Perception of exertion and attention allocation as a function of visual and auditory conditions

Selen Razon*, Itay Basevitch, William Land, Brooke Thompson, Gershon Tenenbaum

Florida State University, Tallahassee, Florida 32306, USA

Keywords: Exercise, Attention, Music, Vision

Abstract

Aim: The aim of the present study was to test the role of auditory (e.g., music) and visual sensory modalities on perceived levels of exertion and attention processes across a 30% dynamometer-squeezing task. The study explored the dynamics embedded within the automated nature of the association–dissociation shift process.

Method: Sixty young adults (33 male and 27 female; M_{age} = 22.21 yrs, SD = 3.49) were recruited to perform a handgrip-squeezing task. They were randomly assigned to 4 groups of 15 participants. After establishing the maximal squeezing value they performed 30% max squeezing-task under one of four assigned condition: full vision and preferred music, full vision and no music, blindfolded and preferred music, and blindfolded and no music until volitional fatigue. Rate of perceived exertion and attention strategies were administered at 30 s intervals.

Results: A set of Repeated Measures ANOVAs indicated an additive effect of visual and auditory cues on the perception of exertion, and the dynamic pattern of attention shift. Participants who were given both forms of sensory information remained in a dissociative strategy for a significantly longer duration than participants in all other conditions.

Conclusions: Several sensory modalities are required to affect perceived exertion and attention allocation while engaging in demanding workload. External stimuli may serve as mediating agents in diverting attention away from internal and painful stimuli. This distraction may likely contribute to the pleasantness of the exercise experience, ultimately leading to increased exercise participation and reduced dropout rates.

© 2009 Published by Elsevier Ltd.

Attention strategies defined as “association” (A) and “dissociation” (D) have been studied extensively in the last 25 years (Hardy & Nelson, 1988; Hollander & Acevedo, 2000; Hutchinson, 2004; Hutchinson & Tenenbaum, 2006, 2007; Morgan & Pollock, 1977; Tenenbaum, 2001, 2005; Tenenbaum & Connolly, 2008). The majority of these studies supported the notion that associative strategies direct an individual’s focus internally, and towards somatic cues, while dissociative strategies direct one’s focus externally, and away from the somatic cues (Masters & Ogles, 1998; Scott, Scott, Bedic, & Dowd, 1999; Tenenbaum, 2005). Associative and dissociative strategies represent two distinct cognitive styles, indicating where the exerciser allocates attention in an effort to improve adjustment to the physical task (Tenenbaum, 2005).

The shift between associative and dissociative strategies was found to depend on workload intensity (Tenenbaum, 2001). Drawing from Tenenbaum’s (2001) effort-related model, attention threshold refers to a time phase where physical symptoms of exertion reach a threshold upon which attention flexibility (e.g., ease of switching back and forth between dissociative to an associative patterns) is compromised. The occurrence of attention inflexibility marks the onset of the final switch from a dissociative to an associative strategy (e.g., increased somatic awareness, and pain) (Tenenbaum et al., 2004), and is likely to lead to the cessation of the applied effort (Pandolf, 1978). Tenenbaum’s (2001) model purports that across low workload intensities, attention can be easily switched back and forth between A/D patterns. When physiological demands are amplified, however, attention-focus remains associative, and the human system loses its flexibility to alter between attention-focuses (e.g., A/D). At this stage, external stimuli lose their effectiveness in promoting dissociative strategies. The A/D shift has been consistently found to occur in enduring tasks including cycling and running (Masters & Ogles, 1998; Tenenbaum...
et al., 2004), as well as in strength-type tasks including dynamometer-squeezing tasks (Hutchinson, Sherman, Tenenbaum, & Martinovic, in press).

The concept of delaying the A/D threshold via the use of external and internal manipulation has not yet been studied to our knowledge. Attending to auditory stimuli (e.g., music tunes) is a common practice in coping with perceptions of exertion related to physical activity. By directing attention away from the exertive stimuli, music could prove beneficial in delaying the A/D threshold occurrence. An additional factor, which may affect the A/D threshold, is related to the sensory modality of vision. The aim of the present study is to test the role of auditory (e.g., music) and visual sensory modalities on perceived levels of exertion and attention processes across a 30% dynamometer-squeezing task.

