**Attentional focus in endurance activity: New paradigms and future directions**

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Abstract

After more than 35 years of investigation research on attentional focus in endurance activity is still mired by a lack of consensus. Specific challenges relate to the conceptualisation of association and dissociation, and discrepancies in methodology, research design, and data collection techniques. This review addresses previously unresolved issues that may limit research findings in this field. Initial concerns include how the endpoint of exercise tasks are defined, how pace is controlled, and the subjects employed within research investigations. An additional objective is to provide direction for future investigations. Traditional views of attentional focus may be limited in their explanatory value. We present a new working model of attentional focus in endurance activity that may more precisely categorise cognitive processes. Finally, research on this topic needs to be grounded in a recognised framework that captures the dynamic nature of human cognition. We propose that existing perspectives are recognised, such as the parallel processing model of pain and the mindfulness approach, and additionally, we propose a metacognitive perspective be explored. Means of integrating these conceptual frameworks are suggested to further enhance the understanding of attentional processes in endurance activity.
Attentional focus in endurance activity has been the subject of much examination since Morgan and Pollock (1977) first categorised the cognitions of distance runners. Developing the concept of two opposing coping strategies, they noted that elite performers reported a tendency to associate, or monitor sensory information, and adjust pace accordingly. This strategy differed from dissociation, where runners (typically non-elite) focused more on distracting stimuli to direct attention away from the pain of exertion (Morgan & Pollock, 1977).

Despite the apparent simplicity of this contention, subsequent investigations have produced equivocal findings. For instance, when compared with dissociative cognitions, association has been linked with improved performance on some endurance tasks (e.g., Brewer, Van Raalte, & Linder, 1996; Clingman & Hilliard, 1990), but not for others (e.g., Gill & Strom, 1985; Weinberg, Smith, Jackson, & Gould, 1984). Furthermore, although some studies have demonstrated increased effort perception with an associative focus (e.g., Johnson & Siegel, 1992; Stanley, Pargman, & Tenenbaum, 2007), others have not (e.g., Connolly & Janelle, 2003; Couture, Jerome, & Tihanyi, 1999).

Despite over 35 years of investigation, conclusive agreement on the merits of both association and dissociation has yet to be reached. The two broad reviews in the past 15 years (Lind, Welch, & Ekkekakis, 2009; Masters & Ogles, 1998a), covering 92 separate studies in total, highlighted this disparity. These authors noted that the research topic was hampered by a lack of conceptual clarity, and issues in both measurement and design (Lind et al., 2009; Masters & Ogles, 1998a).

Building on the major reviews and findings above, over the following sections we will argue that many challenges remain, and continue to perplex attentional focus research. For example, some concerns over the conceptualisation of the associative/dissociative
terminology (e.g., Laash, 1994-1995; Masters & Ogles, 1998a) are currently unresolved. Furthermore, discrepancies in research methodologies, particularly relating to the exercise tasks performed, have yet to be considered as covariates of attentional focus and endurance performance. Finally, the domain continues to search for an accepted conceptual framework. Though some have been proposed, such as a social-cognitive perspective (e.g., Tenenbaum, 2001), and a mindfulness approach (e.g., Salmon, Hanneman, & Harwood, 2010), they have not been fully embraced as of yet. We hope that the investigation of each of these factors will improve the understanding of cognitive processes in endurance activity, and develop new perspectives on the topical issues at the forefront of attentional focus research.

Approach and Method

Purpose and structure of the review

The aims of this paper are fivefold: (i) to collate and review the existing research on attentional focus in endurance activity; (ii) to examine how association/dissociation have been conceptualised in the literature; (iii) to highlight and dispel methodological and data collection issues that continue to confound the research findings; (iv) to provide a roadmap for future investigations regarding study design and data collection techniques; and (v) to introduce conceptual frameworks that can guide future research on attentional focus in endurance activities.

To meet these aims, three main results sections are presented. To examine how association and dissociation have been conceptualised, we appraise the classification systems and terminology used in attentional focus research. Although they provide some explanatory value, current systems may not adequately conceptualise all thoughts individuals engage in.
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This may contribute to the existing research conflict. As a resolution, we propose a working model that may better represent cognitive processes during endurance activity.

The research design and methodological issues section will highlight further concerns within the literature. The neglect of elite athletes within research studies, how exercise protocols have been manipulated, and how attentional focus data has been ascertained will be at the forefront of this discussion. Areas of further investigative interest are signposted to stimulate research in this domain.

Conceptual frameworks will be advanced in the final section to help our understanding of attentional regulation during endurance activity. Existing theoretical frameworks will be briefly summarised, and an additional approach will be advanced to guide future research.

Literature search and inclusion/exclusion criteria

Research on attentional focus during endurance exercise was obtained by conducting searches on databases including Academic Search Complete, SPORTSDiscus, PsychINFO, PsychARTICLES, MEDLINE, and Google Scholar. The terms attentional focus, association, dissociation, task-relevant, task-irrelevant, cognitive strategies, and endurance exercise were used in various combinations to search these databases. Reference lists from articles retrieved were scrutinised for additional studies. A total of 112 studies were identified and reviewed, each relating to attentional focus and either aerobic, or muscular endurance exercise (see Supplementary Tables S1-S4).

Only peer reviewed studies published in reputable journals were considered for this article. Studies included needed to fulfil one of two design requirements. First were studies that employed attentional focus strategies as independent variables influencing endurance
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performance, perceived exertion and/or affective state. Second were studies measuring
attentional focus as a dependent variable under varying exercise conditions or settings.
Articles related to non-endurance forms of activity (e.g., strength/speed), to motor skill
learning or skill performance, and to injury were not included in the review.

Results

Classification systems and terminology

A variety of terms have been interchangeably used to describe association and dissociation.
These have included attentional focus (e.g., Schücker, Hagemann, Strauss, & Völker, 2009),
attentional strategies (e.g., Connolly & Janelle, 2003), cognitive strategies (e.g.,
Okwumabua, Meyers, Schleser, & Cooke, 1983), and cognitive orientations (e.g., Acevedo,
Dzewaltowski, Gill, & Noble, 1992). The use of the word strategy in certain circumstances
might be inappropriate, however. Although the term strategy connotes a planned series of
thoughts or actions, often cognitions may emerge spontaneously during exercise. For this
reason, the present review will use terms such as attentional focus, or cognitive orientations
when cognitions are not necessarily planned or deliberate. The term strategy will be preferred
only when thoughts are intentionally utilised to modify aspects of exercise performance. How
exercise cognitions have been classified will be the first area of discussion.

Are existing classification systems fit for purpose?

It has been suggested that the association/dissociation concept is too simplistic to describe the
attentional focus of endurance athletes (Laash, 1994-1995). In this regard, the dichotomous
terminology may imply cognitive processes that are ‘static and categorical rather than
variable and dimensional’ (Salmon et al., 2010, p. 129). As such, the associative/dissociative
framework may be limited in its ability to capture the dynamic complexities of thought processes.

An alternative classification was posited by Schomer (1986). This system integrated Nideffer’s (1981) attentional style dimensions of width (broad/narrow), and direction (internal/external), with Morgan and Pollock’s (1977) association/dissociation construct. It is questionable whether the inclusion of Nideffer’s (1981) theoretical dimensions was appropriate, however. Some have criticised Nideffer’s propositions for neglecting a dimension of attentional flexibility, for example (e.g., Moran, 1996; Summers, Miller, & Ford, 1991). Others have failed to empirically validate some basic assumptions of Nideffer’s model, such as the narrowing of attention as arousal increases (e.g., Côté, Salmela & Papathanasopoulu, 1992; Salmela & Ndyoe, 1986). Furthermore, both Stevinson and Biddle (1998), and Summers and colleagues (Summers, Sargent, Levey, & Murray, 1982) suggested these systems fail to adequately categorise many thoughts individuals might express.

Most recently, both Heil (1993), and Stevinson and Biddle (1998, 1999) suggested two dimensional classifications of cognitive orientations. Heil (1993) proposed a pain-sport attentional matrix that combined attentional context (pain and sport), and attentional direction (association and dissociation). The resulting combinations were; pain association/sport association; pain association/sport dissociation; pain dissociation/sport association; and pain dissociation/sport dissociation. Unfortunately, however, this model has yet to be examined empirically (Brewer & Buman, 2006). In Stevinson and Biddle’s (1998) system, thoughts during exercise were classified as inward monitoring (e.g., fatigue), outward monitoring (e.g., strategy), inward distraction (e.g., daydreams), or outward distraction (e.g., scenery). The utility of this system was to add to the range of categorisable thoughts. The evolution of existing models has also proved useful to progress attentional focus research. However, the
need still exists for a classification system to adequately differentiate thought categories. The following discussion will highlight why current models may require further development in this regard.

Conceptualising association and dissociation: a blurring of key terms?

In early research, the terms internal and external focus were often viewed as synonymous with association and dissociation, respectively (e.g., Fillingim & Fine, 1986; Padgett & Hill, 1989; Pennebaker & Lightner, 1980; Wrisberg, Franks, Birdwell, & High, 1988). This limited recognition of the complexities of both associative and dissociative dimensions may have blurred some of the inferences drawn from these studies. Many authors have also stressed the importance of recognising that different types of attentional focus exist within each dimension (e.g., Clingman & Hilliard, 1990; Moran, 1998). This is exemplified by Stevinson and Biddle’s (1998) classification system, where both association and dissociation have both internal and external dimensions.

To emphasise the importance of this latter point, research employing muscular endurance tasks have generally omitted an external association condition. Associating subjects have instead been instructed to focus internally on physical sensations (e.g., Gill & Strom, 1985; Weinberg et al., 1984). The subsequent findings have tended to suggest that dissociative type strategies optimise muscular endurance performance (e.g., Birrer & Morgan, 2010; Gill & Strom, 1985; Weinberg et al., 1984).

More recent investigations have challenged this contention, however. For example, in studies employing a lower limb endurance task (Lohse & Sherwood, 2011), or a sit-up exercise (Neumann & Brown, 2013), subjects performed significantly better employing either
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dissociative, or external associative strategies\(^1\), when compared with an internal associative focus. Furthermore, Neumann and Brown (2013) concluded that external association promoted the most efficient muscle movement during the sit-up task. These findings indicate the apparent benefit of dissociative strategies to enhance muscular endurance may well be a legacy of protocols that omit critical associative cognitions (e.g., Neumann & Brown, 2013).

Studies reporting beneficial effects for associative strategies on aerobic endurance have also tended to impose task-relevant cognitions. These have included a focus on cadence (Clingman & Hilliard, 1990), important actions to perform the activity (e.g., Donohue, Barnhart, Covassin, Carpin, & Korb, 2001; Miller & Donohue, 2003; Rushall & Shewchuk, 1989), and staying relaxed (e.g., Goudas, Theodorakis, & Laparidis, 2007; Martin, Craib, & Mitchell, 1995; Morgan, 1978; Smith, Gill, Crews, Hopewell, & Morgan, 1995; Spink & Longhurst, 1986). Conversely, an internal associative focus on physical sensations has been shown to negatively impact performance and effort perceptions (e.g., Johnson & Siegel, 1992; Pennebaker & Lightner, 1980; Stanley et al., 2007). These somewhat incongruous findings may indicate a need to carefully consider how associative cognitions are classified within existing systems. The following example further illustrates this point.

*Where do thoughts related to technique fit within existing systems?*

Thoughts related to technique, or ‘instructions to do actions that would likely result in optimum performance’ (Donohue et al., 2001, p. 23) have not been clearly classified within existing models. For instance, despite suggesting such thoughts might distract (dissociate)

\(^1\) The term *external association* in this case is drawn from research in the motor skill learning domain, and refers to attention directed on the effects of movements on the environment (see Wulf, 2007; Wulf, McNevin, & Shea, 2001). Although it is beyond the scope of this review to discuss attentional focus in motor skill learning, these studies (Lohse & Sherwood, 2011; Neumann & Brown, 2013) are included as muscular endurance tasks were employed. The additional confusion caused by the use of terminology from the motor skill learning domain should be noted, however.
from exertional pain, Stevinson and Biddle (1998) also drew parallels with thoughts related to split timing, hinting that a technical focus might be considered external association.

Conversely, Schomer (1986) included in his internal/narrow associative command and instruction dimension, ‘thoughts reflecting emphatic self-regulatory instructions to specific body parts or instructions to whole body functioning’ (p. 46). The choice based on the prevailing systems, it seems, is whether thoughts related to technique should be classified as internal, or external association?

A new ‘working model’ of attentional focus

In order to better accommodate thoughts such as those related to technique, we suggest a third option; that existing models might be extended. Although focusing on technique requires inward monitoring, the individual is actively attempting to regulate their actions, rather than focusing solely on bodily sensations. Referring to both processes as internal association may not be appropriate, and existing systems do not easily facilitate the inclusion of an active dimension in their present format.

We therefore propose an expansion of the internal associative dimension of Stevinson and Biddle’s (1998) classification system, to distinguish between internal sensory monitoring, and active self-regulation (Table 1). Active self-regulation reflects efforts to control or monitor thoughts, feelings or actions (Cameron & Leventhal, 2003). Thus, in the proposed model, active self-regulation during endurance activity may include a focus on technique (e.g., Donohue et al., 2001; Saintsing, Richman, & Bergey, 1988), cadence (Clingman & Hilliard, 1990), pacing (e.g., LaCaille, Masters, & Heath, 2004; Takai, 1998), or relaxing (e.g., Smith et al., 1995; Spink & Longhurst, 1986).

[TABLE 1 near here]
Self-regulatory cognitions may enhance endurance performance by optimising pace (e.g., Clingman & Hilliard, 1990; Rushall & Shewchuk, 1989; Spink & Longhurst, 1986), or by improving movement economy (e.g., Crews, 1992; Martin et al., 1995). Interestingly, increasing pace by active self-regulation may not necessarily elevate effort perceptions (e.g., Connolly & Janelle, 2003; Couture et al., 1999; Rushall & Shewchuk, 1989). Successful self-regulation may require a period of learning, however, with some runners shown to benefit less from active relaxation strategies after a shorter period of training (e.g., Smith et al., 1995).

Thoughts related to strategy may also fall within the active self-regulation dimension. Such cognitions have traditionally been considered as external association (e.g., Connolly & Janelle, 2003; Stevinson & Biddle, 1998). For endurance athletes, however, strategising typically requires regulation of pacing and effort. Although athletes may outwardly monitor (Stevinson & Biddle, 1998) environmental conditions or competitors, effective strategic decisions are ultimately based on one’s own capabilities. To emphasise this point, Baker, Côté, and Deakin (2005) reported that under passing conditions (i.e. either overtaking, or being overtaken), competitive ultra-endurance triathletes tended to focus more on one’s own performance (e.g., staying within one’s limits), or on strategic decisions (e.g., needing to pass decisively). In the proposed working model, we include other competitors within the outward monitoring dimension as important sources of information for performance regulation.

