhaustion, the use of motivational (e.g., "I can deal with fatigue") or instructional (e.g., "I need to keep this pace") TRT, instead of the more taxing TUT alternatives (e.g., "focus on personal problem solving") can facilitate both runners' and nonrunners' performance. Thus, in view of these results, to maximize running performance, practitioners could train both expert and novice runners to adhere to stable thoughts. Resisting against stable thoughts and imposing unstable thoughts instead would likely add to performer's cognitive load and potentially hinder performance.

Drawing upon the stability properties of thoughts and the application of the dual intrinsic-intentional paradigm the following considerations can aid practitioners and performers optimize mental interventions: (a) thought contents emerge spontaneously and are not the sole product of volitional interventions, (b) TUT and TRT can be equally effective to improve performance depending on their stability profile, (d) to identify the stability profile of those, the intrinsic dynamics of attention focus should be tested, (e) it is not possible to define a priori the workload value during which (i.e., when) the transition toward TRT will occur because the system is multiparametric and highly nonlinear, (f) the stability profile of attention focus and thought contents changes under nonspecific control parameters such as increasing or expanding workload, (g) spontaneous thoughts are more stable, thus can be more easily intentionally sustained than otherwise imposed thought contents that are less stable, consequently, (h) any attempts to keep a focus on thoughts that become predominantly unstable (i.e., TUT) while approaching volitional exhaustion, may be ineffective and cognitively taxing, hence limiting the potentially ergogenic effect of an appropriate attention focus for the performer.

In regards to its limitations, the scientific literature of "mind wandering" (Christoff, Ream, & Gabrieli, 2004; Smallwood & Schooler, 2006) has recognized the drawbacks to self-report methodologies used in this study. Although the reliability of any given introspective report may be subjected to an inquiry, objectively measured neural-based signals (event-related potentials; Kam et al., 2011) provide evidence for the overall validity of self-reported thoughts. Moreover, research findings using direct electrophysiological data provide evidence for the value of self-report data collection methods in the physiological literature (Christoff, Keramatian, Gordon, Smith, & Mädler, 2009). Furthermore, it should be pointed out that the current results are not only the product of a group effect but were present in all participants in the present and previous studies using similar paradigms (Balagué et al., 2014a; Balagué et al., 2012; Balagué et al., 2014b). Specifically, the thought phases found herein remained similar across gender, fitness level, and type of exercise. Participants may have different thoughts contents, change them at different moments, or perform distinctive maximal aerobic velocities, but all participants displayed the same reproducible thought phases, and this should be considered in future research.

A final word of caution is that given the specific nature of the present test constraints, these results and conclusions can only be generalized to effort conditions with little or no environmentally challenging dynamics. Environmentally challenging dynamics such as social influences are usually present at training or competitive situations. Therefore retesting the validity of those conclusions within alternative dynamics could provide unique benefits on both applied and research grounds.

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Intentional thought dynamics during exercise performed until volitional exhaustion

NATÀLIA BALAGUÉ[1], ROBERT HRISTOVSKI[2], SERGI GARCIA[1], DANIEL ARAGONÉS[1], SELEN RAZON[3] & GERSHON TENENBAUM[4]

[1]*INEFC University of Barcelona, Barcelona, Spain,* [2]*University of Saints Cyril and Methodius, Skopje, The Former Yugoslav Republic of Macedonia,* [3]*Ball State University, Muncie, IN, USA and* [4]*Florida State University, Tallahassee, FL, USA*

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Abstract
Using a non-linear approach, intentional dynamics of thoughts were examined during constant cycling performed until volitional exhaustion. Participants ($n = 12$) completed two sessions at 80% W_{max}. Their (1) intrinsic thought dynamics (i.e., no-imposed thoughts condition) and (2) intentional thought dynamics (i.e., imposed task-unrelated thoughts condition; TUT) were recorded and then classified into four categories: internal and external TUT (TUT-I, TUT-E) and external and internal task-related thoughts (TRT-E, TRT-I). The probability estimates for maintaining each thought category stable, the rate of switching from one category to another, and the entropy dynamics along the testing procedure were assessed and compared through time phase. Friedman ANOVA tests revealed a significant effect of effort increase on thought contents only in the imposed TUT test. While TUT-I probabilities decreased significantly ($P < .001$) as effort increased, TRT-I probabilities increased ($P < .05$). Moreover, the entropy to the entire thought dynamics increased at the outset of task performance and decreased upon approaching volitional exhaustion ($P < .001$). As time spent in constant effort increased, and volitional exhaustion approached, task relatedness (TUT, TRT), direction (internal, external), and entropy of thought contents changed unintentionally providing further evidence for a nonlinear dynamics of attention focus.

Keywords: *attention focus, intentional dynamics, emergence, entropy, volitional exhaustion*

Despite the growing literature pertaining to the effect of physical effort on attention focus (see Basevitch et al., 2011; Lind, Welch, & Ekkekakis, 2009; Razon, Basevitch, Land, Thompson, & Tenenbaum, 2009; Razon et al., 2010), there has been scant empirical investigation addressing the intentional dynamics of thought processes within exercise settings. Research into the physical effort–attention allocation relationship has revealed that dissociative attention (i.e., a cognitive strategy in which the individual focuses his/her attention on task-irrelevant cues) decreases perceived levels of effort on task (Basevitch et al., 2011; Razon et al., 2009).

As exercise intensity and time spent exercising increase, associative, internal sensory cues govern attention, even when the individual may be strategically attempting to maintain a dissociative, external focus of attention (Hutchinson & Tenenbaum, 2007; Schücker, Hagemann, Strauss, & Völker, 2009). In previous experiments, participants were tested under conditions of spontaneous thought flow. Under such conditions, attention focus alterations may occur either intentionally or unintentionally (Fox & Raichle, 2007; Fox et al., 2005).

To identify the specific influence of intentions on motor behaviour, Kelso and Schöner (1988) advanced a dual intrinsic-intentional paradigm. Drawing upon this paradigm, recent accounts from exercise science have suggested that increased exercise duration and exercise intensity may influence the stability in thought contents, and task-unrelated thoughts (TUT) may not be amenable to purposeful stabilising or control, particularly at points approaching volitional exhaustion (Balagué, Aragonés, Hristovski, García, & Tenenbaum, 2014; Balagué, Hristovski, Aragonés, & Tenenbaum, 2012).

The psychobiological model of endurance performance posits that exercise terminates when persistence is perceived as impossible, i.e., when the effort required by the task exceeds the greatest amount of

Correspondence: Natàlia Balagué, INEFC University of Barcelona, Barcelona, Spain. E-mail: nataliabalague@gmail.com
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Table I. Four different levels of thought contents categories based on Nideffer (1981) and Schomer's (1986) classification.