Having said these, it is important to note that previous and recent work (Kahneman, Fredrickson, Schreiber, & Redelmeier, 1993; Stone, Broderick, Kaell, DelesPaul, & Porter, 2000) examining exertive/medical pain perceptions led to the development of models pertaining to pain perception conceptualization. These models pertain to exertive/medical pain perceptions as a whole, and seek to examine pain experiences in retrospect. The present study, however, postulates exertive pain experience in its momentary increments. Consequently, in the present study we attempt to provide a unique model conceptualizing the momentary increases associated with the experience of exertive sensations.

Early research has also focused on the facilitative and motivational effects of music on exercise performance (Schwartz, Fernhall, & Plowan, 1990). Music and auditory stimuli have been shown to be effective in reducing perceived levels of exertion (Yamashita, Iwai, Akimoto, Sugawara, & Kono, 2006), enhancing arousal levels (Karageorghis & Terry, 1997), facilitating motor coordination (Simpson & Karageorghis, 2006), and promoting relaxation (Copeland & Franks, 1991). Music’s motivational effects have also been linked to increases in individual perceptions of self-esteem and sense of confidence (Karageorghis & Terry, 1997).

In a more recent work, Tenenbaum et al. (2004) reported that music was beneficial across low-moderate workload intensities. Accordingly, in this study participants performed a running task in which low, moderate, and high levels of workloads were, respectively, defined as 30%, 50% and >75% VO2 max. In the current study, however, due to the difference in the nature of the task (running vs. handgrip-squeezing task) low, moderate and high levels of workloads were defined based on self-reports of perceived exertion (i.e., RPE scales). Similarly to recent work of Hutchinson & Tenenbaum, 2006, 2007), for the present study low, moderate and high levels of workload were defined as 1–3, 3–5 and >5 on RPE scale ranging from 0 to 10. No direct effect of music on performance has been noted in this study under high workload intensities and throughout extended activity durations. The latter finding further supports the notion that an associative attention strategy overtakes as the workload intensity amplifies, and attention threshold is reached. In the present study, the interplay between attending to the auditory stimuli (e.g., music), occurrence of the effort perceptions, and the dynamics of the A/D threshold are investigated under the presence and absence of distinct sensory modalities (e.g., vision and no vision) Thus, the initial contention is that attending to auditory stimuli (e.g., music) will increase tolerance to exertion via prolonged dissociation periods from the exertive symptoms.

In most studies incorporating music, selected types of melodies were played in the background (Karageorghis et al., 2009). Based on Karageorghis et al.’s recent suggestions on the use of music in sport and exercise contexts, it was presumed that individuals’ music preferences reflect their own personal choices. Thus, participants in this study were asked to select their favorite music for the handgrip-squeeze activity to be performed. The contention was that deliberate choice of the particular music type, and its volume level would help magnifying musics’ desired psychophysical effects on task-related A/D, perceived exertion, and performance endurance. Also, a primary interest of this study is the impact of visual input on exertive perceptions and A/D. In the absence of relevant knowledge on the role of visual sensory input in physical activity settings, and lack of sport-related paradigms of deprived vision, we rely on the scientific evidence accounting for cases of congenital blinds. In doing so, we expect, although non-neurological, comparable compensatory processes to occur under experimental conditions that deprive sighted individuals from vision. Accordingly, a main compensatory process in the case of congenital blinds is the concept of cross-modal plasticity, or neuroplasticity. Cross-modal plasticity is based upon the incidence of remarkable improvement of one sensory modality when other modalities undergo considerable sensory deprivation (Bavelier & Neville, 2002). As applied to visual deprivation, the concept of cross-modal plasticity pertains to sensory compensation through strengthening of sensory modalities other than vision (Cohen et al., 1999). Several works point to the occurrence of cross-modal plasticity (Roder, Rosler, & Henninghausen, 1997; UhI, Franzen, Podreka, Steiner, & Deecke, 1993), resulting in improved capacities of blind individuals in sensory modalities other than vision (Niemeyer & Starlinger, 1981).

Based upon these assertions, it is proposed that in the case of visual occlusion of sighted individuals, comparable cross modality-compensations may emerge. Specifically, our contention is that the occlusion of vision while performing an exertive task can potentially lead these individuals to gear towards internal/associative cues thus resulting in increased perception of exertion. It is important to note here that our main rationale in choosing the restricted vision condition rests in the assumption that the modality of vision being an essential component to the exercise experience, its impact could be best evaluated when it is deprived. Thus, in respect to occluded vision condition, it is hypothesized that participants will endure less in conditions where they are blindfolded (e.g., no vision) in comparison to conditions of open-vision. More specifically, the A/D shift is expected to occur earlier in time when individuals are deprived of both external and auditory stimuli. The A/D shift will be delayed, however, when individuals performing an exertive task are deprived of vision, but allowed to attend to the auditory stimuli (e.g., preferred piece of music). Moreover, individuals exposed to both auditory and visual stimuli will adhere to the exertive task for longer durations, and maintain a dissociative-attention strategy for the longest period of time.