In contrast to these self-regulatory processes, internal sensory monitoring alone may exacerbate feelings of exertion (e.g., Pennebaker & Lightner, 1980; Stanley et al., 2007). Concomitantly, pace may decrease, or movement economy may be reduced (Schücker et al., 2009; Schücker, Anheier, Hagemann, Strauss, & Völker, 2013). The added dimensions of active self-regulation and internal sensory monitoring may provide some clarity regarding the
effects of traditionally associative cognitions. These assumptions of this model need further
testing, however.

**Distraction within the ‘working model’ of attentional focus**

The suitability of the term dissociation has previously been debated, particularly as
dissociation also describes a clinical disorder (Masters & Ogles, 1998a). Perhaps the term
distraction is more appropriate and descriptive (Masters & Ogles, 1998a; Stevinson &
delineates distractive cognitions is questionable however, with little difference between
internal (e.g., Stanley *et al*., 2007), and external distraction strategies (e.g., Connolly &
Janelle, 2003) across some studies. Furthermore, little significant difference has been
demonstrated between internal and external dissociation in terms of performance or perceived
effort (e.g., Connolly & Janelle, 2003; Couture *et al*., 1999; Johnson & Siegel, 1992; Padgett
& Hill, 1989; Stanley *et al*., 2007). Perhaps there is a need to reconsider how distractive
cognitions are conceptualised.

In this context, *Attention Restoration Theory* may be particularly relevant (Kaplan,
1995; Kaplan & Berman, 2010). In attempting to explain the restorative effects of natural
surroundings, this theory highlights the benefits of an environment where attractive stimuli
(e.g., picturesque scenery) capture involuntary attention. This is contrasted with settings that
demand active, or directed attention (e.g., a busy urban street; Berman *et al*., 2012). It may
well be that *active distraction* strategies lead to very different outcomes than more passive
thoughts (i.e. *involuntary distraction*). This distinction between active and involuntary
distraction may better define distractive cognitions.
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The existing research provides some support for these assertions (Table 2).

Involuntary distraction has been shown to increase enjoyment and reduce boredom (e.g., Pennebaker & Lightner, 1980), to reduce arousal or frustration (e.g., Aspinall, Mavros, Coyne, & Roe, 2013), and to elevate positive moods (e.g., Callen, 1983; Ekkekakis, 2003, 2009; Goode & Roth, 1993; Masters, 1992). These outcomes may be magnified by exercising in a natural, or ‘green’ outdoor setting (e.g., Barton & Pretty, 2010; Blanchard, Rodgers, & Gauvin, 2004; Butryn & Furst, 2003; Harte & Eifert, 1995; LaCaille et al., 2004). Involuntary distraction may also improve exercise adherence to a greater extent than associative statements (e.g., Martin et al., 1984; Welsh, Labbé, & Delaney, 1991).

[ TABLE 2 near here]

The majority of studies that have imposed active distraction techniques such as calculations or word tasks (e.g., Fillingim & Fine, 1986; Fillingim, Roth, & Haley, 1989; Johnson & Siegel, 1987; Siegel, Johnson, & Davis, 1981; Siegel, Johnson, & Kline, 1984), conversing (e.g., Franks & Myers, 1984; Johnson & Siegel, 1992), or watching videos (e.g., Russell & Weeks, 1994; Stanley et al., 2007) have indicated either reduced, or relatively unaffected effort perceptions during activity (Table 2). In contrast, Delignières and Brisswalter (1994) demonstrated increased effort perceptions for subjects performing a reaction-time task while cycling. The authors suggested the externally paced information processing demands of the reaction-time task may have generated additional stress, thus increasing effort perceptions (Delignières & Brisswalter, 1994).

Distractive techniques generally reduce pace or intensity when compared with self-regulatory cognitions (e.g., Clingman & Hilliard, 1990; Connolly & Janelle, 2003; Spink & Longhurst, 1986). Greater distraction/dissociation has also been reported during lower intensity training activities (e.g., Bachman, Brewer, & Petitpas, 1997; Masters & Lambert,
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1989; Morgan, O’Connor, Ellickson, & Bradley, 1988; Morgan, O’Connor, Sparling, & Pate,
1987; Ogles, Lynn, Masters, Hoeffel, & Marsden, 1993-1994; Okwumabua, Meyers, &
Santille, 1987; Schomer & Connolly, 2002; Summers et al., 1982). There are some
exceptions, however, and it is interesting to note the dissociative techniques used in these
studies. Strategies include rhythmically repeating a phrase (Okwumabua et al., 1983), or
repeating the word ‘down’ on every stride (Morgan, Horstman, Cymerman, & Stokes, 1983;
Saintsing et al., 1988). It may be that these rhythmical phrases unintentionally stimulate a
self-regulatory focus on cadence, for example, rather than distract from the activity. This
assumption demands further research attention, however. Future researchers may need to
carefully consider both athletes’ intent when employing rhythmical mantras, and the resulting
impact on endurance performance.

Distractive techniques appear most effective to reduce effort perceptions during
endurance activity and to enhance mood states post-exercise. However, to optimise
endurance performance and pacing, a focus on self-regulatory cognitions appears critical. In
the following section, methods which might be used to enhance self-regulatory skills will be
explored in more detail.

What methods might be used to enhance self-regulatory skills?

Before employing psychological methods, it is important to fully understand the mental skills
required in a sporting environment. In this regard, Vealey’s (1988) proposal that optimum
physical arousal, optimum mental arousal, and optimum attention are required, remains valid
today. Specific to endurance performance, Taylor (1995) indicated the predominant
psychological constraints may be motivation, boredom, and pain due to duration. In order to
optimise attentional focus during endurance activity, a number of psychological strategies
may be particularly relevant.
Interventional studies aimed at enhancing endurance performance have generally reported using self-talk, imagery, goal setting, and/or relaxation techniques. Combinations of these self-regulatory strategies have assisted performance of skiers (Rushall, Hall, Roux, Sasseville, & Rushall, 1988), an ultra-endurance runner (Bull, 1989), endurance swimmers (Hollander & Acevedo, 2000), non-competitive cyclists (Hamilton, Scott, & MacDougall, 2007), individuals performing sit-ups (Lee, 1990), and athletes running 1600m time trials (Patrick & Hrycaiko, 1998). More recently, Blanchfield et al. (2013) demonstrated how cyclists who received motivational self-talk instruction reported a reduction in perceived exertion, and an 18% increase in endurance performance.

Employing a gymnasium triathlon task, Thelwell and Greenlees demonstrated positive performance effects for a mental skills package in both non-competitive (Thelwell & Greenlees, 2001) and simulated competitive (Thelwell & Greenlees, 2003) settings. Crucially, Thelwell and Greenlees (2003) also reported how participants utilised each strategy. Attention was enhanced by focusing on task goals and motivation (using goal setting and self-talk strategies), reducing focus on pain and optimising arousal (relaxation and imagery), and maintaining task-relevant cognitions on technique, pacing and race plans (relaxation, imagery, and self-talk).

These studies answer some critical questions regarding attentional focus and psychological strategies during endurance activity. For example, Thelwell and Greenlees (2003) highlighted psychological techniques to optimise arousal (Vealey, 1988), enhance motivation, or alleviate exercise induced discomfort (Taylor, 1995). These strategies may also be learned effectively by inexperienced participants (e.g., Hamilton et al., 2007; Thelwell & Greenlees, 2003), who may be less proficient, or resist adopting cognitive...
techniques (e.g., Couture et al., 1994; Okwumabua et al., 1983; Russell & Weeks, 1994; Sachs, 1984; Schomer, 1987; Weinberg et al., 1984).

However, some questions still remain. For example, individuals’ preference for coping strategies may be relevant, with many studies highlighting the importance of preferred coping styles in improving both pain tolerance (e.g., Forys & Dhalquist, 2007), and endurance performance (e.g., Baghurst, Thierry, & Holdener, 2004; Couture, Tihanyi, & St Aubin, 2003; Rejeski & Kenny, 1987). The impact of psychological techniques in ecologically valid, competitive settings may also be a particularly relevant avenue of enquiry (Thelwell & Greenlees, 2003).

Finally, it is noteworthy that the majority of these studies employ relatively short duration endurance tasks, where coping with exertional discomfort may be the priority (e.g., Hamilton et al., 2007; Patrick & Hrycaiko, 1998). However, boredom may be a more prevalent emotional state during longer duration activity bouts (e.g., Taylor, 1995). To cope with boredom, Bull (1989) noted how an ultra-endurance desert runner attempted ‘idiosyncratic forms of imagery’ (p. 261). The benefits of distraction to alleviate boredom have also been noted (e.g., Pennebaker & Lightner, 1980). The optimum use of various coping strategies in such circumstances demands greater clarification.

**Research design and methodological issues**

Paralleling the conceptual limitations raised previously, methodological issues may have similarly contributed to the divergent research outcomes. These include a neglect of elite subjects, how pacing has been controlled, and how the exercise endpoint has been defined. How covariates of perceived exertion have been controlled is a further concern. Finally, data
collection techniques typically employed in studies may also have limited the existing
findings.

A need to study elite endurance athletes

The considerable under-representation of elite athletes (e.g., national level) within well-
controlled, interventional studies needs to be emphasised. The exceptions include Rushall et
al. (1988), Rushall and Shewchuk (1989), and Clingman and Hilliard (1990). This matter
needs to be redressed to broaden our understanding of how elite athletes cope with effortful
endurance exercise.

The evidence suggests that competitive performers benefit from a predominantly
associative, task-relevant focus (Clingman & Hilliard, 1990; Rushall & Shewchuk 1989;
Rushall et al., 1988; Ungerleider, Golding, Porter, & Foster, 1989), and attempting to distract
from the activity may, in fact, be detrimental to performance (e.g., Beaudoin, Crews, &
Morgan, 1998; Kress & Statler, 2007). This does not mean that competitive athletes do not
distract (e.g., Antonini-Philippe, Reynes, & Bruant, 2003), rather, they may employ specific
strategies as the conditions demand (e.g., Kirkby, 1996; Laash, 1994-1995; Moran, 1996;
Silva & Appelbaum, 1989). Their cognitive strategies may be very different to those of less
experienced individuals, for whom distraction may often be a more suitable alternative (e.g.,
Brewer et al., 1996; Freischlag, 1981; Masters & Ogles, 1998b; McDonald & Kirkby, 1995;

What this highlights is the need to perform attentional focus interventions with elite,
experienced endurance athletes. Precedent for this contention can be found in the advocacy of
MacIntyre, Moran, Collet, and Guillot (2013) for a strength-based approach to mental
imagery research. This approach recommended that researchers recruit high-ability
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participants, a process that may better answer many important research questions. Solutions
to the conceptual and methodological issues besetting the attentional focus literature may be
found through a similar approach. Some of these questions will be posed in the following
sections.

Can control over pacing impact on attentional focus and effort perceptions?

There are no published studies within the attentional focus literature directly comparing self-
controlled and externally-controlled paced tasks. Deeper analysis of the literature does
suggest a possible effect, however. In studies employing self-controlled pacing, performance
is typically improved when using associative strategies, without necessarily increasing effort
perceptions (e.g., Connolly & Janelle, 2003; Couture et al., 1999; LaCaille et al., 2004;
Rushall & Shewchuk, 1989). In contrast, with externally-controlled pace designs, associative
thoughts tend to increase perceptions of effort and fatigue when compared with both
dissociative (e.g., Johnson & Siegel, 1992; Stanley et al., 2007), and control conditions (e.g.,
Pennebaker & Lightner, 1980). Pace control may even impact on measures of physiological
capacity such as VO$_{2}^{\text{max}}$, with Mauger and Sculthorpe (2012) reported greater (by 8%)
VO$_{2}^{\text{max}}$, values for untrained individuals engaging in a self-controlled pace protocol.

One explanation for a possible external pace control effect may be that individuals
cannot actively self-regulate under such constraints, and so internal sensory monitoring is
exacerbated. Reviewing their externally-controlled pace protocol, Stanley et al. (2007)
acknowledged the similarity of both internal and external associative conditions, where
participants’ cognitions ‘reflected attention to bodily symptoms such as heart rate,
perspiration, and fatigue’ (p. 358). External control over pacing may have contributed to this
finding.
In related domains, maintaining a perception of control has been shown to moderate stress responses to work conditions (e.g., Steptoe, Evans, & Fieldman, 1997), and painful stimuli (e.g., Bollini, Walker, Hamann, & Kestler, 2004). For athletes, perceived control is a core feature of models of competitive state anxiety (see Jones & Swain, 1995), and of challenge and threat states in competition (see Jones, Meijen, McCarthy, & Sheffield, 2009).

Furthermore, in a qualitative study with Olympic cyclists, Kress and Statler (2007) reported exacerbated perceptions of pain during intense competition when pacing was controlled externally. The accruing evidence suggests that athletes who perceive pacing to be outside of their control may experience an increase in negative emotional states. In these circumstances it may be that other self-regulatory actions are best employed, such as relaxation, or positive self-talk (e.g., Kress & Statler, 2007). Clearly this is a variable worthy of future investigation.

Not only do we need to fully comprehend how pace control influences attentional focus, but also how the potentially negative outcomes can be overcome.

*Does it matter if exercise duration is defined by distance or time?*

Little attention has been paid to protocols that stipulate performance over a specified distance (e.g., Miller & Donohue, 2003; Couture *et al*., 1999), or a predetermined time (e.g., Scott, Scott, Bedic, & Dowd, 1999; Stanley *et al*., 2007). A recent investigation by Chinnasamy, St Clair Gibson, and Micklewright (2013), however, revealed different pacing strategies for children performing a distance task (750m run), in comparison with a time task (matched to their previous 750m performance). During the time task, children completed a lesser total distance, and used a sub-optimal pacing strategy (i.e., no end spurt), suggesting a preference for spatial cues during the task. The authors argued that distance tasks are less cognitively demanding than time-based tasks (Chinnasamy *et al*., 2013), an unrecognised factor within the attentional focus literature to date.
If such findings relate to adults is unknown. Nevertheless, Green, Sapp, Pritchett, and Bishop (2010) noted inferior pacing accuracy amongst recreational runners (mean deviation of 9.5 seconds over 400m) compared with more experienced runners (mean deviation of 2.9 seconds per 400m). In addition, Lambourne (2012) demonstrated how cycling at 90% of ventilatory threshold caused a shift in subjects’ perception of time, such that standard intervals (600 msec) were mistaken as shorter intervals (504 msec). In effect, arousal (increased during exercise) causes an individual’s internal ‘pacemaker’ to speed up (Penton-Voak, Edwards, Percival, & Wearden, 1996), so that chronological time passes more slowly than the individual perceives (Lambourne, 2012). Interestingly, distraction may have the opposite effect during lower intensity exercise (Couture et al., 1994; Padgett & Hill, 1989).