Task relatedness	Attentional direction/width	Subcategories
TUT	Internal/broad TUT-I	Reflective activity (R)
		Personal problem solving (PS)
		Work and career (W)
	External/broad TUT-E	Course information (I)
		Conversational chatter (CC)
		Environmental feedback (E)
TRT	External/narrow TRT-E	Pace monitoring (P)
	Internal/narrow TRT-I	Feelings and affect (FA)
		Body monitoring (B)
		Command and instruction (CI)

Notes: TUT = task-unrelated thought; TRT = task-related thought.

effort that the individual is willing to exert (Marcora & Staiano, 2010).

Of relevance to this study, a 2 × 2 conceptualisation of attentional width was advanced in early research: broad versus narrow and internal versus external (Nideffer, 1981). Additionally, dissociation and association have been theorised as a continuum ranging from TUT to task-related thoughts (TRT) (Schomer, 1986). Drawing upon Nideffer and Schomer's initial conceptual frameworks, the present study included four categories of thought contents: internal task- and external task-unrelated thoughts (TUT-I, TUT-E) and internal task- and external task-related thoughts (TRT-E, TRT-I) (see also Stevinson & Biddle, 1999) (Table I).

A main finding of the non-linear dynamic systems theory (NDST) approach to research on thought processes is that the spontaneous thought flow is characterised by a tendency to shift, or change, spontaneously its course, maintaining a metastable regime (Friston, 1997), where more than one thought state is available. Metastability is the manner in which the brain dynamically integrates specialised functions. Within this regime, specific areas of the brain (visual, auditory, motor) show a tendency to function autonomously, while at the same time exhibit tendencies towards coordinated activity (Fingelkurts & Fingelkurts, 2004; Izhikevich, Gally, & Edelman, 2004; Kelso, 2012).

Metastability might be a generic mechanism underlying the flexibility of thoughts. Sound evidence has shown that the change in the systems stability profile is due to the change of non-specific control parameters (Kelso, 1995). These parameters are non-specific because they do not explicitly prescribe the state of the system, but rather constrain its behaviour. Depending on the relationship between the stability of states and the amount of noise, the system switches from one state to another. We expect from the generic qualitative predictions of NDST to obtain stable, metastable, and unstable thought states as a consequence of changes in a non-specific control parameter such as "time on task" in exercise settings.

"Mind-wandering" of the brain at rest (Christoff, Ream, & Gabrieli, 2004; Smallwood & Schooler, 2009) is amenable to manipulation, and individuals can deliberately facilitate or inhibit selective thought contents. However, prolonged or intensified exercise compromises purposeful control and results in the occurrence of unintended thoughts (Balagué et al., 2012, 2014; Hutchinson & Tenenbaum, 2007; Schücker, Anheier, Hagemann, Strauss, & Völker, 2013; Schücker et al., 2009). Additionally, retrospective reports of thought analysis have shown that as effort duration increases, both the content and the direction of thought process change and destabilise (Balagué et al., 2012, 2014).

The main strength of the NDST in the investigation of thought contents is the generic prediction and explanation of (1) the formation of new thoughts, (2) the dissolution of old thoughts, (3) thoughts stability, and (4) thoughts switching dynamics. Specifically, NDST may show non-proportional effects between independent variables (exercise duration or intensity) and dependent ones (thought states). For example, a small continuous change in time on task produces an abrupt change (critical point or "threshold") of the intended thought state (Balagué et al., 2012) as well as the task disengagement (Hristovski & Balagué, 2010; Marcora & Staiano, 2010). Conversely, a large change of time on task may not produce any change in the thoughts and in the cycling frequency (i.e., a constant thought state or constant cycling frequency).

Similar to other dynamic and emergent cognitive functions (Guastello et al., 2012), thought contents are influenced not only by increased effort but also by the environmental cues that are present during the exercise regimen. Environmental cues mediate direction of attention focus and are important to consider for the ecological validity of the experimental (lab-based) data. Due to relative scarcity of environmental cues in lab research (Brunswik, 1956), individuals may exhibit less TUT-E in lab studies compared to field studies (Mitchell, 2012). This said, compared to TUT-E, TUT-I can be cognitively taxing in that it requires the supply of information that is reflective and from within. The brain expends more energy when a dynamically unstable pattern is intentionally imposed upon the intrinsically more stable pattern (Jantzen, Steinberg, & Kelso, 2009). Therefore, task difficulty can be captured by the dynamic measure of stability, which is inherently related to the energy output of the brain.

Within NDST framework, the stability of a state is measured via dwell time. Dwell time is the time lapse a system remains in its current state and typically corresponds to the probability of remaining in status quo prior to destabilising (Prada-Gracia, Gómez-Gardeñes, Echenique, & Falo, 2009). The *entropy is* a measure of the minimum information needed to identify the system state (Naudts, 2005); it is larger when more states (more thought contents) are available because more information is needed to specify it.

Adopting the NDST perspective (Guastello, 2001), the purpose of the present study was to examine the intentional dynamics of thought contents during a cycling task at 80% of maximal power load (W_{max}) performed until volitional exhaustion. Extant experimental investigations relied on dual categorisation of the dissociative and associative attentional patterns (see Basevitch et al., 2011; Lind et al., 2009; Razon et al., 2009, 2010) and rarely considered its direction (internal vs. external; Stanley, Pargman, & Tenenbaum, 2007). To date, there has been no research to simultaneously examine task-relatedness and unrelatedness dimensions of thought dynamics and entropy measures.

Using a dual intrinsic-intentional paradigm of non-imposed and imposed thoughts (Balagué et al., 2012; Kelso & Schöner, 1988), we hypothesised that at 80% W_{max} and with increased time on task, (1) the intrinsic dynamics will be dominated by TRT patterns; (2) during the intentional dynamics, the probabilities of intentionally imposed TUT contents will decrease and the probabilities of intrinsically stable TRT-I will increase, as well as its percentage of switches to other thought categories; and (3) the diversity of thought contents (entropy) will first increase and afterwards decrease approaching the volitional exhaustion point.

Method

Participants

To determine the sample size, a power analysis was performed. In similar studies of thought processes as a function of time on task (Balagué et al., 2012), large effect sizes have been observed (the smallest value was $d = .83$). Thus, using an effect size of $d = .80$, $\alpha < .05$, power $(1 - \beta) = .95$, with five repeated windows, we estimated a sample size = 12 (Faul, Erdfelder, Lang, & Buchner, 2007). Twelve Caucasian physical education students (six males and six females; mean value 21.41 years, $s = 3.55$) without sport specialisation but engaging in a wide range of aerobic activities at least three times a week volunteered to participate in this study.