As an overall aim, the present study explores the dynamics embedded within the automated nature of the A/D shift process. Of special interest are the fundamental mechanisms that mediate the A/D attention patterns and corresponding perceptions of exertion. An innovative focus of this work is its focus on the effects of relatively unexplored sensory modalities (i.e., audition and vision) in shaping exercisers’ attention patterns and perceived levels of exertion. Our ultimate goal is to determine whether exercise adherence can be improved through direct manipulation of any of these modalities. Strategies that help reduce perceptions of physical discomfort and improve affective responses associated with exercise behaviors may lead to more pleasantly perceived exercise regimens, thus may offer at least partial solutions to the longstanding problem of elevated dropout rates.

Method

Participants

Sixty participants (n = 33 male and n = 27 female) were recruited to perform a handgrip-squeezing task. In the absence of
similar studies, it was not possible to determine effect sizes, and thus subsequent sample sizes. Therefore, using sixty participants was deemed appropriate to elicit small to moderate effect sizes to be significantly different at \( p < .05 \) levels. The study was conducted in a recreational center at a large US South-Eastern university. The participants were randomly assigned to 4 groups of 15 participants each with approximately equal numbers of males and females in each group. Participants’ age ranged between 18 and 39 years \( (M = 22.21, SD = 3.49) \). The GHLQ was administered before performing the task to assure healthy status. All of the participants were active and exercised more than 4 days per week averaging 75 min per day \( (M = 4.34, SD = 1.35 \text{ and } M = 75.42, SD = 29.32, \text{ respectively}) \), had prior experience with physical activity/exercising, and did not suffer any physical illnesses/disability that may have limited their ability to engage in the task. Human Subjects Committee approval was obtained prior to the initiation of the data collecting process.

**Apparatus and handgrip task**

Handgrip capacity was measured using a calibrated LafayetteTM handgrip dynamometer Model 78010 (Lafayette instrument company, Lafayette, Indiana). The device contains an adjustable hand bar connected to a steel spring that, when compressed, moves a pointer. Applied force is recorded in kilograms by the pointer on the face of the device. The testing range for the dynamometer is 0–100 kg.

Participants were required to squeeze the handgrip dynamometer for as long as they could at 30% of their baseline maximal handgrip capacity (measured prior to the start of the task). They were instructed to use their dominant hand, and were required to sit while performing the task. Each participant was asked to indicate his/her dominant hand, thus self-report was used as the method of selection of the dominant hand. While performing the task, participants were not able to observe their performance during the trial.

**Task conditions**

The study consisted of four conditions, in which visual and auditory information was manipulated. The participants in the control condition performed the task in the absence of music and with full vision (i.e., eyes open). Participants in the occluded-only condition performed the task in the absence of music, but were blindfolded with the use of a standard sleeping mask. The music-only condition, required participants to perform the task under full vision, while attending to the music of their choice (i.e., rock, pop, techno, classical/instrumental and hip hop), at their comfortable volume level, using head-phones and various music devices (e.g., MP3 players and iPods). Participants in the fourth condition, both occlusion and music, performed the task blindfolded while listening to music.

**Instrumentation**

**Informed consent**

The consent form informed the participants about the nature of the study, the task they were required to perform, confidentiality, and the risks and benefits associated with the study.

**The general health and life type questionnaire (GHLQ; British Colombia Department of Health, 1975)**

The GHLQ is part of the Physical Activity Rating Questionnaire (PAR-Q). GHLQ includes eight items that are answered in a YES–NO format. The GHLQ consists of more specific items on coronary and cardiovascular conditions. Only items relevant to the study were included. Thus, a shortened version of the GHLQ was used in the study.

**Demographic information**

The form obtained basic demographic information including: name, age, gender, exercising, and physical activity data.