The impact of exercise protocols with a temporal endpoint on attentional focus needs to be clarified. The evidence suggests time-based endurance tasks may be perceived as more challenging and more difficult to pace correctly.

Have data collection techniques impacted the research findings?

One final matter is how studies have determined the attentional focus of performers. The major methods include retrospective questionnaires, intermittent collection, and concurrent data collection during exercise. Some authors have previously discussed the merits and limitations of these methods in considerable detail (see Kirkby, 1996; Masters & Ogles, 1998a; Sacks, Milvy, Perry, & Sherman, 1981; Schomer, 1986; Stevinson & Biddle, 1998). The reliability of using self-report methods to ascertain attentional processes has also been questioned (e.g., Moran, 2012), with some perhaps forcing respondents to declare a specific strategy (e.g., Okwumabua, 1985).

The key limitations include a tendency to forget, or not report thoughts with retrospective recall (e.g., Sacks et al., 1981; Schomer, 1986), particularly if the event is of
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long duration (Tenenbaum & Elran, 2003). Dissociative cognitions may be particularly
underreported (Ericsson & Simon, 1980). Omitting cues to stimulate recall of thought content
(e.g., Baker et al., 2005) may also decrease the congruency of the reported and actual
cognitions (e.g., Bernier, Codron, Thienot, & Fournier, 2011; Tenenbaum & Elran, 2003).
With intermittent collection during exercise, there may be an inclination to generalise thought
content, or report only the most recent thoughts experienced (e.g., Kirkby, 1996). Finally,
during concurrent collection, there may be a risk of disruption to natural thought development
(e.g., Ericsson & Simon, 1980; Masters & Ogles, 1998a). Knowledge that one’s thoughts will
be scrutinised may further affect cognitive processes (Ericsson & Simon, 1980, 1993). These
limitations may have distorted the findings and recommendations over the past 35 years.

More recent approaches may prove effective in overcoming these problems. For
example, Quintana, Rivera, De La Vega, and Ruiz (2012) had exercising subjects
concurrently indicate pleasant or unpleasant cognitions relating to images, emotions,
sensations, and thoughts using directional keys on an adapted, hand held controller. The
quantity of cognitions registered (mean of 67.88 over 30 minutes), with minimal disruption
may prove a significant step forward for attentional focus data collection. Furthermore,
Aspinall et al. (2013) used a portable EEG device to concurrently monitor the emotions and
mental states (e.g., frustration, engagement, excitement/arousal, meditation) of subjects
walking through various environmental locations. The results indicated that exercise setting
may impact cognitive state, with reductions in arousal, frustration, and an increase in
meditative states experienced when moving from an urban location to a more natural space
(Aspinall et al., 2013).

Despite their potential, however, current technological innovations may not ascertain
every aspect of attentional focus as of yet. For example, the content of thoughts, emotions,
and mental states may need further elucidation. A novel approach may be to harmonise the
use of these technological devices with interview methods of retrospective recall.
Specifically, applying recommendations outlined by Côté, Ericsson, and Law (2005), and
Ericsson and Simon (1993), the episodic data gathered using technological devices may be
used to stimulate more accurate and reliable recall of thoughts during subsequent
retrospective interviews. Future researchers may wish to consider the advantages of applying
such a methodological approach.

Conceptual frameworks

The need for an accepted attentional focus framework has been repeatedly advocated (e.g.,
Masters & Ogles, 1998a; Moran, 1996). In this section will review models previously
proposed, namely the social-cognitive perspective (e.g., Tenenbaum, 2001), Leventhal &
Everhart’s (1979) parallel processing model of pain (e.g., Brewer & Buman, 2006), and the
mindfulness approach (e.g., Salmon et al., 2010). We also highlight the potential benefits of
applying a metacognitive approach to the study of attentional focus in endurance activity.

Social-Cognitive Perspective

Tenenbaum (2001) proposed a social-cognitive perspective to the understanding of perceived
exertion and sustained effort in endurance exercise (Tenenbaum, 2001; Tenenbaum &
Hutchinson, 2007). This model proposes that perceptions of exertion are determined by
dispositional characteristics, task familiarity, demographic characteristics, the task
(aerobic/anaerobic), the intensity of exercise, performance conditions (e.g., temperature), and
the use of strategies to cope with stress.

Existing research evidence supports some of these contentions. For example,
dispositional characteristics such as locus of control (e.g., Hassmén & Koivula, 1996;
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Koivula & Hassmén, (1998), metamotivational state (e.g. Thatcher, Kuroda, Thatcher, & Legrand, 2010), and personality traits (e.g. Hall, Ekkekakis, & Petruzzello, 2005) appear to impact effort perceptions. The roles of goal orientation, perceived competence, and self-efficacy are also emphasised within this model. Indeed, Weinberg (1985) demonstrated that individuals in a high efficacy condition performed significantly better on a leg-extension endurance task than either dissociative or positive self-talk strategies.

Relevant to the present discussion, coping strategies within this model may be either active (i.e., associative/dissociative), or passive (Tenenbaum, 2001; Tenenbaum & Hutchinson, 2007). Active strategies supported in this model include dissociation/distraction, self-talk, imagery, and relaxation techniques, underlining the usefulness of these methods to cope with physical effort. Although attention is proposed to move toward an ‘internal-associative’ mode at higher exercise intensities, this assertion was challenged by Schücker et al. (2013) who suggested an external focus may still be possible at such intensities.

What Tenenbaum’s (2001) model recognises is that cognitions during high-intensity exercise are not simply based on the exertion experienced, or indeed the coping strategies employed. Instead, the authors recommend that future studies of perceived exertion and effort tolerance should consider multidimensional measures to provide additional insights into these constructs (Tenenbaum & Hutchinson, 2007). Perhaps most pertinent is the view that coping strategies are only part responsible for effort perception and effort tolerance during endurance exercise. Future researchers should consider each of the components of this model when investigating attentional focus and perceived exertion during endurance exercise.

Parallel Processing approach
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1 Brewer and Buman (2006) proposed Leventhal and Everhart’s (1979) parallel processing
2 model of pain as a useful framework to investigate attentional focus and endurance
3 performance. Previously advocated by Rejeski (1985) to the study of perceived exertion
4 during exercise, the model proposes that both informational features (e.g., location) and
5 emotional components (e.g., negative feelings) of pain are firstly encoded preconsciously.
6 Perception of the pain may subsequently reach conscious awareness depending on
7 competition from other cues in attentional channels (Brewer & Buman, 2006; Leventhal &
8 Everhart, 1979). Focusing on the emotional component of pain may exacerbate feelings of
9 distress, and many studies have indicated that increasing negative affective states may elevate
10 effort perception during endurance activity (e.g., Baden, McLean, Tucker, Noakes, & St Clair
11 Gibson, 2005; Cioffi, 1991; Rejeski & Sanford, 1984; St Clair Gibson et al., 2006).
12
13 In contrast, both self-regulatory (e.g., Couture et al., 1999; Rushall & Shewchuk,
14 1989) and distractive (e.g., Baden, Warwick-Evans, & Lakomy, 2004; Fillingim & Fine,
15 1986; Johnson & Siegel, 1987; Spink, 1988) thoughts may decrease pain perception by
16 competing with pain cues. In doing so, these cognitions occupy attentional resources, and so
17 reduce attention focused on the emotional component of the pain (Brewer & Buman, 2006;
18 Rejeski, 1985). Application of Attention Restoration Theory (Kaplan, 1995; Kaplan &
19 Berman, 2010) may prove useful to better understand how both active, and involuntary
20 distractive techniques serve to occupy attentional resources, and alter effort perception during
21 endurance activity.
22
23 Addison, Kremer, and Bell (1998) also included both the parallel processing model,
24 and gate control theory (Melzack & Wall, 1965) in their integrative model of pain in sport.
25 Within this model, Addison et al. (1998) identified various types of exercise related pain
26 including fatigue/discomfort (i.e. normal sensations during exercise), positive training pain
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(i.e. non-threatening pain during endurance exercise), and negative training pain (i.e. pain perceived as threatening). When sensations occur, Addison et al. (1998) suggested we initially appraise them to determine the type of pain experienced. Extrinsic factors (including previous experience), intrinsic factors (including pain tolerance), and cognitive strategies can influence the outcome of this appraisal, which may be to continue, or to cease activity.

With regard to previous experience, the role of schemata, or cognitive structures developed from previous occurrences of pain, are emphasised (Brewer & Buman, 2006; Leventhal & Everhart, 1979; Rejeski, 1985). These schemata may allow more experienced individuals to appraise exertional signals from the body more accurately, thereby reducing the emotional component of a pain stimulus. This may be particularly relevant at higher exercise intensities, when sensations of physical discomfort become increasingly salient (e.g., Balagué, Hristovski, Aragones, & Tenenbaum, 2012; Hutchinson & Tenenbaum, 2007; Tammen, 1996; Tenenbaum & Connolly, 2008; Welch, Hulley, Ferguson, & Beauchamp, 2007).

However, unless the individual can accurately appraise sensations (Addison et al., 1998), coping with exercise related pain may be more difficult. For example, less experienced individuals, who may not fully understand pain signals during exercise, may be less adept at coping with discomfort (e.g., Brewer et al., 1996; Moran, 1996). These findings emphasise a need to explore the role of experience in coping with exercise induced pain. Brewer and Buman (2006) also suggested a need for further research to better understand the development of schemata from previous experiences of pain. Two perspectives that may be helpful in this regard include mindfulness and metacognition.

Mindfulness approach
The essence of mindfulness is to direct attention to present-moment experiences in a non-judgemental manner, thereby minimising overall stress (Salmon et al., 2010). This approach supports the benefits of non-judgemental awareness (Hardy & Nelson, 1988), and non-emotional interpretation in pain acceptance (McCaul & Malott, 1984; McMullen et al., 2008).

Burg, Wolf, and Michalak (2012) also suggested that an inherent characteristic of mindfulness is self-regulation of present moment experiences in an attentive, conscious and accepting manner. Applied to the parallel processing model (Leventhal & Everhart, 1979), employing a mindfulness approach may help to reduce the emotional interpretation of pain stimuli, thus minimising distress and perception of effort.

Some research exists examining the influence on mindfulness on endurance performance. For example, Gardener and Moore (2004) reported improvements in competitive performance, reductions in sport-related anxiety, and a willingness to accept negative internal states following 16 weeks of mindfulness training in a swimmer. These authors related mindfulness to the experience of flow (e.g., Csikszentmihalyi, 2002). Of relevance to the present discussion, characteristics of flow include concentration on the task at hand, automaticity, loss of self-consciousness, and a sense of control (e.g., Swann, Keegan, Piggott, & Crust, 2012).

Both Kee and Wang (2008), and Ahearne, Moran, and Lonsdale (2011) also found partial support for mindfulness training to enhance flow states in groups of mixed sport athletes. Specific to endurance activity, exercise intensity may particularly impact on flow experiences. For example, reductions in both sense of control and automaticity have been shown during higher intensity, externally-controlled pace exercise (Connolly & Tenenbaum, 2010). Non-exercise samples have also indicated beneficial effects of mindfulness training on aspects of both attention and cognition (see Chiesa, Calati, & Serretti, 2011 for a review),
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including the ability to reduce emotional interference and disengage attention from negative
stimuli (e.g., Ortner, Kilner, & Zelazo, 2007).

Despite these findings, many questions remain unanswered. For example, the majority
of mindfulness studies using exercising samples do not measure performance improvements
per se (e.g., Ahearne et al., 2011; Kee & Wang, 2008). Furthermore, the case study of
Gardner and Moore (2004) involved an athlete with specific anxiety-related disorders. As of
yet, many of the proposed benefits of a mindfulness approach remain hypothetical and
require further study (Chiesa et al., 2011; Salmon et al., 2010). Whether performance benefits
accrue in non-clinical athletic populations remains to be seen.

Metacognitive perspective

Metacognition has been defined as an individual’s insight into, and control over their own
mental processes (Matlin, 2009). Tarricone (2011) indicated the main interaction between
metacognition and self-regulation is to control, monitor, and regulate strategies to meet task
demands and goals. Applied to endurance exercise, metacognitive processes may include
planning, self-instruction, self-monitoring, self-evaluation, relaxation, and strategy (e.g.,
Augustyn & Rosenbaum, 2005; Huber, 1997; Martini & Shore, 2008; Tarricone, 2011). In
effect, the cognitions described in our working model as active self-regulation may each be
considered metacognitive processes.

Little research has specifically employed a metacognitive perspective to attentional
focus in endurance activity. One study by Nietfeld (2003), adapted the Metacognitive
Awareness Inventory (Schraw & Dennison, 1994) to determine metacognitive strategy use
and monitoring skills by competitive middle-distance runners. Using self-report
questionnaires administered one week after a practice mile run, Nietfeld (2003) indicated the
runners relied mostly on monitoring, and information management strategy (i.e., strategy thoughts during running) regulatory cognitions. Although the limitations of retrospective data collection need to be acknowledged, the relevance of a metacognitive approach to the study of attentional focus is clearly evident.

A metacognitive framework has the potential to enhance our understanding of cognitive processes during endurance activity. Metacognition may, for example, provide insights into the role of experience to moderate effort tolerance and perceived effort (e.g., Rejeski, 1981; Tenenbaum, 2001). Linked with the parallel processing model, metacognition may help to explain how more experienced athletes develop schemata to moderate the effects of attentional focus on endurance performance (Brewer & Buman, 2006; Leventhal & Everhart, 1979). Given the scant research available applying a metacognitive approach to the understanding of attentional processes during endurance activity, however, much remains to be objectively demonstrated.

**Summary and Conclusions**

The aims of this paper were to collate and review the attentional focus research as it pertains to endurance activity, to examine conceptual, methodological and data collection issues that continue to confound the research findings, and to provide direction for future research investigations. We finally aimed to present suitable conceptual frameworks within which attentional focus research can progress.

