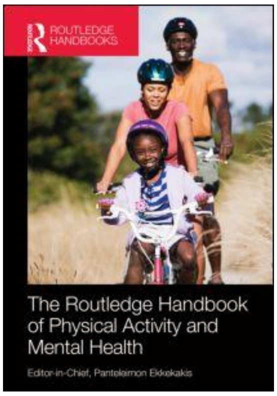


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# Effect of Acute and Regular Aerobic Physical Activity on Positive Activated Affect

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# PART 8

# Energy and fatigue

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*Justy Reed*

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# EFFECT OF ACUTE AND REGULAR AEROBIC PHYSICAL ACTIVITY ON POSITIVE ACTIVATED AFFECT

*Justy Reed*

Physical activity promotes health and well-being (e.g., Warburton, Nicol, & Bredin, 2006). Positive activated affect (PAA) is a subjective mental state of energy and enthusiasm related to health and well-being. For example, PAA correlates favorably with longevity (Kubzansky, Sparrow, Vokonas, & Kawachi, 2001), immune function (Cohen, Doyle, Turner, Alper, & Skoner, 2003), stress response (Steptoe, Wardle, & Marmot, 2005), and marital satisfaction (Rogers & May, 2003). Given that physical activity is a healthy behavior and PAA is a positive mental state, the effect of physical activity on PAA offers a fertile area for health-related scientific inquiry. This chapter will review the quantitative effect of acute and regular physical activity on PAA, discuss a conceptual issue relative to PAA, and provide suggestions for future study. The chapter begins with definitions for the variables of interest: physical activity and PAA.

## Definitions

### *Physical activity*

Physical activity is aerobic or anaerobic movement produced by skeletal muscles that increases energy expenditure above resting (U.S. Department of Health and Human Services [USDHHS], 2008). Physical activity can range from very low in sedentary individuals to very high in well-conditioned athletes, and includes occupational, leisure time, household, and health-enhancing. Exercise is a form of physical activity. Exercise is planned and performed with the goal of improving health or fitness (USDHHS, 2008). Because physical activity is a broader concept than exercise, the term physical activity will be used in this chapter. Specifically, physical activity will refer to aerobic physical activity.

### *Positive activated affect (PAA)*

Affect will be defined as the quality of a subjective mental state along the dimensions of valence and activation or what has been described as core affect (Russell, 2003). Valence describes affect along the positive versus negative quality of a mental state. Activation describes affect along the alertness versus sleepiness quality of a mental state. The core affect theory proposes that all affective states represent varying degrees of valence and arousal and therefore affect can be represented on

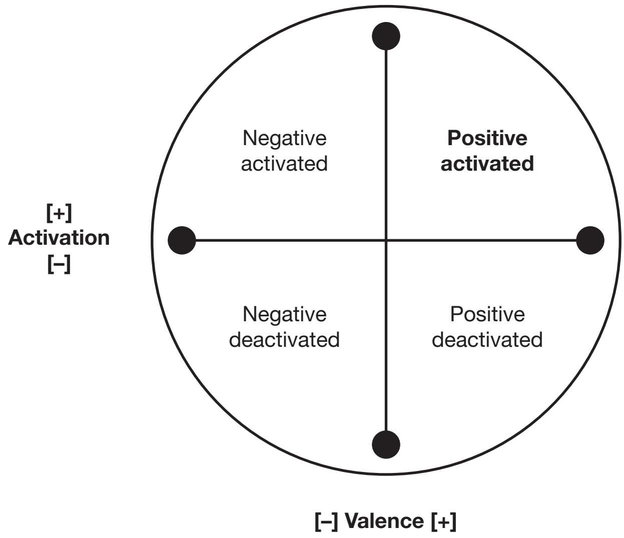


*Figure 28.1* A circumplex model of self-reported affect. The activation dimension is the vertical axis and the valence dimension is the horizontal axis of the circumplex (adapted from Yik, Russell, and Feldman Barrett, 1999).

a two-dimensional circumplex (Posner, Russell, & Peterson, 2005). Several different names have been given to the upper right quadrant of the circumplex (see Yik, Russell, & Feldman Barrett, 1999). For this chapter, the upper right quadrant will be referred to as positive activated affect (PAA; Reed & Ones, 2006). See Figure 28.1 for a representation of the affect circumplex.