Intervention and procedure

During the first week, participants performed a maximum cycling power test and were familiarised with the reporting procedures. In the second week and third week, respectively, they performed the same cycling task twice but under two different instructions (dual paradigm). Participants signed an informed consent prior to taking part in the study. All experimental procedures were approved by the local research ethics committee and carried out according to the Helsinki Declaration.

Maximum cycling power test

W_{max} was determined by means of a progressive and maximum aerobic test (adapted from Hutsebaut, Brunet, Thibault, & Hutsebaut, 2002) consisting of an initial load of 20 W followed by increases of 20 W · min^{-1} until participants could not keep the required cadence (70 rpm) for 10 consecutive seconds.

Familiarisation

Participants practiced a simulated task (see the following section on "Cycling task") under the intrinsic dynamics condition (see later) until they reported on three different keywords. They were afterwards interviewed to delineate the thought content associated with each keyword (for details see section on "Intrinsic dynamics").

Cycling task

Participants cycled (Sport Excalibur 925900) at a constant workload (80% W_{max}) and a constant pace (70 rpm) until volitional exhaustion. The task ended when the participants could no longer maintain the pace for 10 consecutive seconds. Once the tasks began, participants were not exposed to any verbal or other communication interaction.

The dual paradigm

The participants' thought contents under the intrinsic dynamics and the intentional dynamics conditions, respectively, were recorded using the self-caught measurement approach and the experimenter-classified method (Smallwood & Schooler, 2006). The self-caught method requires that the individuals respond whenever they catch their own mind-wandering. In the experimenter-classified method, it is the experimenter, not the participant, that classifies the type of thoughts. Participants are not informed about the category of thinking that is being investigated.

Intrinsic dynamics. During the test, participants were asked to self-monitor and self-report their spontaneous thought flow (emerging thoughts) using a continuous online protocol (Giambra, 1995). They were instructed to report each change of thought content as it occurred using a self-selected single key word to identify it. Some of the key words included “exam”, “poster”, “revolutions”, “pain”, and so on. The test administrator collected verbatim the list of key words and upon task completion interviewed the participants about their adherence level to the cognitive and performance tasks, respectively. Then the interviewee was asked about the thought content related to each key word. Examples of TUT-I included, “thinking about my university exams”; of TUT-E, “looking at the poster on the wall”; of TRT-E, “focus on the cycling pace monitor”; and of TRT-I, “I have a calf pain”. All the participants reported a maximal level of adherence to the experimental protocol. The whole procedure was audio-recorded to validate the content of the key words and its classification (see Table I).

Intentional dynamics. The second test consisted of consciously self-imposing any type of free chosen TUT from the outset and maintaining it intentionally throughout the task. The testing procedure was the same as described under the section on “Intrinsic dynamics” earlier.

Data analysis

The different thought contents obtained in both tests were classified as TUT-I, TUT-E, TRT-E, or TRT-I following the experimenter-classified method (Smallwood & Schooler, 2006). Time series comprising the different thought categories were registered for each participant and divided into five non-overlapping equal temporal windows. Dwell times were then calculated for each interval. Probability estimates for maintaining thoughts in the different categories were computed by dividing the dwell times for each category by the total time within each window. Mean probability values for all the participants were calculated for each category separately within each of the five windows. The percentage of switching among thought categories was also calculated for each temporal window across participants. To analyse the change of the thought content probabilities for different time windows and different thought categories, a Friedman ANOVA was performed separately for each thought category. Effect sizes (Cohen’s *d*) were computed to demonstrate means’ differences where effects reached $P < .05$ level.

To analyse the different stages of diversity (flexibility) of the thought dynamics, we calculated the entropy as follows: $H = \sum_i^n p_i \ln p_i$, where H is the entropy of the thought process expressed as a total average information content and p_i is the probability of finding the i-th thought subcategory. For a system with four thought categories, the maximum entropy is $H_{max} = 1.39$ nit (i.e., natural units). To establish referent values in the first and last parts of the dynamics of participants’ thought content, we divided the first and fifth time windows into two different windows, respectively, defining the new first and seventh windows as $H = 0$ because in that interval only one thought category was kept active (TUT-I and TRT-I, respectively). This was done following the final change and preceding volitional exhaustion and by means of the same procedure previously explained for probabilities. The entropy evolution was first calculated for each participant and each time window separately and then pooled over participants. Friedman ANOVA was performed to analyse the entropy evolution over time. Effect sizes were calculated as PS_{dep} measures (Grissom & Kim, 2012) because some of the analysed variables had no variance.

Results

Intrinsic dynamics

During the non-imposed thought test, TRT-I was the dominant state in all participants throughout the course of the cycling task; performance time was mean value 778.33 s, $s = 138.98$.

Intentional dynamics

During the intentionally imposed TUT test, a changing dynamics was observed and analysed. Performance time was mean value 764.25 s, $s = 154.91$.

Thought probabilities

In the imposed TUT test, an alternating TUT-TRT pattern emerged in all participants. Although any type of TUT could be chosen, all participants self-imposed a TUT-I at the task’s outset. Unable to maintain TUT-I until volitional exhaustion, they switched it not only to intentional TUT-E but also to unintentional TRT-E and TRT-I. The thought probabilities of the four thought categories along five temporal intervals are shown in Figure 1.

The consciously imposed TUT-I decreased progressively from .88 in interval 1 to .15 in interval 5. In contrast, TRT-I increased progressively from .03

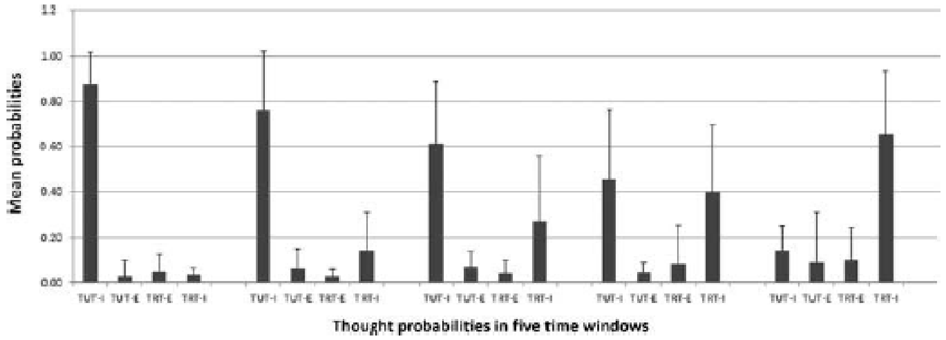

Figure 1. Probability of thought state in the four thought categories for each of the five time windows.