The domain of attentional focus in endurance activity demands much future investigation. Many research directions are signposted within the present review. Alongside conceptual and terminological concerns, we highlight a need for researchers to explore the links between attentional focus, psychological methods (e.g., self-talk, imagery), personal
preferences for strategy use, and endurance performance. We emphasise the many additional factors that can impact individuals’ focus of attention and perceived exertion during exercise tasks. These aspects need to be carefully considered and controlled in future studies. We also support recent innovations in data collection toward the use of minimally invasive technologies. Such approaches may shed new light on the range and flexibility of cognitive processes during endurance activity.

The present review also stresses a need for elite, or experienced athletes to be prioritised in future investigations. Perhaps applying a strength-based approach (MacIntyre et al., 2013) involving elite athletes may answer many of the questions the present review has raised. With this in mind, we prioritise a number key areas researchers may wish to channel their efforts toward.

**Future research**

Firstly, to better categorise cognitive processes, we propose a new working model of attentional focus in endurance activity. Advancing Stevinson and Biddle’s (1998) classifications, suggested amendments to the associative dimensions include active self-regulation, and internal sensory monitoring. Self-regulatory cognitions include thoughts related to cadence, pacing, technique, strategy, or maintaining a relaxed state. Active self-regulation may have beneficial effects on performance in terms of pace and movement economy, without significantly elevating perceptions of effort. These assertions need further empirical validation, however. Future research should begin by exploring the cognitive strategies experienced endurance athletes employ to self-regulate performance. Furthermore, while it was outside the scope of the present discussion, future researchers may consider the benefits of integrating attentional focus findings from a motor learning perspective. This may be particularly relevant considering attentional focus strategies directed at the movement
effect (external association) have been shown to improve speed in endurance type activities (e.g., Freudenheim, Wulf, Madureira, Pasetto, & Corrêa, 2010; Stoate & Wulf, 2011).

Adapting terminology from Attention Restoration Theory (e.g., Kaplan, 1995; Kaplan & Berman, 2010) we also propose that dissociation, or distraction be viewed as either active distraction, or involuntary distraction. This more descriptive terminology may allow the field to move beyond a perhaps outmoded focus on association/dissociation. Distinctions between active distraction, and involuntary distraction demand further investigation, however, as do the performance and affective outcomes of each mode of distractive focus. The pertinent research questions to be answered, and how they relate to each dimension of attentional focus are presented in Figure 1.

The second matter relates to research designs commonly used within attentional focus studies. Accumulating evidence suggests a possible effect of pace control, with self-controlled pace modes (e.g., Connolly & Janelle, 2003; Couture et al., 1999) typically demonstrating greater performance improvements for individuals employing associative strategies. In externally-controlled pace tasks, however, associative thoughts tend to result in increased perceptions of effort and fatigue (e.g., Johnson & Siegel, 1992; Stanley et al., 2007). Future researchers may wish to directly investigate how pace control alters attentional focus, perceived exertion and exercise performance. The possibly negative impact of external control over pacing may have broader relevance for athletes, coaches and sport scientists alike.

Thirdly, the use of time-based exercise protocols may further impinge on cognitions experienced during endurance activity. Recent evidence has suggested time-based exercise
intervals may be perceived to last longer than equivalent distance-based tasks (Chinnasamy et al., 2013; Lambourne, 2012). As a result, time-based protocols may adversely affect attentional focus, and impact on temporally linked activities such as pacing or strategy. However, there is insufficient data at present to further infer a relationship between attentional focus, exercise performance, and how the exercise endpoint is defined.

Future researchers may wish to analyse the impact on attentional focus of factors known to affect perceived exertion and endurance performance. Recent studies have highlighted the negative impact of mental fatigue caused by persisting on demanding cognitive activities (e.g., Dorris, Power, & Kenefick, 2012; Hagger, Wood, Stiff, & Chatzisarantis, 2010; Marcora, Staiano, & Manning, 2009). Furthermore, many recent studies have indicated that that perceived exertion may change in expectation of exercise duration remaining, and serves an anticipatory role in pace regulation (e.g., Baden et al., 2004; Eston, 2012; Tucker, 2009). The subsequent impact of each of these factors on both attentional focus, and cognitive strategies use deserves attention. Whether specific cognitive strategies negate the impact of these factors on endurance performance remains to be seen.

The final concern is the need for an accepted conceptual framework to guide future research activity. Previous researchers have advocated a social-cognitive perspective (e.g., Tenenbaum, 2001), Leventhal and Everhart’s (1979) parallel processing model of pain (Brewer & Buman, 2006), and a mindfulness approach (Salmon et al., 2010). We further propose a metacognitive framework within which investigators may wish to ground their work. It may be that both the mindfulness and metacognitive perspectives broaden our understanding of how experienced athletes develop schemata within the parallel processing model of pain (e.g., Brewer & Buman, 2006; Leventhal & Everhart, 1979), and learn to cope with the pain of exertion, for example. However, given the scant research applying both
mindfulness and metacognitive frameworks to the study of endurance activity, there is a need
for future researchers to first consider the explanatory value of these approaches, and
secondly to utilise the explanation to critically evaluate the workings and effectiveness of the
frameworks.
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Table 1.

Proposed extension to the associative categories of Stevinson and Biddle’s (1998) two dimensional classification system.

<table>
<thead>
<tr>
<th>Category</th>
<th>Thought examples</th>
<th>Category</th>
<th>Thought examples</th>
<th>Key assertions of proposed extension (main studies providing supporting evidence)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal Association</td>
<td>Breathing, muscle soreness, fatigue, perspiration, thirst, blisters, etc.</td>
<td>Internal Sensory Monitoring</td>
<td>Breathing, muscle soreness, fatigue, perspiration, thirst, blisters, etc.</td>
<td>Pace unaltered or decreased, increased effort perceptions. (e.g., Harte &amp; Eistert, 1995; Johnson &amp; Siegel, 1992; Pennabaker &amp; Lighter, 1980; Stanley et al., 2007). Reduced movement economy (Schücker et al., 2009; Schücker et al., 2013).</td>
</tr>
<tr>
<td>(Inward Monitoring)</td>
<td></td>
<td>Active Self-Regulation</td>
<td>Technique, cadence, relaxing, pacing, strategy</td>
<td>Increased pace (e.g., Clingman &amp; Hilliard, 1990; Donohue et al., 2001; Miller &amp; Donohue, 2003; Rushall et al., 1988; Sainsting et al., 1988; Spink &amp; Longhurst, 1986) without necessarily increasing effort perceptions (e.g., Connoly &amp; Janvel, 2005; Couture et al., 1999; Rushall &amp; Shewchuk, 1989). More accurate pacing (Takai, 1998). Improved economy (Martin et al., 1995; Smith et al., 1995) and ventilatory efficiency (Hatfield et al., 1992).</td>
</tr>
<tr>
<td>External Association</td>
<td>Strategy, split times, route, mile markers, conditions, water stations</td>
<td>Outward Monitoring</td>
<td>Other competitors, split times, route, mile markers, conditions, water stations</td>
<td>May alter self-regulatory thoughts such as strategy (e.g., Baker et al., 2005; Nietfeld, 2003), &amp; pacing (e.g., Chinnasamy et al., 2013). May increase “associative” thoughts (e.g., Baden et al., 2004).</td>
</tr>
</tbody>
</table>
Table 2.

Proposed adjustment to the dissociative categories of Stevinson and Biddle’s (1998) two dimensional classification system.

<table>
<thead>
<tr>
<th>Stevinson &amp; Biddle (1998)</th>
<th>Proposed adjustment to dissociative/distraction categories</th>
<th>Key assertions of proposed categories (main studies providing supporting evidence)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Category</strong></td>
<td><strong>Thought examples</strong></td>
<td></td>
</tr>
<tr>
<td>Internal Dissociation</td>
<td>Irrelevant daydreams, imagining music, maths puzzles, philosophy, religion</td>
<td>Non-optimal pacing (e.g., Clingman &amp; Hilliard, 1990; Connolly &amp; Janelle, 2003; Couture et al., 1999; Padgett &amp; Hill, 1989; Saintsing et al., 1988; Scott et al., 1999).</td>
</tr>
<tr>
<td>(Inward Distraction)</td>
<td></td>
<td>Effort perceptions reduced (e.g., Fillingim &amp; Fine, 1986; Johnson &amp; Siegel, 1987; Husfield et al., 1992; Padgett &amp; Hill, 1989; Stanley et al., 2007), relatively unchanged (e.g., Fillingim et al., 1989; Franks &amp; Myers, 1984; Johnson &amp; Siegel, 1992; Russell &amp; Weeks, 1994; Siegel et al., 1981; Siegel et al., 1984), or increased (e.g., Delignières &amp; Bristwai, 1994).</td>
</tr>
<tr>
<td>External Dissociation</td>
<td>Unimportant scenery, spectators, other runners, environment</td>
<td>Unimportant scenery, attractive environment, spectators, other non-competitive runners, reflective thoughts (e.g., philosophy, religion), irrelevant daydreams, imagining music</td>
</tr>
<tr>
<td>(Outward Distraction)</td>
<td></td>
<td>Improved exercise adherence compared with associative means (e.g., Martin et al., 1984; Welsh, Labbé, &amp; Daniel, 1991), greater enjoyment &amp; less boredom (e.g., Pembeaker &amp; Lightner, 1980), reduced effort perceptions (e.g., Harte &amp; Efert, 1995), reduced arousal, frustration &amp; increased meditation (e.g., Asmull et al., 2013). Greater tranquility and positive mood change (e.g., Blanchard et al., 2004; Butryn &amp; Furst, 2003; Callen, 1983; Goode &amp; Roth, 1993; Harte &amp; Efert, 1995; LaCaille et al., 2004; Masters, 1992).</td>
</tr>
</tbody>
</table>

URL: http://mc.manuscriptcentral.com/rirs
Figure 1.

Key research questions and possible conceptual frameworks to guide future research on attentional focus in endurance activity.
## Supplementary Table S1. Main outcomes and possible limitations of studies imposing attentional focus strategies: muscular endurance tasks

<table>
<thead>
<tr>
<th>Study</th>
<th>Subjects</th>
<th>Task/procedure</th>
<th>Attentional focus strategy</th>
<th>Main outcomes</th>
<th>Possible limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weinberg et al. (1984) Study 2</td>
<td>Participants from PE required activity class (n = 230; 115M, 115F)</td>
<td>Leg-lift endurance</td>
<td>A (monitor tension/feelings in leg), D (imagine something pleasant), positive self-talk (Encourage self), &amp; control (no strategy) groups</td>
<td>Better performance in D (155 sec) &amp; positive self-talk (151 sec) groups than A (123 sec) or control (127 sec). No differences on HR</td>
<td>Only Int A assessed</td>
</tr>
<tr>
<td>Gill &amp; Strom (1985)</td>
<td>Female members of intercollegiate teams (n = 34)</td>
<td>Leg-lift repetitions</td>
<td>Int (feelings in legs) v Ext (collage) attentional focus</td>
<td>More reps in Ext (20.2) than Int (17.5). Better improvement going from Int to Ext, than Ext to Int</td>
<td>No control condition. Terms: Int equated to A; Ext equated to D</td>
</tr>
<tr>
<td>Weinberg (1985)</td>
<td>Volunteer uni students (n = 120; 60M, 60F)</td>
<td>Leg extension endurance</td>
<td>High/Low self-efficacy conditions with D (something pleasant but unrelated), &amp; positive self-talk</td>
<td>Subjects in high-efficacy condition (161 sec) performed better than low-efficacy (133 sec). No effect for D or positive self-talk</td>
<td>No control condition. Only Int D assessed</td>
</tr>
<tr>
<td>Rejeski &amp; Kenny (1987)</td>
<td>Female volunteers from university PE courses (n = 60)</td>
<td>Isometric hand-grip contraction @ 40% max</td>
<td>Simple Cognitive task (SCT), Complex Cognitive task (CCT), control group (CG)</td>
<td>SCT (209.15 sec) &amp; CCT (217.15 sec) better fatigue tolerance than CG (159.4 sec). Preferred strategy important. On 2nd trial, preferred SCT did better on simple (232.04 sec) than complex (188.34 sec) condition.</td>
<td>No A condition. Only Int D assessed</td>
</tr>
<tr>
<td>Spink (1988)</td>
<td>High school PE students (n = 36; 20M, 16F)</td>
<td>Leg-hold task</td>
<td>D (own form of Int distraction) D with analgesic suggestion, &amp; control groups</td>
<td>Sig better perf for D with analgesic suggestion (198.3 sec) over D (149.6 sec) &amp; control (147.8 sec).</td>
<td>No A condition. Only Int D assessed</td>
</tr>
<tr>
<td>Lohse &amp; Sherwood (2011)</td>
<td>Healthy, physically active university students (n = 40)</td>
<td>Wall-sit or ‘air chair’ task</td>
<td>Int focus (focus on thigh position), Ext A (draw imaginary lines knee to hip, parallel to floor), Ext D</td>
<td>Ext A (91.35 sec) &amp; Ext D (93.81 sec) sig longer time to failure than Int focus (84.98 &amp; 86.54 sec). Ext</td>
<td>No control condition. Use of terminology from motor skill</td>
</tr>
<tr>
<td>Neumann &amp; Brown (2013)</td>
<td>Female university students (<em>n</em> = 23)</td>
<td>8 sets of 12 sit-ups on sit-up bench.</td>
<td>Ex A (focus on smooth reps), Int A (focus on abdominal muscles contracting), Ex D (watch netball video), Int D (mental arithmetic)</td>
<td>EMG activity lower for Ex A than Int A, &amp; lower for combined D over combined A. Lower HR but greater range of movement in Ex A than Int A &amp; both D. Int D least satisfying condition.</td>
<td>No control condition. Use of video in all conditions required ext focus. Use of terminology from motor skill learning.</td>
</tr>
</tbody>
</table>

*Key:* A = Association; D = Dissociation; Int = Internal; Ext = External; M = Male; F = Female; RPE = Rating of Perceived Exertion; SCT = Simple Cognitive Task; CCT = Complex Cognitive Task; EMG = Electromyography.