Affect-laden terms (e.g., gloomy or delighted) typically provide the link between a self-reported affective state and the circumplex. Similar affect-laden terms comprise the scales of common self-report affect instruments, for example, the Energy scale of the Activation-Deactivation Adjective Checklist (AD-ACL; Thayer, 1996) or the Positive Affect scale of the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988). Analyses conducted by Yik et al. (1999) revealed that affect terms and therefore affect scales having positive valence and moderately high levels of activation map to the upper right quadrant of the circumplex. This chapter examines the effect of acute and regular aerobic physical activity on the scale scores of self-report affect instruments that map to the PAA quadrant of the affect circumplex.

## Effect of aerobic physical activity on PAA: meta-analytical evidence

### *Acute aerobic physical activity*

This section discusses the review by Reed and Ones (2006). These authors conducted a meta-analysis on the effect of acute aerobic physical activity on post-activity self-reported PAA. The database consisted of 158 studies dated from 1979 to 2005. Studies examining affect in relation to aerobic exercise (e.g., aerobic dance, walking, jogging, running, swimming, and cycling) were identified using computer databases and manual searches of narrative reviews, quantitative reviews, and books. Reference lists of published articles, theses, and dissertations were checked for additional studies. The mean age of participants in the database was 24.50 years with a standard deviation (*SD*) of 11.64. Twenty-three percent of study samples were male, 35 percent female, and 40 percent mixed gender. Sixty-two percent of study samples were college students, 19 percent community participants, 8 percent athletes, 4 percent clinical participants, and 5 percent mixed samples of university faculty, staff, and students. Effect sizes (ESs) were obtained for physical activity groups and control groups. The majority of control samples were attention controls. ESs for each study were computed by subtracting the mean post-activity PAA from the mean pre-activity PAA and dividing the difference by the pooled *SD*, resulting in a *d*-value ES (Cohen, 1977). The random effects approach of Hunter and Schmidt (2004) was utilized to conduct the analysis and therefore *d*-values were corrected for measurement error and sampling error. Positive *d*-values reflected increased pre- to post-activity PAA.

The mean corrected ES ($\bar{d}_{corr}$) estimated the average population effect. The standard deviation of corrected *d* values ($SD_{corr}$) and 90 percent credibility interval (90 percent CrI) were used to detect the presence of moderators in the overall analysis and to verify whether the results of individual moderator analyses generalized across study settings. For the overall analysis, if $SD_{corr}$ was large relative to $\bar{d}_{corr}$ or the 90 percent CrI included zero (Whitener, 1990), moderators were present. For moderator analyses, if the 90 percent CrI did not include zero, the $\bar{d}_{corr}$ effect generalized. That is, the moderator effect retains a positive or negative sign across study settings and situations (Ones, Viswesvaran, & Schmidt, 1993).

The overall activity $\bar{d}_{corr}$ of 0.47 indicated PAA increased by nearly one half of a *SD* on average from pre- to post-aerobic activity. The control $\bar{d}_{corr}$ of -0.17 indicated PAA decreased by roughly two-tenths of a *SD* from pre to post control. These results show that the effect of aerobic activity on PAA is nearly four times the magnitude of the effect in control conditions. The overall activity $SD_{corr}$ of 0.37 and 90 percent CrI (lower limit, upper limit) of (-0.01, 0.94) signified the presence of moderators. Therefore, activity-related moderator analyses were conducted for pre-activity (baseline) PAA, activity intensity, duration, and dose, and post-activity PAA assessment times. Study-related moderator analyses included study quality (defined as the number of internal validity threats controlled) and source (published vs. unpublished). Moderator analyses were not conducted for control groups.

To examine whether pre-activity PAA moderated the effect of aerobic activity on post-activity PAA, pre-activity mean PAA scores were converted to standard scores (z scores). Studies were divided into three categories based on pre-activity z score: less than -0.5 z, -0.5 z to 0.5 z, and greater than 0.5 z. For studies in the less than -0.5 z category, $\bar{d}_{corr} = 0.63$, twice the magnitude of the other two categories. The 90 percent CrI did not include zero (0.16, 1.10), indicating generalizable increases in PAA when baseline PAA is lower than average. Effects were not generalizable in the other two categories.