**Ratings of perceived exertion (RPE; Borg, 1982)**

The RPE is a 10-point category-ratio scale ranging from 0 (nothing) to 10 (extremely strong), and is used to measure perceived exertion during a task. The higher the RPE score, the higher the rating of perceived exertion. The scale has been shown to have high intra-test \( (r = .93) \) and re-test \( (r = .83–.94) \) reliabilities, in addition to being a reliable measure of physical discomfort. The scale is extensively used in most sport labs around the world because of its strong connection and correlation with many physiological and chemical measures such as Lactic Acid (LA), HR, VO\(_2\) and VE \( \text{(Borg, 1982, 1998).} \)

**Attention (Tammen, 1996)**

This is a 10-point scale ranging from 0 (external thoughts, daydreaming, environment) to 10 (internal thoughts, how body feels, breathing technique), which measures attention-focus throughout the task. The scale was designed to represent the continuum of attention strategies ranging from 0 (pure dissociation) to 10 (pure association). On the 10-point scale, a score of 5 or higher represents a shift from a dissociative focus to an associative focus of attention. Tammen (1996) found the one-question scale to be an efficient and valid measure of attention strategies during effort engagement of elite runners. Other researchers have also used a one-question scale asking runners to estimate the percent of time they spent associating or dissociating \( \text{(Baden, McLean, Noakes, & St. Clair Gibson, 2005).} \) Findings indicated that participants’ use of association and dissociation varied along a continuum, and that the one-item measure was an effective way of capturing participants’ attention-focus. Masters and Ogles (1998) reported that the use of a one-item measure is a method of capturing the participants’ attention-focus immediately following the experimental session. Though one-item measures cannot be assessed for their internal reliability, the ecological validity of the scale was found to be sound (see detailed elaboration on this issue in Tenenbaum, Kamata, & Hayashi, 2007). For example, using similar measures, Connolly and Tenenbaum (in press), Hutchinson and Tenenbaum (2007), and Tenenbaum and Connolly (2008) indicated clearly that during physical effort, attention shifted from dissociation to association as the intensity of the workload increased.

**Task-specific self-efficacy (TSSE; Bandura, 1977, 1986)**

The TSSE is an individual’s belief about one’s capacity to allocate resources required for the successful accomplishment of a task \( \text{(Bandura, 1977, 1986).} \) The TSSE scale measures participants’ beliefs in their physical capabilities to tolerate the physical exertion/discomfort associated with task performance. The scale consists of three items. For each item on the scale, participants were asked to indicate their degree of confidence on a 10-point scale ranging from 1 (very low) to 10 (very high). TSSE score is the average rating on the three items. The format and content of this scale are similar to measures previously used to examine self-efficacy in an exercise setting \( \text{(Hutchinson, 2004; McAuley, Talbot, & Martinez, 1999).} \) Self-efficacy measures are limited in estimating reliability; TSSE scales fall into this category. As such, typical measures of reliability for TSSE are irrelevant since the scale measures increasing gradations of self-efficacy. The TSSE was developed based on Bandura’s guidelines for self-efficacy scales \( \text{(Bandura, 1977, 1986), and similar} \)
formats have been successfully used in recent research (Hutchinson, Sherman, Martinovic, & Tenenbaum, 2008).

Commitment check
This scale consists of three questions related to task commitment: (a) “how committed were you to the task while performing?” (b) “how well do you think you tolerated the effort associated with the task?” and, (c) “how much effort did you invest in the task?” Participants rated each question on a scale ranging from 0 (none/not at all) to 5 (very much/very well). In the music condition, three additional questions pertaining to the type of music and effect the music had on the participants were included as follows: (a) “Please indicate the name/artist of the music piece you were attending to while performing the task,” (b) “To what degree the music motivated you in your physical effort?” (c) “To what degree the music diverted your attention to other things than the physical effort itself?”

Duration of task
Using a standard stopwatch, the amount of time participants were able to squeeze the handgrip dynamometer at 30% was recorded. Time was measured to the nearest second.

Procedure
Two investigators conducted the study. They recruited participants entering the university’s gym by asking them to participate in a short study and perform a handgrip task. Once agreed to take part in the study, a detailed explanation of the study was provided to each participant individually, including the written informed consent (approved by the IRB committee) along with the health history form, and demographic information, prior to data collection. These ensured participants have no contraindications to exercise testing.