A best on a 2nd fatiguing trial. Ext focus on 1st trial lower RPE$_{\text{initial}}$ than Int focus. On 2nd trial, RPE$_{\text{initial}}$ and RPE$_{\text{final}}$ both lower for Ext focus subjects.
### Supplementary Table S2. Main outcomes and possible limitations of studies imposing attentional focus strategies: aerobic endurance tasks

<table>
<thead>
<tr>
<th>Study</th>
<th>Subjects</th>
<th>Task/procedure</th>
<th>Attentional focus strategy</th>
<th>Main outcomes</th>
<th>Possible limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Self-controlled pace studies</strong></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Okwumabua et al. (1983)</td>
<td>Undergraduate students from jogging classes (n = 31; 11M, 20F)</td>
<td>5 X 1½ mile runs on an outdoor track</td>
<td>A (monitor body signals), D (focus on non-running object, repeat rhythmic phrase), Control (relaxation)</td>
<td>D pretest sig slower than A &amp; control. Greater A thoughts over trials for all groups (pretest to midtest). No sig group or interaction effect midtest to posttest. Regrouping to relative strategy use reported showed D (12.6 min) improved posttest perf more than A (13.6 min)</td>
<td>Subjects did not adopt recommended strategy (tendency to associate). Relaxation may not be effective control. Rhythmic phrase for D may have stimulated cadence</td>
</tr>
<tr>
<td>Martin et al. (1984) Study 5</td>
<td>Healthy sedentary adults (n = 16; 5M, 11F)</td>
<td>3 sessions p.w. x 12 wks @ 60-80% age predicted HR max for 15-45 mins</td>
<td>A group (attend to internal sensations while exercising). D group (attend to environment &amp; distracting stimuli)</td>
<td>D better attendance (76.6%) than A (58.7%). D better out-of-class adherence (57.2%) than A (46.9%). Adherence correlated with fitness improvements. D greater adherence at 3, &amp; 6mths</td>
<td>Only sedentary adults included in study. No control group</td>
</tr>
<tr>
<td>Weinberg et al. (1984) Study 1</td>
<td>Males from conditioning class who ran regularly (n = 60)</td>
<td>Individually run as far as possible on track in 30mins</td>
<td>A (monitor sensations/level of exertion), D (imagine something pleasant), positive self-talk (encourage self), &amp; control (no strategy) groups</td>
<td>No difference between groups on distance covered, lap times, HR, symptoms, or fatigue ratings.</td>
<td>Subjects given time feedback. Pre-test instructions on pacing given to all.</td>
</tr>
<tr>
<td>Fillingim &amp; Fine (1986)</td>
<td>College students ‘active joggers’ (n = 15; 8M, 7F)</td>
<td>1 mile jog on indoor track</td>
<td>Ext (listen for words on tape), Int (Focus on breathing) Control condition</td>
<td>Symptoms of effort reduced for Ext focus. More positive mood in Ext. No sig difference in jogging times across conditions</td>
<td>Terms: Int equated to A; Ext equated to D.</td>
</tr>
<tr>
<td>Spink &amp; State &amp; National</td>
<td>Swim 2 x 400m</td>
<td>15 mins of either A (monitor)</td>
<td>A group improved 400m (mean</td>
<td>No control condition.</td>
<td></td>
</tr>
<tr>
<td>Study</td>
<td>Participants</td>
<td>Intervention Details</td>
<td>Findings</td>
<td></td>
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<tr>
<td>Longhurst (1986)</td>
<td>Level youth (mean age 14.6 yrs) swimmers (n = 23; 14M, 9F)</td>
<td>IM time trials discomfort &amp; use as a signal to relax or D (distract by focusing on self-selected, non-swim related topic) training before the 2nd of two time trials</td>
<td>of 11.8 sec quicker) time sig more than D group (mean of 5 sec slower). 78% A swam lifetime bests, compared with 21% D in 2nd time trial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rushall et al. (1988)</td>
<td>Members of potential Olympic ski team (n = 10, 4M, 6F) &amp; Jnr Nat team (n = 8; 4M, 4F)</td>
<td>Time taken to ski a test track (typical duration 70 to 130 seconds)</td>
<td>Think task-relevant statements, mood words, positive self-talk &amp; ‘normal’ skiing control. Avg improvements of 3.85% task-relevant statements, 3.60% mood words, 3.20% positive self-talk. Instructions enhanced performance beyond that attributable to increased effort. Exercise task short in duration. Improvements may be influenced by pre-trial expectancies.</td>
<td></td>
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</tr>
<tr>
<td>Saintsing et al. (1988)</td>
<td>Undergraduate students from a phys conditioning class (n = 50; 31M, 19F)</td>
<td>Times to run 1,500m on a 400m outdoor asphalt-base track pre- &amp; post intervention</td>
<td>4 groups: A (technique of running), D (non-task-specific thoughts &amp; say “down” on every stride), Psyching-up (emotional charging), Control (2-min lecture) Run time for A (58.3sec) improved sig more than that for D (39.5sec), Psyching-up (37.9sec) &amp; control (26.8sec). Improvement positively related to strategy for both A &amp; D groups D strategy (“down”) could be interpreted as Int A No objective measures of intensity/effort</td>
<td></td>
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</tr>
<tr>
<td>Padgett &amp; Hill (1989) Study 2</td>
<td>Male University Track Team members (n = 20)</td>
<td>1 mile run on outdoor track at ‘normal’ pace</td>
<td>D (self selected distraction), Ext focus (attend environment), No imagery control Ext focus (5:50) faster than D (5:56) &amp; sig faster than control (6:00). Estimated greater effort in Ext &amp; D conditions Ext focus condition may allow for Ext A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rushall &amp; Shewchuk (1989)</td>
<td>Nat ranked members of swimming club (n = 6; 4M, 2F)</td>
<td>2 X 400m swims (S1), &amp; 8 X 100m swims (S2)</td>
<td>Task-relevant focus (technique) Positive Thoughts, Mood words, Control (‘normal’ thinking) All thought instructions produced sig improvements. Task-relevant focus (3.09% &amp; 2.5%), positive thoughts (1.39% &amp; 2.13%), mood words (3.09% &amp; 2.3%). No diff in effort perception between conditions or control Small sample size No qualitative data on how participants utilised intervention methods</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clingman &amp; Hilliard (1990)</td>
<td>Race walkers (n = 16; 8M, 8F).</td>
<td>Race walk 4x½ mile segments</td>
<td>Int (cadence), Int (stride length), ext (anything unrelated to race) Faster performance using focus on cadence (321.86sec) than ext No control condition</td>
<td></td>
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</tr>
<tr>
<td>Source</td>
<td>Description</td>
<td>Variables/Conditions</td>
<td>Findings</td>
<td>Notes</td>
<td></td>
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<tr>
<td>-------------------------------</td>
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</tr>
<tr>
<td>Couture et al. (1999)</td>
<td>PE students, able to swim (n = 69; 36M, 33F)</td>
<td>2 X 500m freestyle swims; 2nd swim using A/D strategies</td>
<td>A (think “air” on inhale), Int D (imagine something pleasant), Ext D (count shapes)</td>
<td>No control condition</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>A swam 2nd 500m sig faster (by 54.54 sec). No sig improvement for control (7.5 sec), Int D (1.1sec), or Ext D (0.2 sec slower). No sig diff on RPE</td>
<td></td>
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</tr>
<tr>
<td>Scott et al. (1999)</td>
<td>Novice rowers (n = 9; 4M, 5F)</td>
<td>40 min ergometer row. Multiple baseline across individuals design</td>
<td>A (listen to coxswain tape), D (music), D (video)</td>
<td>All rowed further than baseline. A (+3.77%) greater gains than D video (+1.27%), &amp; D music (+0.77%). Use of tape/video in all conditions required focus on external cues. Proportion of A Int or Ext not fully clear.</td>
<td></td>
</tr>
<tr>
<td>Donohue et al. (2001)</td>
<td>Female members of NCAA Div. 1 cross-country team (n = 6)</td>
<td>3 X 1000m runs. 1 x 1000m prior to intervention as baseline</td>
<td>Administered 5 min pre run: 1) script of motivation statements, 2) script of actions consistent with optimum performance, or 3) thoughts/feelings prior to run.</td>
<td>Actions focus greatest improvement (19 sec) over baseline, followed by motivation (17 sec) &amp; thoughts/feelings (12 sec)</td>
<td></td>
</tr>
<tr>
<td>Connolly &amp; Janelle (2003) Study 1</td>
<td>Female varsity rowers (n = 9)</td>
<td>20 min row @ aerobic steady-state or 75% pressure</td>
<td>A (breathing, body &amp; technique), D (focus on collages)</td>
<td>A (4369.8m) rowed further than D (4286.5m). No sig diff on RPE (12.5 v 12.2) or HR (164.5bpm v 158.2bpm)</td>
<td></td>
</tr>
<tr>
<td>Connolly &amp; Janelle (2003) Study 2</td>
<td>Varsity collegiate rowers (n = 22; 10M, 12F)</td>
<td>2000m ergometer row @ HR 160-180</td>
<td>Int A (breathing, technique &amp; body), Ext A (race &amp; strategise), Int D (solve maths problems), Ext D (watch video)</td>
<td>Int A &amp; Ext A rowed faster than baseline. Int A &amp; Ext A rowed faster than Int D. HR higher for Int A &amp; Ext A than baseline, &amp; Ext A v Int D. RPE higher for Int A &amp; Ext A than baseline. No sig diff between conditions for RPE</td>
<td></td>
</tr>
<tr>
<td>Miller &amp; Donohue</td>
<td>High school middle distance</td>
<td>2 x 1.6km runs on 400m track 1</td>
<td>3 groups receiving intervention 3 mins prior to 2nd run; (a) self-</td>
<td>Sig improvements for motivational/running technique (8 All participants received list of</td>
<td></td>
</tr>
<tr>
<td>(2003)</td>
<td>runners ((n = 90; 45M, 45F))</td>
<td>week apart</td>
<td>selected music, (b) blank CD (control), &amp; (c) personalised statements of running technique &amp; motivational statements</td>
<td>Control group perceived lower intervention improvement &amp; satisfaction than other groups</td>
<td>statements post baseline run. No measure of how interventions worked</td>
</tr>
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</tr>
<tr>
<td>Baghurst et al. (2004)</td>
<td>Physically active Uni Sport Sci. students ((n = 60; 47M, 13F))</td>
<td>15 minute maximal distance possible row</td>
<td>D (answer multiplication questions), A (observe digital display)</td>
<td>‘Externalisers’ performed better on D than A ((3618m v 3343m)), ‘Internalisers’ performed better on A than D ((3471m v 3316m)). Reported difficulty adhering to non-preferred strategy</td>
<td>No Ext D or Int A conditions</td>
</tr>
<tr>
<td>LaCaille et al. (2004)</td>
<td>Individuals ((n = 60, 63%F)) who ran 15 miles p.w. on average</td>
<td>Self-controlled pace 5k runs: treadmill, indoor track, &amp; outdoor road route</td>
<td>A (monitor heart rate display &amp; monitor pace), D (listen to music).</td>
<td>A faster (by 1:47 mins on average). Treadmill slower than indoor track or outdoor route but higher RPE. D greater tranquillity post-exercise. Highest positive effect, satisfaction, &amp; least exhaustion on outdoor route. No diff in RPE between strategies.</td>
<td>No control condition</td>
</tr>
<tr>
<td>Goudas et al. (2007)</td>
<td>Female PE students ((n = 75))</td>
<td>2 x Submax endurance test on cycle erg, up to HR of 170bpm</td>
<td>Gp 1 (goal to lower HR, provided concurrent HR feedback), Gp 2 (goal to lower HR, provided concurrent HR &amp; time feedback), Gp 3 (goal for increasing time on task, provided concurrent time feedback), Gp 4 (“do your best”)</td>
<td>Groups provided HR feedback (likened to A) &amp; set goals to reduce HR increased perf. Time feedback may have increased anxiety. Participants reported using relaxation, rhythm on the pedal, &amp; breathing to lower HR</td>
<td>No additional measures of movement economy. Strategies used by participants need clarification</td>
</tr>
</tbody>
</table>

### Externally-controlled pace studies

<p>| Pennbaker &amp; Lightner (1980) Study 1 | Male psych students ((n = 56)) | Treadmill walking @ 3.4mph &amp; 12° for 10 min | Int (listen to own breathing), Ext (listen to recorded street sounds), Control (no sound) | Greater fatigue symptoms for Int compared with Ext &amp; Control | Terms: Int equated to A; Ext equated to D |</p>
<table>
<thead>
<tr>
<th>Study</th>
<th>Participants</th>
<th>Task</th>
<th>Conditions</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morgan et al. (1983)</td>
<td>Healthy U.S. Army males ($n = 30$)</td>
<td>80% VO$_2$ max walk on treadmill</td>
<td>D (repeat word “down” rhythmically on each leg movement), &amp; control group</td>
<td>D group exercised 7 mins (32%) longer than control</td>
</tr>
<tr>
<td>Siegel et al. (1981)</td>
<td>Untrained F undergrad students ($n = 15$)</td>
<td>2 min cycle erg at 60rpm at workloads of 300, 600 or 900 kpm/min</td>
<td>D by performing mathematical calculations at either 3, 5 or 7 second intervals. No calculation control</td>
<td>No effect on perceived effort for attentional load or for interaction of attentional &amp; physical loads.</td>
</tr>
<tr>
<td>Franks &amp; Myers (1984) Study 1</td>
<td>Volunteer college students ($n = 16; 8M, 8F$)</td>
<td>2 graded treadmill tests. Start 4.8km/h &amp; 5%. Increase each 2 mins to max</td>
<td>No talking, talking (personal activity conversation) conditions performed in randomised order.</td>
<td>Lower HR during light work when talking &amp; a tendency to stop sooner when talking</td>
</tr>
<tr>
<td>Franks &amp; Myers (1984) Study 2</td>
<td>M &amp; F students ($n = 20$) in Independent groups ($n = 10$)</td>
<td>Incremental exercise test to max. 1st 2 stages walking, following stages running</td>
<td>1 group asked questions during walking stages, none through running stages. 2nd group asked questions only on running stages</td>
<td>No differences in HR at any stage or on time to exhaustion. Work perceived as less severe only with talking (2nd walking stage) &amp; not talking (1st running stage)</td>
</tr>
<tr>
<td>Siegel et al. (1984)</td>
<td>‘Volunteers’ ($n = 44; 36F, 8M$)</td>
<td>2 X Erg cycle at 50% or 75% VO$_2$ max</td>
<td>‘Information’ (calculations), No-information control group</td>
<td>Control group overestimated 1st trial workload on 2nd trial, information group performed same amount on both trials</td>
</tr>
<tr>
<td>Johnson &amp; Siegel (1987)</td>
<td>Untrained F subjects ($n = 26$)</td>
<td>Cycle erg for 5 min @ at either 60% or 90% predicted VO$_2$max</td>
<td>Active (arithmetic problems) or passive (asynchronous music) attention demanding tasks &amp; unfilled control</td>
<td>Active D lower fatigue @ 90% VO$_2$max. Active D lower RPE. No difference between passive D &amp; control. No differences in HR</td>
</tr>
<tr>
<td>Wrisberg et al. (1988)</td>
<td>Physically active subjects ($n = 20; 10M, 10F$).</td>
<td>Progressive graded treadmill run to exhaustion</td>
<td>Induced self-focus (look at self in mirror &amp; hearing own breathing), induced ext focus (viewing &amp; listening to film).</td>
<td>M higher max heart rate during self-focus. M higher perceived exertion on ext focus, F higher perceived exertion on self-focus</td>
</tr>
</tbody>
</table>