Data are presented as mean ± *s*. TUT-I = internal task-unrelated thoughts; TUT-E = external task-unrelated thoughts; TRT-E = external task-related thoughts; TRT-I = internal task-related thoughts.

to .65. TUT-E and TRT-E typically increased throughout the five intervals until reaching values close to .10. Thus, although consciously imposed, participants encountered greater difficulties in maintaining TUT-I as time on task increased while spontaneous switches to TRT-I were more frequent and of longer duration. The TUT state (TUT-I plus TUT-E) remained stable in windows 1 and 2; window 4 showed metastability of TUT and TRT (TRT-E plus TRT-I) meaning spontaneous alternating or switching dynamics between them and the TRT state prevailed in window 5.

Moreover, the direction of TUT and TRT also changed as the volitional exhaustion approached, that is, TUT-E probability was progressively closer to the consciously imposed TUT-I probability (.09 and .15, respectively, in the last window), and TRT-I probability was progressively higher than TRT-E probability (.65 and .10, respectively, in the last window). In interval 5, when participants were close to their volitional exhaustion, the highest probability corresponded to TRT-I. As an unpredicted finding, all participants finished with a specific TRT-I subcategory: feelings and affect (Schomer, 1986).

The probability changes over time of the different thought categories are depicted in Figure 2. The Friedman ANOVA applied to the TUT-I probability profile showed a significant effect of effort accumulation on the stability of TUT-I thought category, χ^2 (12, 4) = 35.41, $P < .001$ (see Figure 2A). Cohen's *d* values were 1.49, 6.94, and 2.76 for means between the first and third, first and fifth, and third and fifth time windows, respectively. The same procedure applied to the TUT-E and TRT-E probability change failed to show a significant effect of effort accumulation on their stability: $\chi^2(12, 4) = 6.61$, $P = .158$, and $\chi^2(12, 4) = 3.53$, $P = .474$, respectively (see Figures 2B and 2C). However, the Friedman ANOVA applied to the TRT-I probability showed a significant effect of effort accumulation on the stability of TRT-I thought category $\chi^2(12, 4) = 28.60$, $P < .001$ (see Figure 2D). Cohen's *d* values were

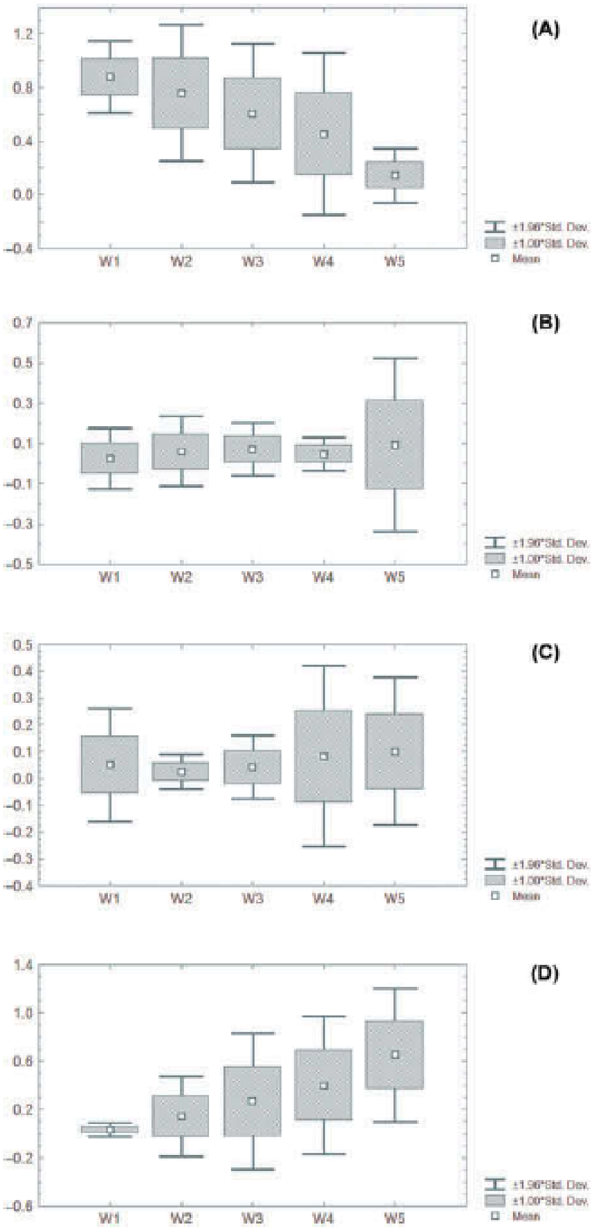

Figure 2. TUT-I, TUT-E (internal and external task-unrelated thoughts), TRT-E, and TRT-I (external and internal task-related thoughts) probability changes over time. Data are presented as mean ± *s*.

0.43, 2.30, and −1.49 for means between the first and third, first and fifth, and third and fifth time windows, respectively.

Percentage of thought switches

The percentage of total switches to the different thought categories for all participants showed similar results as those obtained through the thought probability estimations (see Figure 3). The Friedman ANOVA applied to the TUT-I probability switches resulted in a significant effect of effort accumulation on the switching dynamics of TUT-I thought category, χ^2 (12, 4) = 33.84, $P < .001$ (see Figure 3). Cohen's d values were 1.44, 3.29, and 1.79 for means between the first and third, first and fifth, and third and fifth time windows, respectively. Similar results were revealed for the switching dynamics of TRT-I thoughts. χ^2 (12, 4) = 19.15, $P < .001$. Cohen's d values were −1.10, −2.59, and 0.72 for means between the first and third, first and fifth, and third and fifth time windows, respectively. As the percentage of switches to TUT-I progressively reduced, the percentage of switches to TRT-I progressively increased. Statistically non-significant ($P > .05$) changes were noticed in TUT-E and TRT-E.

Entropy dynamics

The evolution of the mean group entropy dynamics profile is presented in Figure 4. To highlight the initial and ending events of the test, window 1 and window 5 have been subdivided into two smaller windows (seven windows in all). The Friedman ANOVA applied to the entropy change showed a significant effect of effort accumulation on the entropy of thought processes, χ^2 (12, 5) = 32.9, $P < .001$. PS_{dep} values were all 1.00 for comparisons between the first and the seventh zero entropy

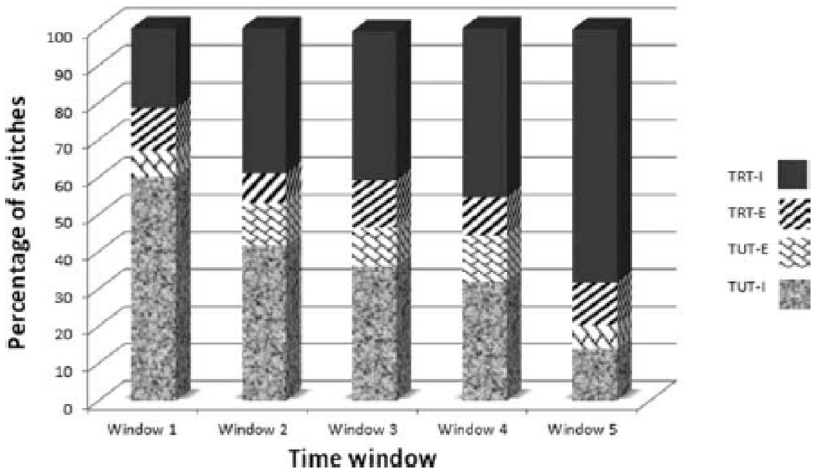

Figure 3. Percentage of total switches to a different thought category for all participants.