Intensity was coded using percent oxygen uptake reserve (percent $\dot{V}O_2R$). The data allowed formation of categories for low (15 to 39 percent $\dot{V}O_2R$), moderate (40 to 59 percent $\dot{V}O_2R$), and high (60 to 85 percent $\dot{V}O_2R$). The low-intensity $\bar{d}_{corr}$ of 0.57 ($SD_{corr} = 0.33$) indicated a generalizable effect nearly twice the magnitude of the other two categories. Moderate- and high-intensity effects were not generalizable.

Duration (session time) was coded in minutes per session, and studies were grouped into five time intervals. The $\bar{d}_{corr}$ ($SD_{corr}$) for the first three intervals were 7 to 15 minutes, 0.56 (0.38); 20 to 28 minutes, 0.46 (0.31); and 30 to 35 minutes, 0.57 (0.33). The 90 percent CrIs for these intervals did not include zero and all $\bar{d}_{corr}$ were within .10 *SD* indicating similar generalizable effects. Effects tapered in the 40- to 60-minute interval, 0.37 (0.31) and were markedly reduced in the fifth interval for studies having durations greater than 75 minutes, -0.72 (0.66).

Dose was quantified as the product of intensity and duration. Low doses (e.g., 20 minutes' brisk walking) increased post-activity PAA, $\bar{d}_{corr} = 0.45$ ($SD_{corr} = 0.30$). Similar results were found for moderate doses (e.g., 30 minutes at 65 percent heart rate maximum), $\bar{d}_{corr}$ = 0.46 ($SD_{corr}$ = 0.34). High doses (e.g., 90 minutes at 70 percent heart rate maximum) produced null effects, $\bar{d}_{corr}$ = 0.09 ($SD_{corr}$ = 0.27). Very high doses (e.g., marathon) resulted in markedly reduced post-activity PAA, $\bar{d}_{corr}$ = -0.98 ($SD_{corr}$ = 0.37). The authors characterized the dose results in terms of "zones" of effect. Low and moderate doses are optimal because effects were positive and generalizable. High doses are unstable because the effect was null on average, but may increase or decrease depending on other moderators such as activity history (see Hallgren, Moss, & Gastin, 2010). Very high doses are unpleasant because they render considerable physiological and psychological fatigue and significantly lower post-activity PAA in virtually all situations.

PAA during recovery was examined using intervals of 0 to 2, 5 to 10, 15 to 30, and 40 to 1440 minutes post activity. The $\bar{d}_{corr}$ ($SD_{corr}$) ranged from a generalizable 0.61 (0.40) at 0 to 2 minutes to a non-generalizable 0.10 (0.31) at 40 to 1440 minutes' recovery. Effects for the other time intervals were not generalizable. Post-activity PAA is important because knowledge of response patterns may provide insight about conditions that maximize the effect.

Study quality was analyzed using categories of studies whose authors attempted to control 1 to 2, 3 to 4, 5 to 6, or 7 to 10 threats to internal validity. The results suggested a positive association between study quality and ES, indicating larger effects for studies with higher internal validity. However, the authors noted that this association should be interpreted cautiously due to the near complete overlap of the 90 percent CrIs for each of the categories. For study source, the effect in published studies, $\bar{d}_{corr}$ = 0.47 ($SD_{corr}$ = 0.39), was significantly greater than for unpublished studies, $\bar{d}_{corr}$ = 0.26 ($SD_{corr}$ = 0.37), pointing to a source bias.