Terms: self-focus equated to A; Ext focus equated to D. Perceived exertion assessed post-activity
<table>
<thead>
<tr>
<th>Study</th>
<th>Participants</th>
<th>Protocol</th>
<th>Measures</th>
<th>Findings</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fillingim et al. (1989)</td>
<td>Inactive, low fitness female psych students</td>
<td>Cycle @ 50rpm on erg @ 49W until stop. Increased to 98W to noticeable discomfort</td>
<td>High demand distraction slides, low demand distraction slides, &amp; no systematic distraction (control) groups</td>
<td>Exertion ratings increased throughout for all 3 groups. No differences found between groups on symptoms/emotions, exercise perf or tolerance</td>
<td>Lack of a no exercise control group</td>
</tr>
<tr>
<td>Padgett &amp; Hill (1989) Study 1</td>
<td>PE students</td>
<td>Fixed rate stationary cycle for 30 min</td>
<td>Ext (complete a survey), Int (no distraction)</td>
<td>Ext condition perceived less effort, &amp; time went faster</td>
<td>Terms: Int equated to A; Ext equated to D. No control condition</td>
</tr>
<tr>
<td>Hatfield et al. (1992)</td>
<td>Male intercollegiate cross-country runners</td>
<td>36 min continuous run just below Ventilatory Threshold (mean 71% VO₂max)</td>
<td>3 x 12 min attentional sets; Feedback (subjects provided with Vₑ &amp; EMG display), Distraction (coincident timing task), Control (no attentional set)</td>
<td>Feedback sig lower for Vₑ/VO₂, Vₑ, RR, Vₑ/VCO₂ &amp; PETO₂. Mean TV &amp; PETCO₂ higher during Feedback. Distraction RR lower than control. No differences on VO₂. Reduced RPE in Feedback &amp; distraction</td>
<td>Low ecological validity. Feedback attentional set may be viewed as Distraction</td>
</tr>
<tr>
<td>Johnson &amp; Siegel (1992)</td>
<td>College females</td>
<td>Stationary cycle @ 60% VO₂ max for 15 min</td>
<td>A (focus on phys symptoms), Int D (recall names), Ext D (hold conversation), Control (unfilled)</td>
<td>RPE higher for A than Int D &amp; control. No diff between Int D, Ext D &amp; control. A greater fatigue than Int D.</td>
<td>Only Int A assessed</td>
</tr>
<tr>
<td>Couture et al. (1994)</td>
<td>Male infantry soldiers</td>
<td>2 X 16km route marches in indoor gymnasium</td>
<td>Treatment groups of: Biofeedback, Meditation, Combined biofeedback &amp; meditation. No treatment control group</td>
<td>1st march: 22 chose D &amp; 18 chose A strategies. A more accurate at predicting time remaining. All treatment groups perceived 2nd march more fatiguing, though reduced for control. All groups lower HR on 2nd march</td>
<td>Group completing march together (40) may impact on imposed strategies</td>
</tr>
<tr>
<td>Delignières &amp; Brisswalter</td>
<td>Subjects (n = 8; 4M, 4F) mean</td>
<td>4 X 4 min erg cycles at 20, 40, 60</td>
<td>D (externally-paced cognitive reaction-time task performed)</td>
<td>RT task increased perceived exertion during cycling task</td>
<td>No control condition. Experience level of</td>
</tr>
<tr>
<td>Year</td>
<td>Methodology</td>
<td>Intervention</td>
<td>Results</td>
<td>Notes</td>
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<tr>
<td>Russell &amp; Weeks (1994)</td>
<td>Trained male cyclists aged 18-23 (n = 7)</td>
<td>4 cycle erg bouts; a graded test to max &amp; 3 X 60 min rides @ 75% Max HR</td>
<td>A (attend to HR monitor &amp; report every minute), D (watch videotape &amp; respond to keyword), Control</td>
<td>No sig effect of strategies on HR or RPE. 4 subjects claimed A ride easier, 3 claimed control easier. Small sample size. A strategy may have been distracting. D viewed as lacking motivation properties.</td>
<td></td>
</tr>
<tr>
<td>Harte &amp; Eifert (1995)</td>
<td>Male amateur triathletes or marathon runners (n = 10)</td>
<td>Treadmill run for 45 min @ pace determined by RPE during trial run. 12k Outdoor run</td>
<td>Int stimuli (listen to own breathing), Ext stimuli (listen to tape of outdoor noises). Control condition (quiet inactivity)</td>
<td>Pos mood change outdoor run only. Pref for outdoor run. Higher adrenaline &amp; cortisol indoor run. Int. Perceived exert higher for Int over Ext in indoor &amp; outdoor run. Terms: Int equated to A; Ext equated to D.</td>
<td></td>
</tr>
<tr>
<td>Smith et al. (1995)</td>
<td>Least economical distance runners (n = 12; 10M, 2F)</td>
<td>Counterbalanced 3 X 10 min treadmill runs @ 6.5min/mile (M) or 7.5min/mile (F)</td>
<td>Pre-run session on passive A (aware of bodily states), active A (relaxing tensed muscles) or control (information about graduate school)</td>
<td>Less economical runners used more D &amp; less relaxation in races. No diff on physiological variables (HR, (V_E), (VO_2)) or mood states for least economical runners using passive A, active A or control. Limited training on techniques. Subjects reported difficult using relaxation technique during run.</td>
<td></td>
</tr>
<tr>
<td>Hassmén &amp; Koivula (1996)</td>
<td>Female Uni psych students (n = 50)</td>
<td>16 min erg cycle starting @ 60rpm. 4 mins each @ 4 power levels</td>
<td>HR, RPE recorded. Questionnaire responses classified subjects as internal or external locus of control</td>
<td>At increased workloads, externals rated their exertion higher than internals. HR @ RPE of 15 sig lower for externals. Externally-controlled pace task may have biased outcome.</td>
<td></td>
</tr>
<tr>
<td>Koivula &amp; Hassmén (1998)</td>
<td>Female Uni psych students (n = 30)</td>
<td>16 min erg cycle &amp; 16 min treadmill run; 4 mins each @ 4 power levels</td>
<td>HR, RPE recorded. Questionnaire responses classified subjects as internal or external locus of control</td>
<td>Exts rated effort (central, local &amp; overall) higher than ints during cycle at HR 150bpm. No differences when running. Externally-controlled pace task may have biased outcome.</td>
<td></td>
</tr>
<tr>
<td>Stanley et al. (2007)</td>
<td>Female Uni. students from spinning classes (n = 13)</td>
<td>Stationary cycle @ 75% (VO_2) max for 10 min</td>
<td>Int A (bodily sensations), Ext A (reading on screen), Int D (watch video), Ext D (count people.</td>
<td>RPE increased for combined Int/Ext A over Int/Ext D. No differences between A conditions, or between D conditions. No control condition.</td>
<td></td>
</tr>
<tr>
<td>Schücker et al. (2009)</td>
<td>Trained runners ((n = 24, 18M, 6F))</td>
<td>30 min treadmill run at 75% VO(<em>2)(</em>{\text{max}}) consisting of 3 x 10 mins blocks</td>
<td>Int focus (running movement, especially movement of feet), Int focus (breathing), &amp; Ext focus (surroundings) conditions</td>
<td>Ext focus more economical than int focus on running movement &amp; breathing</td>
<td>No control condition Terms: Int equated to A; Ext equated to D. No Ext A condition</td>
</tr>
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<tr>
<td>Schücker et al. (2013)</td>
<td>Trained runners ((n = 20; 16M, 4F))</td>
<td>30 min treadmill run at 85% VO(<em>2)(</em>{\text{max}}) consisting of 3 x 10 mins blocks</td>
<td>Inf focus (breathing), Ext focus (video of simulated running competition), &amp; control (usual attentional focus) conditions</td>
<td>Int focus sig less economical ((\text{VO}_2 = 44.90 \text{ ml/min/kg})) than Ext focus ((43.02 \text{ ml/min/kg})), &amp; control ((42.30 \text{ ml/min/kg})). No sig difference between Ext &amp; control. Reduced RR &amp; greater respiratory volume for Int compared with Ext</td>
<td>Video available for control condition. Lack of a no exercise/ lower intensity exercise control for video condition. No subjective ratings of perceived effort</td>
</tr>
</tbody>
</table>

**Key:** A = Association; D = Dissociation; Int = Internal; Ext = External; M = Male; F = Female; HR = Heart rate; RPE = Rating of Perceived Exertion; EMG = Electromyography; \(V_E\) = Volume of air expired; \(VO_2\) = Volume of oxygen used; \(V_E/VO_2\) = Ventilatory equivalent for oxygen; \(V_E/VCO_2\) = Ventilatory equivalent for carbon dioxide; RR = Respiratory Rate; \(VCO_2\) = Volume of carbon dioxide produced; PETO\(_2\) = Pressure of end-tidal O\(_2\); TV = Tidal Volume; PETCO\(_2\) = Pressure of end-tidal CO\(_2\).
## Supplementary Table S3. Main outcomes and possible limitations of studies employing psychological methods to manipulate attentional focus and performance during endurance activities

<table>
<thead>
<tr>
<th>Study</th>
<th>Subjects</th>
<th>Task/procedure</th>
<th>Psychological methods/intervention</th>
<th>Main outcomes</th>
<th>Possible limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rushall et al. (1988)*</td>
<td>Members of potential Olympic ski team ($n = 10$, $4M$, $6F$), &amp; Jnr Nat team ($n = 8; 4M$, $4F$)</td>
<td>Time taken to ski a test track (typical duration 70 to 130 seconds)</td>
<td>Think task-relevant statements, mood words, positive self-talk &amp; ‘normal’ skiing control.</td>
<td>Average improvements of 3.85% task-relevant statements, 3.60% mood words, 3.20% positive self-talk. 16 subjects improved in all conditions. Instructions enhanced performance beyond that attributable to increased effort (as measured by heart rate).</td>
<td>Exercise task short in duration. Improvements may be influenced by pre-trial expectancies.</td>
</tr>
<tr>
<td>Rushall &amp; Shewchuk (1989)*</td>
<td>Nat ranked members of swimming club ($n = 6; 4M$, $2F$)</td>
<td>2 X 400m swims (S1), &amp; 8 X 100m swims (S2)</td>
<td>Task-relevant focus (technique) Positive Thoughts, Mood words, Control (‘normal’ thinking)</td>
<td>All thought instructions produced sig improvements. Task-relevant focus (3.09% &amp; 2.5%), positive thoughts (1.39% &amp; 2.13%), mood words (3.09% &amp; 2.3%). No diff in effort perception between conditions or control</td>
<td>Small sample size No qualitative data on how participants utilised intervention methods</td>
</tr>
<tr>
<td>Lee (1990) Study 1</td>
<td>Male students ($n = 52$)</td>
<td>2 x bent knee sit-ups in 30 sec (as many as possible). 5 min recovery between sets</td>
<td>30 sec psych-up relevant imagery, psych-up irrelevant imagery, or distraction control (counting) prior to set 2</td>
<td>Relevant image (13.9%) group improved sig better in set 2 than irrelevant (6.7%) or control (1.1%) groups</td>
<td>Perceptions, content or vividness of imagery not measured</td>
</tr>
<tr>
<td>Study</td>
<td>Participants</td>
<td>Intervention</td>
<td>Measures</td>
<td>Findings</td>
<td>Notes</td>
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<tr>
<td>Lee (1990) Study 2</td>
<td>Male participants ($n = 142$)</td>
<td>2 x bent knee sit-ups in 30 sec (as many as possible). 5 min recovery between sets</td>
<td>As Lee (1990) S1. Profile of Mood States (POMS) measured between intervention &amp; set 2</td>
<td>Relevant image (13.9%) group improved sig better in set 2 than irrelevant (7.7%) or control (3.7%) groups. Vigor higher, fatigue lower for irrelevant over relevant &amp; control</td>
<td>Perceptions, content or vividness of imagery not measured</td>
</tr>
<tr>
<td>Patrick &amp; Hrycaiko (1998)</td>
<td>Male triathletes ($n = 3$) &amp; elite male runner ($n = 1$)</td>
<td>11 x 1,600m track runs. Multiple baseline across individuals design</td>
<td>Relaxation, imagery, self-talk, &amp; goal setting, presented in a self-teaching workbook</td>
<td>1,600m time improved for 3 athletes post intervention (between 8.25 – 28.95sec on average). Mental skill use improved post intervention for all. Positive relationship between mental skill use &amp; running performance</td>
<td>No qualitative data on how participants utilised intervention methods. Lacks ecological validity</td>
</tr>
<tr>
<td>Thelwell &amp; Greenlees (2001)</td>
<td>Male members of a local gym ($n = 5$)</td>
<td>10 x gym triathlons (2000m erg row, 5,000m cycle, 3,000m run). Multiple baseline across individuals design</td>
<td>Relaxation, imagery, self-talk, &amp; goal setting introduced via workbook exercises &amp; follow-up over 4 days</td>
<td>Triathlon performance improved for all individuals post intervention (between 16 – 68sec on average). Mental skill use improved post intervention for all participants.</td>
<td>No qualitative data on how participants utilised intervention methods. Lacks ecological validity. Participants had no prior triathlon experience</td>
</tr>
<tr>
<td>Thelwell &amp; Greenlees (2003)</td>
<td>Male members of a university gym ($n = 4$)</td>
<td>10 x competitive gym triathlons (2000m erg row, 5,000m cycle, 3,000m run). Multiple baseline across individuals design</td>
<td>Relaxation, imagery, self-talk, &amp; goal setting introduced via workbook exercises &amp; follow-up over 4 days</td>
<td>Triathlon perf improved for all individuals post intervent (40-128sec on average). Mental skill use improved post intervention for all participants. Qualitative reports on how participants employed each mental strategy</td>
<td>Simulated competitive environment. Participants had no prior triathlon experience</td>
</tr>
<tr>
<td>Hamilton et al. (2007)</td>
<td>Active un students ($n = 9$) “familiar” with cycling</td>
<td>10 x 20min erg cycle. Single-subject multiple-baseline design.</td>
<td>Self-regulated positive, positive assisted, &amp; negative assisted self-talk strategies</td>
<td>Assisted positive self-talk greatest improvement (mean 32%), followed by self-regulated positive (23.4%) &amp; negative assisted (11%).</td>
<td>Small sample size in each group (3 individuals).</td>
</tr>
</tbody>
</table>