TUT-I = internal task-unrelated thoughts; TUT-E = external task-unrelated thoughts; TRT-E = external task-related thoughts; TRT-I = internal task-related thoughts.

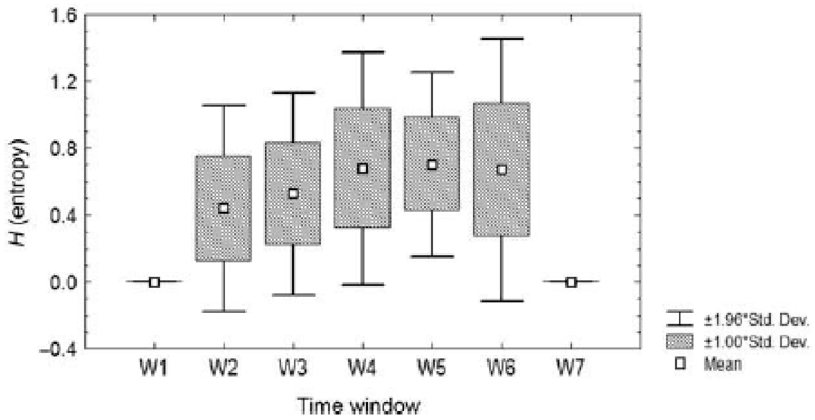

Figure 4. Evolution of the information entropy measured over seven time windows. Data are in nit (natural units).

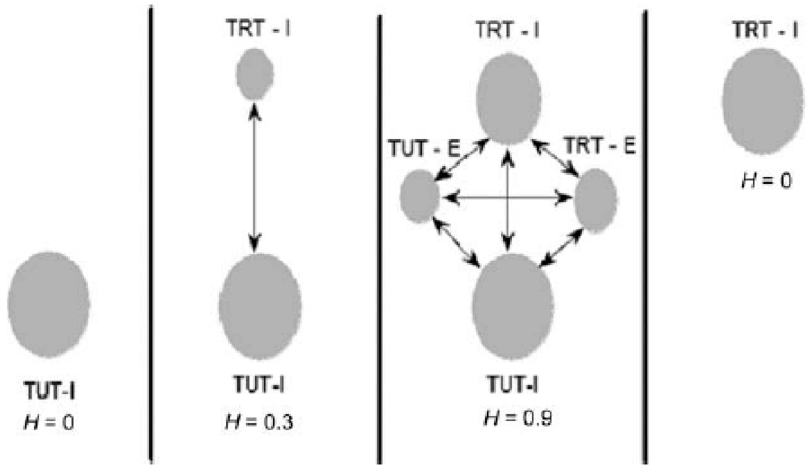

Figure 5. A typical example of participant with emerging and dissolving thought contents creating a metastable switching regime. The size of the shaded ovals is proportional to the absolute probabilities of thought states. Left most panel: The intentionally imposed TUT-I (internal task-unrelated thoughts) is the only stable category. Second panel: The time on task brings about the emergence of TRT-I (internal task-related thoughts). Third panel: A fully developed metastability between the four thought categories. Right most panel: TRT-I becomes the only stable state as the other three lost stability. The arrows show the possible switches among the thought categories. H = Entropy. Data are in nit (natural units).

windows with the rest of non-zero entropy windows. The only significant difference between non-zero entropy windows was found between windows 2 and 5: $Z = 2.12$, $P = .03$. The PS_{dep} effect size for this pair was 0.66, window 2 having less entropy.

Figure 4 depicts that entropy starts from the referent point $H = 0$ in window 1, then increases, reaches a plateau, and afterwards sharply decreases to reach again the referent point $H = 0$ in window 7, when only one thought category is present up to the moment of volitional exhaustion. An example of a typical evolution of thought contents in one of the participants is depicted in Figure 5. At the beginning, the intentionally imposed TUT-I was the only stable category. Hence, the entropy was equal to zero. This regime lasted 2.3 min. A small continuous change of time on task brought about the emergence of the TRT-I thoughts. A metastable dynamics was formed between TUT-I and TRT-I. As more thought states became available, the entropy shifted to a higher value $H = 0.3$. This regime lasted 0.6 min. Again for a small continuous change in time on task, a fully developed metastability between the four thought categories emerged, including TUT-E and TRT-E. The entropy of the system shifted to $H = 0.9$. This metastable regime lasted 9.5 min. Close to the point of volitional exhaustion, the coalition of the TUT-I, TUT-E, and TRT-E lost its stability and TRT-I became the only stable thought category, reducing the attentional flexibility as represented by the entropy value $H = 0$. This regime lasted 1.9 min after which the point of voluntary exhaustion was reached.

Discussion

The present study was conceived to examine the intentional thought content dynamics along two dimensions: task-relatedness versus task-unrelatedness, and two directions, internal versus external during exercise at constant high intensity. Our findings indicate that increased time on task affects attentional task relatedness dimension (TUT or TRT), direction (internal or external), and entropy (i.e., range) of thought contents. The main results of this study revealed (1) a dominance of TRT-I patterns during the intrinsic dynamics assessment resulting from the high workload-level (80% W_{max}) imposed effort; (2) decreasing probabilities of TUT-I and increased switching rates from TUT-I to alternative categories during the intentional dynamics assessment; (3) a first threshold manifested in involuntary occurrence of TRT-E and TRT-I, with increased probabilities and decreased switching rates to alternative categories; (4) a second threshold manifested in involuntary transition to a sole TRT-I thought category, and (5) intentional debut of thoughts entropy from zero at task onset with unintentional increase at middle effort, and spontaneous return to zero approaching the point of volitional exhaustion.

During the intrinsic dynamics assessment, the dominant TRT-I thought category shifted very rarely to other categories, supporting previous findings obtained during a running task (Balagué et al., 2012). The dominance of TRT attentional focus in the intrinsic dynamics complies with recent findings of Blanchfield, Hardy, de Morree, Staiano, and Marcora (2014) where a TR motivational self-talk reduced the rate of perceived exertion (RPE) and prolonged the exertion time in participants. Such results are in accordance with the non-linear model predictions (Balagué et al., 2012), which state that cooperating with the more stable mode of attention focus is beneficial due to the low cognitive cost of such strategy (Jantzen et al., 2009).