Participants’ maximal handgrip capacity was established by recording three consecutive squeezes with a 2 min rest between each attempt. They were asked to squeeze the handlebar of the dynamometer as strong as they could in one explosive effort. This effort was repeated three times. The strongest of the three squeezes in kilogram was considered their maximal handgrip capacity. After establishing the maximal squeezing value (i.e., highest value of the three attempts), 30% of the max was calculated using a standard calculator to the nearest decimal point. The use of 30% of maximal squeeze pressure was based on results of a pilot study providing an average squeezing time of 4 min for the pilot group. Furthermore, similar rates (e.g., 20–50%) were used in previous studies that made use of a handgrip dynamometer task to examine exercise-related cognitive and affective components (Hutchinson et al., in press; Koltyn & Umeda, 2007). Each participant was randomly assigned to one of the four conditions (i.e., full vision-with and without music; occluded vision-with and without music). Prior to task performance, participants were given the TSSE form measuring their beliefs of self-efficacy related to the task specifics. Furthermore, RPE and attention scales were explained to participants before they performed the task. RPE instructions were given following Borg’s (1998) guidelines in that participants were given simple examples of intensities, and were asked to confirm their understanding. In addition participants were asked to practice squeezing the handlebar for a few seconds to insure that they understood the task, and felt comfortable with it.

Following the completion of the forms, participants were asked to engage in the squeezing task under their assigned condition. In order to control for the variability of 30% set limits, the static gage of the dynamometer was set for each participant to his/her respective 30% effort limits. Across task performance, the researcher monitored and controlled the dynamic (i.e., moving) gage of the dynamometer not to swing above or below the set limits. The test was terminated when either the participant reached volitional fatigue, or when the participant could no longer hold the contrac-

Statistical analysis
Task-specific self-efficacy and commitment to task performance were subjected to a 2 (music, no music) by 2 (vision, no vision) MANOVA procedure. Furthermore, conditions that employed music were used to assess the extent to which music motivated performance and the degree to which music diverted attention away from physical exertion using one-way MANOVA procedure with music condition as a BS factor (music + vision, music + no vision). To examine rates of perceived exertion (RPE) and attention allocation (dissociative–associative range) for the groups throughout the grip test, a 7 (time intervals) by 2 (music, no music) by 2 (vision, no vision) mixed model RM ANOVA consisting of time intervals as a within subjects factor, and music and vision conditions as between subject factors was performed. Because significant (p < .05) sphericity was obtained, Greenhouse–Geisser (GGms) procedure replaced the Wilk’s l multivariate estimate, and the df were adjusted accordingly. The effect of music and vision on grip duration was examined via a 2 (music, no music) by 2 (vision, no vision) ANOVA.

Results
Manipulation checks
To ensure group similarity across conditions, participants were assessed on levels of task-specific self-efficacy (3 items) and commitment to task performance (3 items). For self-efficacy, a 2 (music, no music) by 2 (vision, no vision) MANOVA revealed non-significant main effects for both music, Wilks l = .97, F (3, 54) = .658, p = .58, n2 = .04, and vision, Wilks l = .89, F (3, 54) = 2.14, p = .11, n2 = .11. An interaction between music and vision also failed to reach significance (p > .05). Thus, prior to participation, experimental conditions resulted in similar self-efficacy levels (Mgrand = 7.33, high self-efficacy).

Similarly, commitment to task performance was assessed. A 2 (music, no music) by 2 (vision, no vision) MANOVA on task commitment revealed non-significant main effects for both music, Wilks l = .92, F (3, 54) = 1.63, p = .19, n2 = .08, and vision, Wilks l = .91, F (3, 54) = 1.76, p = .17, n2 = .09. An interaction between music and vision also failed to reach significance. Again, no differences were revealed across groups for levels of task commitment. All groups reported “high” levels of task commitment (Mgrand = 4.33).

Furthermore, conditions that employed music were assessed on the extent to which music motivated performance and the degree...
to which music diverted attention away from physical exertion. A one-way MANOVA examining conditions with music (music + vision, music + no vision) revealed a non-significant main effect of condition, Wilks $\lambda = .88$, $F(2, 27) = 1.83$, $p = .18$, $\eta^2_p = .12$, indicating that conditions employing music were similar on the extent to which music motivated performance and diverted attention away from physical effort.

Grip performance

Examination of overall grip performance revealed that approximately 75% of all participants performed the grip task through the 7th time interval (210 s). Attrition was almost equal across groups leaving 12, 11, 11, and 11 participants in the music–vision, music–no vision, no music–vision, and no music–no vision, respectively. Furthermore, only 60% of participants maintained performance through the 8th time interval (240 s), leaving 9 participants in each of the groups. Due to high levels of attrition beyond the 8th time interval, grip performance, as measured through both the 7th and 8th time interval, was used for all subsequent analyses.