*Studies also included in Table S2 due to methods/strategies imposed*
### Supplementary Table S4. Main outcomes and possible limitations of studies measuring attentional focus as a dependent variable during endurance activities

<table>
<thead>
<tr>
<th>Study</th>
<th>Subjects</th>
<th>Measurement tool and exercise task</th>
<th>Main outcomes</th>
<th>Possible limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morgan &amp; Pollock (1977)</td>
<td>World class ((n = 19)), split into middle-long ((n = 11)), &amp; marathon ((n = 8)) subgroups, &amp; College middle dist. runners ((n = 8))</td>
<td>Race strategies for marathoners obtained during clinical interview</td>
<td>Elite runners (sub 2:20) use an A strategy. Pace governed by ‘reading their bodies’.</td>
<td>G, S, NR, F</td>
</tr>
<tr>
<td>Pennebaker &amp; Lightner (1980)</td>
<td>Introductory psychology students ((n = 13; 8M, 5F))</td>
<td>Self-report answering; ‘While jogging I experienced:’ after completing 10 X 1,800m cross-country, or lap course runs</td>
<td>Greater satisfaction, enjoyment, &amp; less boredom on cross-country course. Time faster on cross-country (9:17) than lap (10:08)</td>
<td>G, S, NR, R, F</td>
</tr>
<tr>
<td>Freischlag (1981)</td>
<td>Marathon runners ((n = 55; 52M, 3F)). Mean best finish time of 3:23</td>
<td>Group drawn randomly from 180 volunteers for “a series of pre-race tests”</td>
<td>Thoughts in race: personal affairs (15), finish race (13), position (12), body (7), running mechanics (6), or nothing (2). To cope with pain: some ran through it (13), or slowed pace (13). Some displaced sensations with other concerns (18), or self/situation assessed (6)</td>
<td>G, S, NR, F</td>
</tr>
<tr>
<td>Sacks et al. (1981)</td>
<td>Male Ultraendurance runners ((n = 10)).</td>
<td>Verbalise in response to periodic (every 3 hours) questioning during a 100 mile race</td>
<td>Progressive decline in mood during race. No impairment in memory, attention or concentration. No correlations with performance. More A thoughts reported, though responses were sparse. D thoughts also reported</td>
<td>G, S, NR, R, DN, F</td>
</tr>
<tr>
<td>Study</td>
<td>Description</td>
<td>Methods</td>
<td>Findings</td>
<td></td>
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<tr>
<td>Summers et al. (1982)</td>
<td>Non-elite, middle-aged first time marathoners ($n =$ 363; 345M, 18F). Mean finishing time of 4:26</td>
<td>Cognitive strategies assessed via pre- &amp; post-race (1 week) questionnaires</td>
<td>Most (69%) adopted D in training. Marathon: 6% used D, 30.7% used A. 63.3% not classified as A or D.</td>
<td></td>
</tr>
<tr>
<td>Callen (1983)</td>
<td>Runners responding to distributed questionnaire ($n =$ 424, 72% M, 28% F)</td>
<td>Questionnaires including characteristics of mental processes during running</td>
<td>More M than F, &amp; younger runners report trance-like experience while running. F &amp; younger more likely to use imagery to counteract unpleasant sensations. F, older individuals, &amp; more serious M feel more creative while running.</td>
<td></td>
</tr>
<tr>
<td>Okwumabua (1985)</td>
<td>Marathon runners ($n =$ 90; 82M, 8F). Mean finishing time of 3:42</td>
<td>Pre- &amp; post-marathon questionnaires</td>
<td>A sig related to longest training runs, faster goal times, expectation of even race pace. A/D use not related to expected pain or finishing time. Reported increasing A from 2nd quarter of race. 60/40 split in favour of A during race.</td>
<td></td>
</tr>
<tr>
<td>Salmela &amp; Ndoye (1986)</td>
<td>Healthy male PE students ($n =$ 10)</td>
<td>Pedal stationary bicycle @ 50rpm. Workload increased by 1kg/2min up to 3kg, then 0.5kg/2min to max. Respond verbally to a visual 5-choice RT task while pedalling to exhaustion.</td>
<td>Use of terms Int &amp; Ex attention. No control condition</td>
<td></td>
</tr>
<tr>
<td>Schomer (1986)</td>
<td>Inactive ($n =$ 12: 6M, 6F). Average marathoners ($n =$ 10; 6M, 4F). Highly competitive marathon runners ($n =$ 9; 6M, 3F)</td>
<td>Verbally express current thoughts continuously during training runs</td>
<td>All groups associate, A not greater for superior runners. Superior group spend more time body monitoring. Positive relationship between A &amp; RPE</td>
<td></td>
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<tr>
<td>Study</td>
<td>Participants</td>
<td>Methodology</td>
<td>Findings</td>
<td>Notes</td>
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<tr>
<td>Okwumabua et al. (1987)</td>
<td>Masters (&gt;40 years old) runners (n = 279; 213M, 66F)</td>
<td>Questionnaire including description of thoughts before, during &amp; after long run. Check list of cognitive topics during run. Estimate percent time used A/D during each quarter of 10k race &amp; entire race</td>
<td>More A before &amp; after long run. More D during long run. Increasing D during run, though increased A in last quarter.</td>
<td>G, S, NR, F</td>
</tr>
<tr>
<td>Schomer (1987)</td>
<td>Novice (n = 4), average (n = 2), &amp; superior/elite (n = 4) marathoners</td>
<td>5 week, once weekly mental strategy training sessions. Verbally express current thoughts continuously during training (1st, 3rd &amp; 5th sessions). RPE measured after each training session.</td>
<td>A linked with increased intensity/RPE. 8 used A more &amp; increased training intensity. 2 increased intensity but not A use.</td>
<td>NR, DN. Small sample sizes</td>
</tr>
<tr>
<td>Morgan et al. (1987)</td>
<td>F distance runners (n = 27; 15 elite, 12 competitive controls) from 1500m to marathon</td>
<td>Interview to explain the types of thoughts during a typical training run.</td>
<td>More likely to use D (56%) in training, &amp; A (56%) in races. Some used both A &amp; D in races (22%) &amp; training (44%). No sig diff between elite &amp; competitive controls.</td>
<td>G, S, NR, F</td>
</tr>
<tr>
<td>Morgan et al. (1988)</td>
<td>Male elite distance runners (n = 14) ranging from 1,500m to marathon distances</td>
<td>Interview to explain cognitive strategies (type of thoughts during a typical training run and a typical race) as part of a series of psychological tests</td>
<td>Training runs: 21% A, 43% D, &amp; 36% combined A/D. 4/5 runners reporting combined A/D used A for more intense training sessions. Races: 72% A, 28% combined A/D.</td>
<td>G, S, NR, F</td>
</tr>
<tr>
<td>Silva &amp; Appelbaum (1989)</td>
<td>US Olympic Marathon trialists (n = 32). Top 50 time sub 2:20</td>
<td>Completing the RSQ after marathon run</td>
<td>Top 50 placers used A more during race, used a mix of A &amp; D early in race, but used D more during miles 18-24, used more self-talk to push or psych, “marked” other racers more often early in race.</td>
<td>G, S, NR, F</td>
</tr>
</tbody>
</table>