## *Regular aerobic physical activity*

This section summarizes the review by Reed and Buck (2009). These authors conducted a meta-analysis on the effect of aerobic activity programs on post-program self-reported PAA. The database consisted of 115 studies dated from 1980 to 2008. Whereas a single session provided the unit of inquiry in the acute activity meta-analysis (Reed & Ones, 2006), an activity program served as the unit of inquiry for this meta-analysis. Studies of affect in relation to aerobic exercise programs were identified using computer databases and manual searches of narrative reviews, quantitative reviews, and books. Reference lists of published articles, theses, and dissertations were checked for additional studies. The mean age of participants in the database was 42.41 years (*SD* = 15.93). Fourteen percent of study samples were male, 42 percent female, and 43 percent mixed gender. Fifty-eight percent of study samples were community participants, 22 percent clinical, 13 percent college students, 5 percent mixed samples of university faculty, staff, and students, and 2 percent athletes. ESs were obtained for physical activity groups and control groups. The majority of control samples were attention controls. Study ESs were computed by subtracting the mean post-program PAA from the mean pre-program PAA and dividing the difference by the pooled *SD*, resulting in a *d*-value ES (Cohen, 1977). Similar to Reed and Ones (2006), this review utilized a random effects model, ESs were corrected for measurement error and sampling error, and activity-related and study-related variables were coded as potential moderators.

The overall activity $\bar{d}_{corr}$ of 0.57 indicated PAA increased by six-tenths of a *SD* on average from pre to post program. The control $\bar{d}_{corr}$ of 0.03 ($SD_{corr}$ = 0.11) indicated PAA remained unchanged on average from pre to post control. These results show that aerobic physical activity programs increase PAA and control conditions produce little change in PAA. The overall activity program $SD_{corr}$ and 90 percent CrI (lower limit, upper limit) were 0.48 (-0.04, 1.18) signifying the presence of moderators. Therefore, activity-related moderator analyses were conducted for pre-program (baseline) PAA, activity frequency, intensity, and time, program duration, and activity dose. Study-related moderator analyses included study quality (defined as the number of internal validity threats controlled) and source (published vs. unpublished). Moderator analyses were not conducted for control groups.

The baseline analysis was conducted in a similar manner to that of Reed and Ones (2006). The effect for studies in the lower third of the z-score distribution (less than -0.5 z) was $\bar{d}_{corr}$ = 0.81 ($SD_{corr}$ = 0.40), almost twice the magnitude of studies in the middle category (-0.5 z to 0.5 z) at $\bar{d}_{corr}$ = 0.45 ($SD_{corr}$ = 0.34), and three times greater than studies in the upper category (greater than 0.5 z) with $\bar{d}_{corr}$ = 0.26 ($SD_{corr}$ = 0.02). The results show a clear inverse relation between baseline PAA and the magnitude of improvement from aerobic exercise programs. Unlike Reed and Ones (2006), effects were generalizable for all baseline categories.

A moderating effect was found for frequency (days per week), with higher frequencies producing larger effects. The $\bar{d}_{corr}$ ($SD_{corr}$) for the three frequency categories were: less than 3 days per week, 0.57 (0.29); 3 days per week, 0.52 (0.37); and greater than 3 days per week, 0.79 (0.34). Activity intensity was coded as percent $\dot{V}O_2R$. The $\bar{d}_{corr}$ ($SD_{corr}$) for low- and high-intensity programs resulted in the largest PAA increases of 0.72 (0.00) and 0.68 (0.34), respectively. Moderate-intensity programs produced smaller, but respectable, effects of 0.50 (0.46). The effects for moderate-intensity programs did not generalize, however. The $\bar{d}_{corr}$ ($SD_{corr}$) for activity duration (session time) were 15 to 25 minutes, 0.55 (0.38); 30 to 35 minutes, 0.68 (0.43); and 40 to 60 minutes, 0.49 (0.37). Program duration was coded in weeks, and studies grouped into three categories. The $\bar{d}_{corr}$ ($SD_{corr}$) were 4 to 9 weeks, 0.51 (0.28); 10 to 12 weeks, 0.63 (0.42); and 13 to 32 weeks, 0.45 (0.28). The moderator analyses for session time and program duration showed a tendency toward smaller effects with longer session times and longer programs.