Rate of perceived exertion

To examine rates of perceived exertion (RPE) for the groups throughout the grip test, a 7 (time intervals) by 2 (music, no music) by 2 (vision, no vision) mixed model RM ANOVA consisting of time intervals as a within subjects factor, and music and vision conditions as between subject factors was performed. Because significant ($p < .05$) sphericity was obtained, Greenhouse–Geisser (GG) procedure replaced the Wilks' $\lambda$ multivariate estimate, and the df have been adjusted accordingly. Results from the mixed model RM ANOVA revealed a significant main effect for time interval, $GG ms = 326.61$, $F (2.28, 93.63) = 112.31$, $p < .001$, $\eta^2_p = .73$. As grip duration increased, RPE ratings increased, respectively. Furthermore, model fit indicated that a linear function best represented the change in RPE overall, $F (1, 41) = 185.04$, $p < .001$, $\eta^2_p = .82$. The main effects for music and vision, as well as, their interaction effects failed to reach significance ($p > .05$).

While analysis of RPE and performance revealed a significant main effect for time interval, 60% of the participants continued squeezing beyond 7 time intervals (210 s). In order to examine performance of participants who performed for longer durations, an 8 (time intervals) by 2 (music, no music) by 2 (vision, no vision) mixed model RM ANOVA was performed. Again, the mixed model RM ANOVA revealed a significant main effect for time interval, $GG ms = 237.65$, $F (2.35, 75.30) = 75.54$, $p < .001$, $\eta^2_p = .70$. Similarly, a significant linear function represented the best model fit to the data, $F (1, 32) = 124.53$, $p < .001$. In addition, the mixed model RM ANOVA indicated a significant main effect by music interaction, $GG ms = 9.44$, $F (2.35, 75.30) = 3.00$, $p = .04$, $\eta^2_p = .09$ and by time interaction, $GG ms = 9.25$, $F (2.35, 75.30) = 2.94$, $p = .05$, $\eta^2_p = .08$. Early in performance, attending to music was associated with lower ratings of perceived exertion. However, during later stages of performance, under increased physical workload, music tended to have a negative impact resulting in increased levels of RPE (see Fig. 1a). Furthermore, when vision was available, participants reported lower perceived exertion while squeezing the dynamometer than when vision was occluded (see Fig. 1b).

Attention

Similar to RPE, a 7 (time intervals) by 2 (music, no music) by 2 (vision, no vision) mixed model RM ANOVA tested attention fluctuations during the squeezing dynamometer task. Results revealed a significant main effect for time intervals, $GG ms = 198.99$, $F (1.84, 75.40) = 31.03$, $p < .001$, $\eta^2_p = .73$. As grip duration increased, participants were more likely to adopt an internal and associative focus of attention. A significant linear function represented the best model fit to the data, $F (1, 32) = 124.53$, $p < .001$, $\eta^2_p = .80$. Additionally, the mixed model RM ANOVA indicated a non-significant, but sound, time interval by music by vision interaction, $GG ms = 17.70$, $F (1.84, 75.40) = 2.760$, $p = .07$, $\eta^2_p = .063$. Visible inspection of this interaction is presented in Fig. 2. The interaction reveals that during full vision, participants who listened to music remained in a dissociated attention-pattern longer than participants deprived of music. Furthermore, this increased duration of dissociation during the vision + music condition remained evident when compared to squeezing the dynamometer under no vision + music, or without music conditions. This interaction suggests that, alone, alterations in visual information or auditory stimuli do not appear to play a significant role in altering associative strategies of attention. However, when visual information is paired with auditory stimuli, there appears to be a tendency for an additive effect on dissociative strategies of attention. Fig. 3 depicts differences in effect sizes over the duration of the grip task between the vision + music condition and all other conditions (vision + no music, no vision + music, and no vision + no music). Evident in Fig. 3 is the fact that the additive effect of vision paired with music
is most prominent at earlier and later stages of grip performance (ES's ranging from .03 to .5), while less pronounced during mid performance (ES's ranging from .02 to .07).

Similar to RPE, attention strategy was further analyzed for grip duration beyond 7 time intervals (210 s). RM ANOVA indicated a significant main effect for time interval, $GG_m = 143.32, F(2.06, 65.80) = 24.98, p < .001, \eta^2_p = .44$, but main effects for music, vision, and their interaction effects failed to reach significance ($p > .05$). Thus, as grip duration increased, participants were more likely to implement an associative strategy of attention. Again, model fit indicated that this shift was best represented by a linear change, $F(1, 32) = 36.96, p < .001, \eta^2_p = .54$.