Attentional stability aligns with the theoretical assertions stipulating that the attentional bandwidth narrows during high-intensity exercise as the physiological symptoms of fatigue dominate awareness (Basevitch et al., 2011; Ekkekakis, 2005; Lind et al., 2009; Razon et al., 2009, 2010; Tenenbaum, 2001). The non-linear dynamic systems approach provides an explanation to the previous theoretical assertions and descriptive observations. Specifically, it explains how thresholds (non-linear changes) arise and, as a consequence of it, how the system changes its attention and thought flexibility level. It is the emergence of new and dissolution of old stable states that generate the changes in the attentional flexibility. These processes are generic non-linear effects.

Consequently, the results support the notion that the mind can wander under low workload and rest conditions (Mason et al., 2007; Smallwood & Schooler, 2006), and it destabilises as a function of increased time on task. With reference to intentional dynamics assessment, however, attention allocation exhibited an almost paradoxical pattern: a spontaneous non-intentional recruitment of new thought categories, and afterwards a spontaneous transition to a sole TRT-I content approaching the task disengagement. This is attributable to the progressive instability of the imposed TUT and the increasing stability of the TRT (Balagué et al., 2012, 2014).

The participants also adopted TUT-I pattern, instead of TUT-E, at the task onset. Given the high-intensity nature of the exercise, the use of TUT-I at the task onset is likely to have a beneficial effect in terms of promoting a dissociative focus and improving performance output (see Razon et al., 2009, 2010; Tenenbaum, 2001). More scientific effort is warranted to examine if this result can be attributable to the nature of laboratory testing because TUT-I thought pattern can limit the access to external information and prime inner information as a more stable state.

As evidenced by rates of thought switching and the reduction of the thought probabilities in TUT-I (see Figures 1 and 2), ongoing intense effort appeared to decrease the stability of the TUT-I and generate novel thought states. This was consistent with the proposed non-linear model of attention focus (Balagué et al., 2012). More specifically, cognitive overload to uphold TUT was associated with an increase of TUT-E, which is a context-dependent external focus. Key words related to TUT-E included "window", "poster", "treadmill", and "table" – implying that relative to TUT-I, TUT-E is less cognitively taxing (Jantzen et al., 2009) and assists in promoting a dissociative focus of attention (Schücker et al., 2013).

Metastability increased in the mid-phase of effort providing further evidence for the notion of competition between the intentional TUT-I and TUT-E with the unintentional TRT-I and TRT-E. Although all types of thoughts evidenced some stability, approaching the point of volitional exhaustion a minimal upsurge in effort output yielded to a qualitative non-linear shift towards TRT-I. Specifically, as evidenced by most of the intentional dynamic test results, the spontaneous emergence of non-imposed thoughts and the metastability of brain dynamics to switch in between the imposed TUT-I to TUT-E, TRT-E and TRT-I lend direct support to the presence of non-linear effects within the brain—body—environment system. Intentions may modify the intrinsic dynamics of thoughts, but they are also subject to dynamic instabilities and decay under increased time in constant effort. These results further concur with previous findings indicating signs of non-linearity in psychobiological variables during constant exercise up to volitional exhaustion (Balagué et al., 2012; Hristovski & Balagué, 2010; Hristovski, Venskaitytė, Vainoras, Balagué, & Vazquez, 2010).

Based on the TUT imposed test results for entropy change, it becomes apparent that at the task outset, the system was intentionally held rigid and inflexible. As evidenced by a plateau of the high entropy values, additional alternative coping options emerged in a spontaneous manner. This said, approaching the point of volitional exhaustion, the TUT-I, TUT-E, and even TRT-E thought patterns were destabilised and only TRT-I patterns remained stable. Hence, the volitional effort disengagement was preceded by a transition from a multistable to a monostable (TRT-I) regime.

It is worth noting that the spontaneous formation of TRT-I and TRT-E contents, as well as the final involuntary transition to sole TRT-I contents, occurred at threshold points and for a short lapse of time on task. This was also the case for the task disengagement event. Hence, the formation or dissolution of a thought category or the task disengagement itself can be defined as a non-linear phenomenon that can be adequately captured and studied through the NDST approach (Meyer-Lindenberg, Zieman, Hajak, Cohen, & Faith Berman, 2002). The RPE appears to be a key constraint that brings about the volitional exhaustion in endurance type of activities (Marcora & Staiano, 2010). In their model, the sudden motor task disengagement arises in the vicinity of a point when the effort required by the task starts to exceed the greatest amount of effort that the individual is willing to exert. Within the NDST conceptual framework, the disengagement emerges when the intention suffers dynamical instability and spontaneously dissolves to another stable, less energy demanding state (Hristovski & Balagué, 2010). In both models, the sudden change may be explained as a consequence of the generic dynamical non-linear "loss of stability" mechanism.

A number of experimental studies attested to the psychological, physiological, and ergogenic effects of select cognitive strategies, such as mental imagery, music, and olfactory cues on attention focus (see Lind et al., 2009 for review). Consequently, research is warranted to test the effectiveness of a range of cognitive strategies for their potential to shape thought dynamics and influence thought contents probabilities. Additionally, to extract most information from observations, there may be a need to conceptualise attention from a NDST standpoint, and as such to discern it in four distinct categories (related vs. unrelated, internal vs. external) during exercise. Research can also be directed to measuring the change in the dynamics of thought categories in alternative sport and exercise settings such as triathlon, cross-country, and orienteering as well as in training and competitive situations.

Based on the evidence presented herein, practitioners should be aware that time on task appears to influence thought dynamics. It seems that when approaching the point of volitional exhaustion, individuals fail to maintain TUT strategies, particularly TUT-I. At this point, however, when other thoughts are unstable, they may benefit from collaborating with the dominantly stable TRT-I with motivational commands such as "I can push it for a few more minutes," or "you can do it" rather than competing with them imposing unstable contents of TUT-I, TUT-E, or TRT-E (Balagué et al., 2012, 2014). Given the possibility that laboratory and close-loop settings may limit generation and reduce stability of TUT-E and TRT-E patterns, to extend TUT-E and TRT-E and delay TRT-I, practitioners may strategically introduce previously tested add-ons including visual and auditory stimuli (see Razon et al., 2009) at specific times during constant power exercise.