URL: [http://mc.manuscriptcentral.com/rirs](http://mc.manuscriptcentral.com/rirs)
<table>
<thead>
<tr>
<th>Reference</th>
<th>Sample Description</th>
<th>Methodology</th>
<th>Findings</th>
<th>Terms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ungerleider et al. (1989)</td>
<td>Qualifiers for National Masters Championships ($n = 587$; 79.8% M)</td>
<td>Respondents to a mailed survey instrument</td>
<td>70% used mental practice. 76% reported monitoring body signals &amp; pain zones in competition. 35.3% used physical relaxation methods</td>
<td>G, S, NR, F</td>
</tr>
<tr>
<td>Wrisberg &amp; Pein (1990)</td>
<td>University students ($n = 187$). ‘Experienced’ ($n = 87$; 49M, 38F), &amp; inexperienced ($n = 100$; 66M, 34F) recreational runners</td>
<td>Complete AFQ post-exercise (training run on outdoor track) to determine D use.</td>
<td>More ‘experienced’ recreational runners more likely to use D. F used D more than M across experience levels</td>
<td>G, S, NR, F</td>
</tr>
<tr>
<td>Cioffi (1991)</td>
<td>Healthy male subjects ($n = 56$)</td>
<td>Erg cycle for 10 mins @ 60% VO$_{2\text{max}}$. Instructions to closely monitor somatic sensations, &amp; no instructions control. Half each group expected electric shock</td>
<td>Monitoring subjects reported same phys sensations as no instructions group. More negative interpretation of sensations under threat of shock, &amp; more positive under no threat</td>
<td>NR, DN</td>
</tr>
<tr>
<td>Welsh et al. (1991)</td>
<td>Sedentary women ($n = 26$)</td>
<td>Adherence to a 6 week jogging programme. 1 group received exercise related, positive cognitive self-statements ($n = 16$), 1 group did not ($n = 10$).</td>
<td>No significant difference between groups on distance run (12 min run) or exercise compliance</td>
<td>Instructor/group reinforcement may have influenced outcome</td>
</tr>
<tr>
<td>Acevedo et al. (1992)</td>
<td>Participants in ultramarathons ($n = 112$, 86M, 26F)</td>
<td>Forced-choice &amp; open-ended questions measuring Int or Ext thoughts during 100-mile races</td>
<td>Strategies reported were 50.4% Ext, &amp; 49.6% Int on forced-choice. 75% of responses categorised as Ext on open-ended questions</td>
<td>G, S, NR, F Terms: Int equated to A; Ext equated to D.</td>
</tr>
<tr>
<td>Côté et al. (1992)</td>
<td>Male PE students ($n = 17$)</td>
<td>Pedal stationary cycle @ 50rpm. Workload increased by 1kg/2min up to 3kg, then 0.5kg/2min to max. Respond verbally to a visual 5-choice RT task while pedalling to exhaustion.</td>
<td>No discernable pattern or sig findings. No evidence of attentional narrowing as intensity increased</td>
<td>Use of terms Int &amp; Ex attention. No control condition</td>
</tr>
<tr>
<td>Masters (1992)</td>
<td>Marathon participants ($n$)</td>
<td>Complete Marathon Race Diary &amp; a</td>
<td>Significant positive relationship</td>
<td>G, S, NR, F</td>
</tr>
<tr>
<td>Study Authors</td>
<td>Participants</td>
<td>Measures</td>
<td>Findings</td>
<td>Notes</td>
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<tr>
<td>Goode &amp; Roth (1993)</td>
<td>Runners averaging 7 years experience running (n = 150, 69%M, 31%F)</td>
<td>Natural focus measured using TDRS &amp; POMS after a ‘typical training run’</td>
<td>Sig. positive correlations between D &amp; lowered fatigue, tension &amp; increased vigour on POMS post-run. Positive correl A &amp; fatigue</td>
<td>G, S, NR, F Only one A subscale on TDRS</td>
</tr>
<tr>
<td>Ogles et al. (1993-1994)</td>
<td>Marathon runners (n = 131; 104M, 27F)</td>
<td>Responses to questionnaires including Thinking Styles Questionnaire and Training Run Thoughts</td>
<td>Ext focus reported more frequently in training runs (45.9% - 67.9% of time) than during races (10.1%). Internal focus reported more frequently in races (52.9%) than training runs (28.8% - 30.6%)</td>
<td>G, S, NR, F</td>
</tr>
<tr>
<td>Martin et al. (1995)</td>
<td>Locally competitive male distance runners (n = 18). Mean 10km time 34:17</td>
<td>Self-attention assessed using 9-item PSC subscale after 10 minute treadmill runs at 4.13 m.s⁻¹</td>
<td>High PSC scores (Greater A, inward attention &amp; self-regulation) associated with better running economy</td>
<td>G, S, NR, F No control condition</td>
</tr>
<tr>
<td>McDonald &amp; Kirkby (1995)</td>
<td>Adolescent cross-country (3km-8km) competitors (n = 40; 20M, 20F). Ability: International, national, state, &amp; club (each group: n = 10; 5M, 5F)</td>
<td>Cognitive strategy during hard competition or training information collected by structured interview (n = 20) or questionnaire (n = 20)</td>
<td>Use of D decreased as level of ability increased. Level of ability sig correlated with age. No gender effect</td>
<td>G, S, NR, F Sample not random</td>
</tr>
<tr>
<td>Smith et al. (1995)</td>
<td>Most (n = 12), &amp; least (n = 12) economical distance runners from sample (n = 36; 27M, 9F)</td>
<td>Attentional style measured using an adapted version of the RSQ to assess association, dissociation &amp; relaxation.</td>
<td>Least economical runners reported greater D &amp; less relaxation in races. No difference in A between groups.</td>
<td>G, S, NR, F</td>
</tr>
<tr>
<td>Brewer et al. (1996)</td>
<td>Members of NCAA Div. 1 cross-country team (n = 9; 4M, 5F), &amp; Introductory psychology students (n = 35; 23M, Complete version of AFQ to measure A, D &amp; distress, pre- &amp; post 12 minutes on stairclimbing apparatus (max steps climbed). Post-trial RPE, BS-11 pain rating, &amp; Feeling Scale also completed</td>
<td>A facilitated perf, D &amp; distress detracted from perf. Runners higher A than students, &amp; F distress higher than M pre-trial. F higher D &amp; distress than M post-trial. No sig</td>
<td>G, S, NR, F</td>
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<tr>
<td>12F</td>
<td>Kirkby (1996)</td>
<td>Case study of female ultraendurance runner</td>
<td>Answer: ‘What were you thinking about in the moments immediately before these questions?’ during Ultra-endurance run</td>
<td>Effects on RPE, pain &amp; affect.</td>
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<td>12F</td>
<td>Tammen (1996)</td>
<td>Elite middle &amp; long distance runners (n = 8; 4M, 4F)</td>
<td>Rate A/D on a 10-cm bipolar scale (Mental Readiness Form) immediately after each trial of a flat track graded exercise test</td>
<td>As pace increases, RPE increased, D decreased, &amp; focus more on A (body sensations)</td>
</tr>
<tr>
<td>12F</td>
<td>Bachman et al. (1997)</td>
<td>Varsity cross country runners (n = 33, 13M, 20F)</td>
<td>Cognitions measured using TDRS after completing easy training run, interval workout or competition</td>
<td>Greater D (daily events &amp; external surroundings) during easy training run. Greater A during competition &amp; interval workout</td>
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<tr>
<td>Only one A subscale on TDRS</td>
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<tr>
<td>12F</td>
<td>Beaudoin et al. (1998)</td>
<td>Well-trained male distance runners (n = 11). Mean best 10km time of 32:56</td>
<td>Verbal report of thoughts intermittently during 30-minute run @ 90% VO₂ max</td>
<td>Finishers reported Int rather than Ext focus. Focused more on body &amp; rhythm, &amp; feeling confident, in control, smooth, &amp; relaxed. Non-finishers more negative thoughts &amp; feelings. RPE &amp; FS responses higher for non-finishers at 19 min</td>
</tr>
<tr>
<td>12F</td>
<td>Masters &amp; Ogles (1998b) Study 1</td>
<td>Marathon runners (n = 127, 89%M)</td>
<td>Completed Marathon &amp; Training Thoughts questionnaire after training &amp; Marathon runs</td>
<td>61% training time D versus 32% D in marathon. D: slower perf, less enthusiasm to train post-marathon, &amp; less motivated by competition or personal goals</td>
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</tbody>
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<table>
<thead>
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<tr>
<td>Takai (1998)</td>
<td>Male, varsity long-distance runners (n = 60)</td>
<td>Post-race questions about strategies for recall of pace (including attention</td>
<td>More accurate pace recallers were more likely to attend to exertion, self-motion, running</td>
<td>G, S,</td>
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<td></td>
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<td>strategies)</td>
<td>tempo, &amp; imaging past running, &amp; follow other runners less.</td>
<td>NR, R,</td>
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<tr>
<td>Hollander &amp; Acevedo (2000)</td>
<td>Individuals who completed English Channel swim (n = 8; 3M, 5F)</td>
<td>In person or telephone interviews performed between 1 week - 2 years post</td>
<td>Cog strategies used included goal setting, compartmentalisation of time &amp; distance, positive</td>
<td>G, S,</td>
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<td>channel crossing (majority 2 months). Part of interview related to cognitive</td>
<td>self-talk, attentional control/relaxation (pain management) &amp; strategic D. Time-competitive</td>
<td>NR, F</td>
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<td></td>
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<td>strategies used</td>
<td>swimmers used pain mgt &amp; compartmentalisation more.</td>
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<tr>
<td>Schomer &amp; Connolly (2002)</td>
<td>Inactive (n = 12; 6M, 6F). Average marathoners (n = 10; 6M, 4F). Highly</td>
<td>Verbally express current thoughts continuously during training runs. Data</td>
<td>Greater D during first 3 quartiles. Greater A during last quartile. Greater D at lower RPE</td>
<td>G, S,</td>
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<td>divided into quartiles and analysed according to thought categories</td>
<td>(7-14). Greater A at higher RPE (15-18).</td>
<td>NR, DN,</td>
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<td>RPE recorded after training runs</td>
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<td>Antonini-Philippe et al.</td>
<td>National (n = 25; 12M, 13F), regional (n = 25; 19M, 6F), &amp; departmental</td>
<td>Taped clinical interview consisting on questions regarding thoughts subjects</td>
<td>No difference on A or D scores across ability levels or activity. Both M &amp; F preferred to</td>
<td>G, S,</td>
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<tr>
<td>(2003)</td>
<td>(n = 10; 3M, 7F) level endurance activity participants</td>
<td>had during a race. A/D thoughts based on Schomer’s (1986) classifications.</td>
<td>use A strategies. F scored higher on D than M.</td>
<td>NR, R,</td>
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<tr>
<td>Butryn &amp; Furst (2003)</td>
<td>Female distance runners (n = 39).</td>
<td>Completed TDRS &amp; POMS after 2 X 4 mile runs; one park, one urban setting</td>
<td>D thoughts associated with positive mood changes and feeling states</td>
<td>G, S,</td>
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<td>NR, F</td>
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<td>Only one A subscale on TDRS</td>
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<td>Couture et al. (2003)</td>
<td>Volunteers from a University Masters Swim Club (n = 22; 11M, 11F)</td>
<td>2 X 800m freestyle swims one week apart. Determine preferred cognitive strategy</td>
<td>78.1% preference for A, 9.6% D, or mixture (12.3%). Post-Swim, 73% preferred A. A higher</td>
<td>Type of</td>
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<td>(A/D) using SACT. Perceived fatigue measured using PFQ &amp; exertion using</td>
<td>mid-swim. No test of BIS conformation</td>
<td>A/D</td>
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<tr>
<td>Study Authors &amp; Year</td>
<td>Sample Description</td>
<td>Methodological Details</td>
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<td>Nietfeld (2003)</td>
<td>NCAA Div 1 runners (n = 45; 25M, 20F)</td>
<td>Completed a Racing the Mile Questionnaire &amp; described thoughts during a typical race one week after run</td>
<td>Greater (88%) internally-focused thoughts racing, primarily monitoring (42%) &amp; information management strategies (41%) Strategic knowledge &amp; ability to monitor pace correlated</td>
<td>G, S, NR, F</td>
</tr>
<tr>
<td>Baden et al. (2004) Study 1</td>
<td>Members of running club (n = 22; 14M, 8F)</td>
<td>Rate A/D on a 10-cm bipolar scale intermittently during short (8 mile) &amp; long (10 mile) forest runs</td>
<td>RPE higher on short run &amp; increased over distance. Greater A on short run. Positive relationship between RPE &amp; A</td>
<td>G, S, R No distinction within A or D</td>
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<tr>
<td>Baden et al. (2004) Study 2</td>
<td>Healthy sports students (n = 18; 10M, 8F).</td>
<td>Rate A/D on a 10-cm bipolar scale intermittently during short (10min) or long (20min) runs on treadmill</td>
<td>RPE higher on short run &amp; increased over time. A thoughts increased over time. A &amp; RPE sig relationship toward end of runs</td>
<td>G, S, R No distinction within A or D</td>
</tr>
<tr>
<td>Blanchard et al. (2004)</td>
<td>Physically active female recreational runners (n = 69)</td>
<td>Runners verbally reported thoughts concurrently during 25 &amp; 40 min runs @ 70% HR Reserve. 40 min no exercise control</td>
<td>Ext D related with greater increases in revitalisation &amp; decreases in physical exhaustion post-exercise</td>
<td>DN, NR</td>
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<tr>
<td>Baden et al. (2005)</td>
<td>Healthy club runners (n = 16; 8M, 8F)</td>
<td>Rate on a 100 (A) – 0 (D) scale intermittently during expected 20 min run &amp; unexpected 20 min run (unexpectedly doubled after 10 mins)</td>
<td>RPE &amp; A increased with duration, affect decreased. RPE increased &amp; affect decreased (mins 10-11) when told run time would be increased.</td>
<td>G, S, R No distinction within A or D</td>
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<tr>
<td>Baker et al. (2005)</td>
<td>Ultraendurance athletes (n = 21): Experts (n = 8), Mid-pack (n = 7), back-pack (n = 6)</td>
<td>Recall of cognitions with aid of a video montage</td>
<td>Experts reported more performance-relevant &amp; proactive thoughts. Thoughts influenced by specific situations. Reported greater A when passing/being passed</td>
<td>S, F</td>
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<tr>
<td>Study</td>
<td>Participants</td>
<td>Task Description</td>
<td>Findings</td>
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<tr>
<td>Hutchinson &amp; Tenenbaum (2007) Study 1</td>
<td>University students ($n = 35; 21M, 14F$)</td>
<td>Verbally express current thoughts continuously while squeeze Handgrip dynamometer @ 25% max as long as possible</td>
<td>Greater D at beginning (71%), Greater A (94%) during final stages of task.</td>
<td>DN, NR</td>
</tr>
<tr>
<td>Hutchinson &amp; Tenenbaum (2007) Study 2</td>
<td>Moderately active university students ($n = 13; 7M, 6F$)</td>
<td>Verbally express current thoughts continuously during cycles for 5 min @ 50%, 5 min @ 70%, &amp; to fatigue at 90% VO$_2$ max</td>
<td>D greater (78% D thoughts) at low intensity Greater A at moderate (61%) &amp; high (93%) intensities</td>
<td>DN, NR</td>
</tr>
<tr>
<td>Kress &amp; Statler (2007)</td>
<td>Male former Olympic cyclists ($n = 9$)</td>
<td>Interviews to describe perceptions of exertional pain when racing or training and how cyclists coped with it.</td>
<td>Higher (&amp; lower order themes) included; pain (description, perception, &amp; time to termination), preparation, mental skills (focus, awareness, goals, imagery, positive self-talk), mind/body link, optimism (confidence, positive results of pain, positive perspective, pain acceptance), control.</td>
<td>G, S, NR, F</td>
</tr>
<tr>
<td>Welch et al. (2007)</td>
<td>Inactive F University students &amp; staff ($n = 20$)</td>
<td>Erg Cycle at &gt;50rpm to max on incremental exercise test (IET). Work rate increased at rate of 15W/min. Measure: affect using Feeling Scale (FS) &amp; Felt Arousal Scale (FAS), Rate A/D on a 10-cm bipolar scale intermittently, RPE &amp; HR</td>
<td>FS decreased &amp; FAS increased throughout IET. FAS stabilised just above VT. Improvements in FS 10mins, &amp; 20mins post-ex. FAS returned to baseline 10min post-ex. Attn focus progressively more A as intensity increased.</td>
<td>G, S, R, No distinction within A or D</td>
</tr>
<tr>
<td>Tenenbaum &amp; Connolly (2008)</td>
<td>Experienced ($n = 30; 15M, 15F$) &amp; novice ($n = 30, 15M, 15F$) rowers</td>
<td>Rate A/D on a scale (0-10) intermittently (every 60 sec) during task, &amp; write down thoughts post-exercise after 10 min rows at 30%, 50% &amp; 75% max</td>
<td>Attention shifted from D (low intensity) to A (high intensity) as intensity increased. No main gender or experience differences, though novice women greater A.</td>
<td>G, S, NR, R, F</td>
</tr>
<tr>
<td>Connolly &amp;</td>
<td>Experienced ($n = 30$)</td>
<td>Rate A/D on a scale (0-10) intermittently</td>
<td>Attention shifted from D (low intensity) to A (high intensity) as intensity increased.</td>
<td>G, S, NR, R, F</td>
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<tr>
<td>Study</td>
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<td>Findings</td>
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<tr>
<td>Tenenbaum (2010)</td>
<td>15M, 15F &amp; novice (n = 30, 15M, 15F) rowers</td>
<td>(every 60 sec) during task, &amp; write down thoughts post-exercise after 10 min rows at 30%, 50% &amp; 75% max. RPE also recorded. Flow State Scale-2 used to measure flow experiences</td>
<td>intensity) to A (high intensity) as workload increased. Flow experiences: greater challenge–skill balance (at 50%, 75% &amp; max), greater merging of action &amp; awareness (at 30% &amp; at 50%), clearer goals (at 30% &amp; 50% than max), increased concentration (from 30% to 50% to 75%), greater sense of control (at 30% &amp; 50% than 75%), decreased loss of self-consciousness with increased workload. Unambiguous feedback, time transformation &amp; autotelic experience relatively unchanged. Higher global flow states for F at 75% &amp; max. Elements of task design (e.g. requirements for max output) may have influenced responses &amp; flow state.</td>
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<tr>
<td>Thatcher et al. (2010)</td>
<td>Healthy volunteers either telic dominant (n = 10; 5M, 5F), paratelic dominant (n = 10; 5M, 5F), or non-dominant (n = 10; 9M, 1F)</td>
<td>As Baden et al. (2004), rate A/D using a visual analogue scale during a 30 min treadmill run at the ‘gas exchange threshold’. RPE also determined</td>
<td>No main effects for dominance. RPE &amp; HR increased with exercise duration. Sig higher in telic than paratelic state at 25 &amp; 30 mins. Attentional focus sig more A in telic than paratelic state at 20, 25, &amp; 30 mins. HR sig higher in telic than paratelic state at 23 mins. No sig association between dominance &amp; state.</td>
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<td>Balagué et al. (2012)</td>
<td>PE students (n = 11; 6M, 5F)</td>
<td>Indicate attentional focus with thumb down/up signal &amp; post-test interview on content @ 80% Max HR to exhaustion</td>
<td>A more frequent as fatigue sensations increased. Attention shift from flexible to A with intensified workload level.</td>
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<tr>
<td>Authors</td>
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<td>Findings</td>
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<tr>
<td>Quintana et al. (2012)</td>
<td>Competitive male long distance runners ($n = 17$)</td>
<td>Indicate cognitions in real-time using hand-held controller during 30 min treadmill run @ 80% HR max (20 min) &amp; 90% HR max (10 min)</td>
<td>An average of 67.88 cognitions registered. Increased unpleasant sensations &amp; cognitions related to physical effort during 90% run. As RPE increased, sense of control decreased.</td>
<td>DN</td>
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<tr>
<td>Aspinall et al. (2013)</td>
<td>Uni students ($n = 12; 8M, 4F$)</td>
<td>Walk through 3 zones; 1 (urban shopping street), 2 (path in green space), 3 (busy commercial district). Use wireless EEG headset capable of indicating various mental states &amp; emotions</td>
<td>Reduced arousal, frustration, &amp; engagement, increased meditation moving into zone 2 from zone 1. Alertness increased from zone 2 to zone 3. Equipment did not always function correctly. No self-report of mental states.</td>
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</table>

**Key:** A = Association; D = Dissociation; Int = Internal; Ext = External; M = Male; F = Female; RT = Reaction Time; RPE = Rating of Perceived Exertion; HR = Heart Rate; RSQ = Running Style Questionnaire; AFQ = Attentional Focusing Questionnaire; TDRS = Thoughts During Running Scale; POMS = Profile of Mood States; PSC = Private Self-Consciousness; SACT = Subjective Appraisal of Cognitive Thoughts; PFQ = Perceived Fatigue Questionnaire; BIS = Behavioural Instruction Sheet; FS = Feeling Scale; FAS = Felt Arousal Scale; EEG = Electroencephalography.

**Limitations key:** G = May generalise thought content. S= May only remember salient thoughts, NR = May not report some thoughts, R = May only report most recent thoughts, DN = May experience disruption to natural thought processes, F = May forget thought content.