Grip duration

The effect of music and vision on grip duration was examined via a 2 (music, no music) by 2 (vision, no vision) ANOVA. This analysis revealed a non-significant, but sound, main effect for music on grip duration, $F(1, 56) = 3.43, p = .069, \eta^2_p = .058$, but not for vision or their interaction ($p > .05$). Fig. 4 illustrates the mean difference in grip duration (time in seconds) between conditions with and without music. When listening to music, participants sustained grip performance for longer durations ($M = 304.01, SE = 19.35$) than when no music was present ($M = 252.47, SE = 20; ES = .48$).

Discussion

The main purpose of the present study was to examine the interplay between attendance to music, effort perceptions, and A/D dynamics under the presence of distinct sensory modalities (i.e., vision and no vision). The findings indicated that as exercise duration increased, individuals' perceptions of exertion increased linearly, consequently initiating a shift from a disassociative to an associative strategy of attention. These findings are in accord with Tenenbaum's (2001) effort-related model, and previous empirical research (Hutchinson et al., in press; Masters & Ogles, 1998; Tenenbaum et al., 2004), which assert that increases in physical demands result in an associative strategy of attention. Although the current findings indicate that the manipulation of sensory modality-related stimuli (i.e., music and vision) is related to decreases in RPE in the early stages of the task, such alterations alone do not appear to be related to changes in the A/D shift towards the end of task engagement. It is important to note, however, that visual and auditory information appear to have an additive effect resulting in a delay in the shift from a disassociative strategy to an associative attention strategy.
Current findings revealed that in open-vision condition, participants who listened to music sustained a dissociative-attention focus longer than those who did not attend to music. Both music and non-music groups increased associative attention-focus towards the end of the task, but the music group still remained more dissociative compared to the no music group. Thus, attendance to music allowed participants to dissociate and divert attention away from the exertive task. The external focus resulted in decreases in perceptions of exertion, as participants were attending less to physical/bodily sensations. Although attendance to music in general improved time on task (e.g., grip durations), across the end stages of the task (i.e., after approximately 150 s), attendance to music was related to increased levels of RPE. It is important to note here that boredom cannot possibly account for these effects given that each participant was exposed to a variety of self-selected auditory stimuli (i.e., music tunes) as opposed to repeatedly exposure to one identical stimulus (e.g., music tune).

Thus, listening to music appears to help at low workload levels; however, at high workload levels, music does not appear to be as effective in attention diversion. Indeed, across higher intensity, and extended durations of workloads, dissociative-attention strategies have a limited effect (Tenenbaum et al., 2004). Results extant on the use of altering sensory modalities (e.g., vision and audition) on attention strategies and RPE is non-existent. It was assumed, therefore, that visual deprivation would shift attention inward, and result in elevated levels of RPE. This assumption was derived from literature unrelated to physical effort.

Research on the cross-modal plasticity of congenital blind patients has demonstrated that the deprivation of visual stimulation is linked with increased attention to somatic sensory cues (Hyvärinen, Hyvärinen, & Linnankoski, 1981) and auditory input (Weeks et al., 2000). Accordingly, it was hypothesized that when vision was occluded, individuals would likely be geared towards internal cues and thus, indicate increased perceptions of exertion. It was also assumed that the A/D shift would occur earlier with individuals in no vision conditions, as the focus on internal cues would lead to a rather associative attention strategy. Some findings have indicated that attendance to music (Yamashita et al., 2006) and the manipulation of visual cues (Hyvärinen et al., 1981; Weeks et al., 2000) can decrease RPE and delay the onset of A/D shift, thus when the two were combined it was expected that the effects on RPE and attention would be the strongest. Results of the current study revealed that music in general improved time on task (e.g., handgrip squeeze duration). Open-vision on the other hand, helped lower the RPE levels, while the opposite held true for occluded vision. Combination of music and open-vision improved time on dissociative focus, with an effective delay of A/D shift comparatively to open-vision and no music conditions. These findings are partially in line with the original assumption that the occlusion of vision would relate to increases in RPE. The deprivation of visual input led to increased perceptions of effort-related cues (e.g., higher RPE levels). Although open-vision helped lowering RPE levels, attending to music failed to mirror these effects. More specifically, towards the end of the task, participants in music conditions perceived higher levels of RPE relatively to their counterparts in non-music conditions. It is important to note, however, that when combined, open-vision and music had a positive effect on attention by delaying the A/D shift.