Limitations to self-report methodologies were recognised in the scientific literature of "mind-wandering" (Christoff et al., 2004; Smallwood & Schooler, 2006). Although the reliability of any given introspective report may be used as a subject for inquiry, the overall validity of the collection of reports herein was borne out by state-dependent differences in objectively measured neural-based signals (event-related potentials) (Kam et al., 2011). Moreover, research findings using electrophysiology provide direct evidence of the value of self-report data collection methods in the physiological literature (Christoff, Keramatian, Gordon, Smith, & Mädler, 2009).

Regardless of the agreement of the current results with those from previous accounts (Balagué et al., 2012), a final word of caution is that given the specific nature of task constraints, the results herein can only be generalised to exercise conditions with little or no environmentally challenging dynamics, usually present at some training sessions and competition.

In conclusion, the time on task changed the intentional thought contents dynamics task relatedness (TUT, TRT), direction (internal, external), and attention flexibility. Consequently, it may be impossible to intentionally sustain TUT cognitive strategies upon the system to the point of volitional task disengagement. The progressive destabilisation of TUT-I, TUT-E, and TRT-E lead to a creation of a sole stable TRT-I pattern close to volitional exhaustion. Efficient coping strategies should take into account the thought dynamics stability profile. As a result, nearing volitional exhaustion, athletes may benefit from collaborating with their spontaneous idiosyncratic stable thought state rather than competing with it or imposing more taxing alternative unstable thought contents.

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CAPÍTOL 5: Discussió general

En aquesta tesi doctoral s’ha testat el model no lineal del focus d’atenció (Balagué et al., 2012), sota diferents protocols d’exercici i de recollida de dades en diversos tipus de població. A banda, s’ha investigat per primera vegada la dinàmica de les subcategories del focus d’atenció, és a dir, no només respecte a la relació del pensament amb la tasca (TUT/TRT), sinó també respecte a la direcció del seu contingut (intern/extern). Els resultats han mostrat que es troben les mateixes fases de pensament establertes pel model no lineal del focus d’atenció, independentment de la tipologia d’exercici, protocol de recollida de dades, nivell d’entrenament i gènere. Cal assenyalar que els resultats experimentals obtinguts no són únicament el producte d’un efecte grupal, doncs es van trobar en tots els participants i en els tres estudis, inclús en l’estudi I, que proposa un protocol de menor sensibilitat per capturar els canvis. Tot i que els participants van reportar continguts de pensament diferents, van canviar-los en diferents moments i van assolir diferents nivells de rendiment en els tests, tots van mostrar les mateixes fases de pensament, confirmant així la consistència del model proposat per Balagué et al. (2012).

Complementant les troballes d’autors que descriuen la reducció de l’amplitud del focus d’atenció amb la intensitat d’esforç (Tenebaum, 2001), el model dinàmic i no lineal del focus d’atenció explica *com* i *per què* es produeix el canvi qualitatiu i no voluntari cap a TRT. A l’inici de l’esforç és possible tant transitar entre diferents categories de pensament (TUT/TRT) com modificar-les voluntàriament, focalitzant-se en una única (com ara el TUT). Quan el sistema no està fatigat disposa de suficients graus de llibertat per focalitzar l’atenció a voluntat. Contràriament, prop de l’exhauriment el sistema és incapaç de decidir i imposar voluntàriament el tipus de pensament que vol mantenir (com ara un TUT). La formació de coalicions psicobiològiques que intenten compensar els efectes inhibitoris creixents provocats per la fatiga acumulada redueix els graus de llibertat del sistema, dificultant la realització de funcions cognitives alternatives a les intrínsecament estables (Vázquez, Hristovski, & Balagué, 2016). Segons els resultats obtinguts, el canvi qualitatiu cap a TRT es dóna a diferents valors relatius del temps de cursa i d’intensitat d’esforç dels participants, i no a valors predeterminats com postula Tenenbaum (2001). El moment en el qual es produeix aquest canvi qualitatiu (que podríem denominar *llindar*) no depèn només de la intensitat de càrrega sinó també d'una constel·lació de factors, que interactuen en aquell moment (inclosa la motivació, l'entorn, etc.). No obstant, poden ser parametritzats a través de l'efecte no proporcional de l'esforç acumulat, considerat en aquest cas com un paràmetre de control no específic. És a dir, mentre un canvi important de l'esforç acumulat no produeix cap efecte sobre el focus d'atenció, un canvi subtil genera un canvi abrupte cap a TRT.

Tot i que els corredors entrenats van assolir velocitats aeròbiques màximes significativament majors que els no entrenats, tant en la condició intrínseca com intencional, aquesta diferència en el nivell d'entrenament tampoc va afectar la reproductibilitat de les fases de pensament. L'única diferència entre grups fou que els corredors entrenats van mostrar una fase estable de TRT significativament més llarga, amb un ús més freqüent de pensaments del tipus *pace monitoring* (veure Taula 1) que els no entrenats. Aquests resultats coincideixen amb estudis previs, els quals van mostrar com els corredors entrenats tendeixen a focalitzar en TRT més freqüentment que els corredors menys experimentats (Masters & Lambert, 1989; Silva & Appelbaum, 1989; Tammen, 1996; Tenenbaum, 2002), i amb d'altres que indiquen que els TRT relacionats amb tècnica, cadència o ritme poden millorar el rendiment (Brick, MacIntyre, & Campbell, 2013; Crews, 1992; Martin, Craib, & Mitchell, 1995). El resultats obtinguts suggereixen també que l'ús més habitual de TRT no pot ser purament volitiu. Concretament, en la dinàmica intencional s'imposà un TUT però els corredors entrenats van canviar involuntàriament el seu focus d'atenció cap a TRT, els quals van ser estabilitzats durant l'últim interval d'intensitat. Tot i això, es requereixen més estudis d'intervenció per tal de confirmar si l'ús més freqüent de TRT per part dels entrenats és realment estabilitzat espontàniament com a conseqüència de l'entrenament.

De la mateixa manera que no es van observar diferències en la dinàmica de pensaments respecte al nivell d'entrenament, tampoc se'n van trobar respecte al gènere. Tant dones com homes van mostrar les mateixes fases de pensament en els tres estudis. Tot i això, seria recomanable estudiar en un futur les possibles diferències sexuals respecte a la quantitat de canvis en les subcategories de pensament no relacionats amb la tasca reportats durant l'esforç.

Els resultats de l'Estudi III van mostrar com tant la dimensió relació amb la tasca (TUT o TRT) com la direcció (interna o externa) del contingut de pensaments van canviar de forma involuntària en funció del temps de tasca. Els resultats principals van desvetllar com l'acumulació de fatiga redueix l'estabilitat del TUT-I i genera noves categories de pensament, coincidint amb les prediccions del model no lineal del focus d'atenció (Balagué et al., 2012). Concretament, s'observà una reducció progressiva de TUT-I, un primer canvi qualitatiu que va mostrar l'emergència involuntària de TRT-E i TRT-I, i un segon canvi qualitatiu que va manifestar una transició involuntària cap a TRT-I prop de l'exhauriment. A diferència del TUT-I, el TUT-E va augmentar progressivament doncs, en comparació amb el TUT-I resulta cognitivament menys exigent (no és necessari subministrar informació reflexiva). Tot i que totes les categories de pensament van mostrar certa estabilitat durant el test, un mínim canvi en el temps prop de l'exhauriment va portar a un canvi qualitatiu no lineal i irreversible cap a TRT-I. Per tant, la formació o dissolució d'una categoria de pensament o inclús la cancel·lació de la tasca per sí mateixa, poden ser definits com a fenòmens no lineals (Meyer-Lindeberg, Zieman, Hajak, Cohen, & Faith Berman, 2002). En aquesta línia, doncs, seria convenient estudiar en un futur la correspondència d'aquests canvis no lineals que delimiten les diferents fases de pensament amb els llindars fisiològics. Concretament, el canvi que delimita la fase metaestable amb la fase estable de TRT (veure Figura 2), podria coincidir amb el llindar anaeròbic determinat mitjançant una prova de gasos convencional. La determinació del llindar anaeròbic a través de l'anàlisi de la dinàmica del focus d'atenció, podria suposar una forma ràpida, senzilla i econòmica per a complementar la detecció clàssica mitjançant proves de gasos. A més, la utilització de forma periòdica d'aquest test, i el conseqüent control de la ubicació del canvi qualitatiu i de la llargada de les diferents fases de pensament, podria donar molta informació sobre l'adaptació i evolució de l'atleta durant el procés d'entrenament.

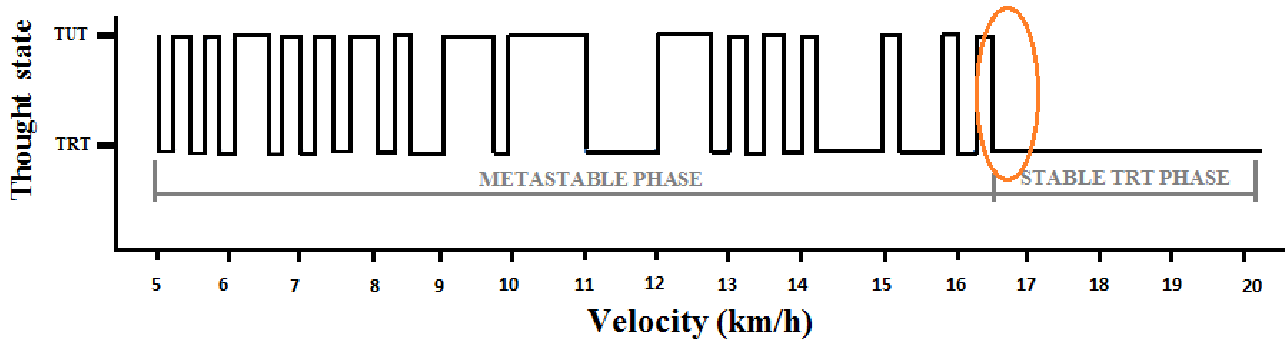

Figura 2. Exemple de la condició intrínseca d'un corredor entrenat durant un test incremental en cinta rodant i fins l'esgotament. El cercle indica el canvi qualitatiu que delimita les fases metaestable i d'estabilitat de TRT (en aquest cas el canvi qualitatiu es troba sobre els 17 km/h)

Pel que fa a les limitacions de les metodologies d'auto-informe utilitzades en aquesta tesi, cal tenir en compte les mencionades per la literatura científica relacionada amb el *mind wandering* (Christoff, Ream, & Gabrieli, 2004). Tot i que es podria posar en dubte la fiabilitat de qualsevol dada reportada mitjançant auto-monitoratge, les mesures objectives basades en senyals electrofisiològiques (Christoff, Keramatian, Gordon, Smith, & Mädler, 2009), recolzen els resultats dels mètodes d'auto-informe de pensaments. A més, després de cadascun dels tests realitzats en aquesta tesi, els participants van respondre a diverses preguntes per tal de verificar el grau d'adherència envers les instruccions inicials (ex.: imposar-se un TUT), per avaluar la fiabilitat de l'auto-monitorització i dels auto-informes. D'altra banda, també cal tenir en compte les limitacions relacionades amb la validesa externa dels resultats d'aquesta tesi. A causa de la naturalesa específica dels constrenyiments de les tasques físiques imposades (sempre utilitzant ergòmetres) i de l'entorn (sempre en laboratori), els resultats i conclusions només poden ser generalitzables a condicions d'esforç similars o realitzades en contextos semblants, que no solen ser els propis de situacions competitives. Per tant, testejar de nou la consistència d'aquests resultats durant la competició i en diferents entorns (naturals o urbans) podria ajudar a reforçar-los.

5.1. Conclusions i criteris per al disseny d’estratègies cognitives

Tenint en compte les propietats d’estabilitat dinàmica dels pensaments i a través de l’aplicació del *dual intrinsic-intentional paradigm* (Kelso et al., 1988), les següents consideracions poden ajudar als esportistes a optimitzar les seves estratègies cognitives durant l’exercici: (a) els pensaments relacionats (TRT) o no-relacionats (TUT) amb la tasca poden ser igualment efectius per a millorar el rendiment, tot dependrà del seu perfil d’estabilitat; (b) mentre que a intensitats moderades tant els TUT com els TRT són estables, prop de l’exhauriment només són estables els TRT; (c) el perfil d’estabilitat dinàmica del focus d’atenció i dels continguts de pensament canvia en funció dels constrenyiments de la tasca, personals i de l’entorn; (d) els pensaments espontanis són més estables i, per tant, es poden mantenir més fàcilment que d’altres continguts de pensament imposats menys estables; (e) conseqüentment, qualsevol intent de mantenir el focus en pensaments que esdevenen inestables prop de l’exhauriment (com ara els TUT), podria ser ineficient i cognitivament exigent, limitant així l’efecte ergogènic del focus d’atenció per a l’atleta; (f) els corredors entrenats podrien beneficiar-se de la utilització de pensaments del tipus *pace monitoring* per tal de distreure l’atenció envers les sensacions psicosomàtiques de fatiga (*feelings and affect*), que típicament caracteritzen als períodes propers a l’exhauriment; (g) no és possible determinar *a priori* el valor de la càrrega en el qual es produeix el canvi qualitatiu cap a TRT, perquè el sistema és multi-paramètric i altament no lineal.

CAPÍTOL 6: Referències dels capítols 1 i 5

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