The combined effect of visual and auditory stimuli allowed longer dissociative-attention periods comparatively to all other conditions. Consequently, open-vision seemed to have direct effect on RPE levels while combined open-vision and music appeared to have an effect on attention across time. Likewise, absence of vision alone did not result in the expected accelerated shift to the associative attention strategy. While individuals in the occluded vision condition were experiencing heightened perceptions of exertion, they may have also been attending to increased auditory stimulation thus, resulting in insignificant changes in A/D shift patterns.

While attendance to music in the open-vision condition had an effect on the expansion of a dissociative attention strategy, its effects were minimized when the visual information was occluded, and music was the only sensory stimuli present. When vision is occluded, other sensory cues are magnified, and thus attendance to those cues (e.g., perceptions of exertion or pain) increases (Hyvärinen et al., 1981). Furthermore, visual exposure, when experienced alone, did not appear to play a role in altering A/D patterns. These findings suggest that the presence of one external stimulus may not be sufficient in producing alternations in attention strategies. Thus, more sensory modalities are required to affect RPE and attention allocation while engaging in high levels of physical effort.

As the amount of sensory information increased, participants were more responsive to the distinctive qualities of these external stimuli and thus, their focus on internal cues was minimized. The increased duration of dissociation during the vision and music condition above and beyond all other conditions indicates that the additive effect is most prominent in delaying the onset of the A/D shift. The effectiveness of dissociative attention strategies (i.e., attention to external stimuli) used to examine the effect of these intensity or duration is increased (Tenenbaum et al., 2004).

Previous studies have only examined this phenomenon with one external stimulus. The current findings suggest that the presence of selected external stimuli (i.e., music) help delaying the A/D shift thereby, allowing individuals to dissociate from somatic cues for longer periods of time. The current findings suggest that the presence of selected external stimuli (i.e., music) helps delaying the A/D shift thereby, allowing individuals to dissociate from somatic cues for extended period of times. Earlier models of pain perception including the ones developed by Kaheman et al. (1993) and Stone et al. (2000) have in fact suggested a non-linear function of pain memories. This assertion may be well due to the fact that these models attempted to predict experience of pain as a whole and in retrospect. Nevertheless, in the present study, we evaluated exertive pain in its momentary increases hence a unique conceptualization of painful reports was herein proposed.

Findings of the study land further support to the relative importance of the attention, RPE, and overall (task) sustenance linkage. As such, across low to moderate workload intensities, attention manipulations appear effective in lowering RPE. Consequently, extended external (i.e., dissociative) attention-focus along with lowered perception of exertion seems to increase levels of task sustenance. Specifically, current findings support the use of additional external stimuli while exercising in order to delay the onset of the A/D shift. Exercisers experience increased benefits by attending to multiple sources of external information (e.g., watching television while listening to music, scanning the crowd while talking to a friend, etc.). Such external stimuli may serve as mediating agents in diverting attention away from internal and painful stimuli. These approaches may likely contribute to the perceived pleasantness of the exercise experience, ultimately leading to increased exercise participation, and thus potentially offering at least partial remediation to the problem of high dropout rates.

It is nevertheless important to recognize that the participants in the present study appeared to be particularly active (i.e., averaging 75 min of exercise per day). Thus, caution is warranted in further attempts to generalize the present findings to alternative populations. Future research is warranted to examine the effect of these modalities within other populations. Additional concern here is the measure of RPE and attention taken during the squeezing task. It seems likely that the process of assessing participants’ focus of attention and RPE every 30 s may have affected their ratings of tension...
attention and RPE, though a vast amount of studies in the sport medicine and exercise physiology and psychology domains utilized introspective and “think allowed” procedures to elicit exercisers’ thoughts, feelings, and attention allocation. This, however, is a note of caution in future research.

Future work is also recommended to evaluate additional sensory modalities on perceptions of exertion and attention dynamics. It would be useful to assess the unique effects of uninvestigated sensory modalities (i.e., olfactory, tactile, and gustatory) on effort perceptions and attention focus. Finally, considering the benefits of the presentation of multiple stimuli indicated within this study, further examination towards the additive effects of a variety of external stimuli would prove valuable to the advancement of research on A/D dynamics and related shift patterns.

Acknowledgements

The authors would like to thank the director of facilities; Steven N. Powell, staff, and participants at the Florida State University’s Bobby E. Leach Student Recreation Center. Without their support and assistance this investigation would not have been completed.

References


Please cite this article in press as: Razon, S., et al., Perception of exertion and attention allocation as a function of visual and auditory conditions, *Psychology of Sport and Exercise* (2009), doi:10.1016/j.psychsport.2009.03.007