Dose was quantified as the product of activity intensity, time per session, frequency per week, and program duration, and coded into categories of low (e.g., 2 days per week, 20-minute sessions, moderate intensity, 8 to 10 weeks), moderate (e.g., 3 days per week, 30-minute sessions, moderate intensity, 10 to 12 weeks), and high (e.g., 4 days per week, 40-minute sessions, moderate intensity, 12 to 14 weeks). Dose effects ranged from $\bar{d}_{corr}$ = 0.56 ($SD_{corr}$ = 0.40) for moderate to $\bar{d}_{corr}$ = 0.65 ($SD_{corr}$ = 0.38) for high aerobic program doses. The maximum dose category ES difference was 0.09, signifying dose as a weak moderator. Importantly, however, with respect to the activity-related moderator analyses, 90 percent CrIs did not include zero for nearly all variable categories, suggesting that a variety of aerobic activity programs result in generalizable increases in PAA.

The authors analyzed study quality using categories of studies whose authors attempted to control 1 to 3, 4 to 5, 6 to 7, or 8 to 9 threats to internal validity. The results revealed a positive association between the number of threats controlled and ES. The $\bar{d}_{corr}$ ($SD_{corr}$) were 0.27 (0.00) for studies controlling 1 to 3 threats and 0.77 (0.00) in studies controlling 8 to 9 threats, indicating larger effects in studies with higher internal validity. There was no source bias: the effect in published studies of 0.56 (0.36) mirrored the result for unpublished studies of 0.54 (0.43).

## *Summary of meta-analytical findings*

Considered together, the two meta-analyses show that acute and regular aerobic physical activity increase self-reported PAA by approximately one half a *SD* in experimental participants who perform aerobic activity compared to control participants who do not. Stated differently, the findings indicate that a randomly selected person who just completed aerobic activity would be about 65 to 70 percent more likely to report higher PAA than a randomly selected sedentary person (Ellis, 2010). Moderator analyses show effects are consistently positive under the following conditions: lower than average pre-activity or pre-program PAA, low-intensity activity, activity sessions of 10 to 35 minutes, and low- to moderate-activity doses as quantified for single sessions or progams. Additionally, PAA for acute bouts is consistently positive during the first two minutes post activity (except after very high-intensity activity) and the analysis of regular aerobic activity shows that a variety of programs produce generalizable increases in PAA. Study-related moderator analyses revealed a weak study quality bias and a significant trend toward larger effects in published studies for the acute data and a strong study quality bias, but no source bias (published vs. unpublished) in the aerobic program data. Thus, in the acute literature, the data suggest a tendency for larger effects in published studies independent of study quality, but in the aerobic program literature, effect magnitude appears driven by study quality, not publication status. The number of studies was relatively small for some of the moderator analyses and these findings should therefore be considered preliminary (see Reed & Buck, 2009, and Reed & Ones, 2006, for more details). Finally, meta-analytical findings, in particular the results of moderator analyses, provide information only about the conditions under which ES magnitudes will differ, but not how or why the effects occur (Miller & Pollock, 1994).

## A conceptual issue

### *Is PAA fundamentally core affect or natural kind?*

A natural kind in science is a category from which researchers can form testable hypotheses and make valid and reliable generalizations from samples of the category to the whole category (Boyd, 1999). Some have argued core affect may be a natural kind (e.g., Barrett, 2006) and by deduction the dimensions of valence and arousal are natural kinds. Core affect theorists share the assumption that PAA is a blend of positive valence and moderately high activation. In other words, core affect theory implies that PAA occurs only because of the fundamental dimensions of arousal and valence. Others dispute these claims. Scarantino (2009) suggests the evidence supports only positive affect and negative affect separately as natural kinds. Martinez Bedard (2008) argues that the four quadrants of the affect circumplex are separate natural kinds because each of these categories, apart from the theory of core affect, share causally related properties and are therefore more scientifically homogeneous than core affect. PAA may therefore be a natural kind distinct from core affect per se. The important conceptual issue is whether PAA is fundamentally core affect or a natural kind and the point of this discussion is to remind readers that core affect and the associated circumplex model is not necessarily the only way to conceptualize the study of PAA or affect in general. See Watson (2000) for a similar, but alternative theory of affect.

## Future research directions

Future research should help clarify why physical activity enhances PAA in some people and not in others. Cognitive and individual difference variables along with genetic factors are potentially productive avenues.

Cognitive variables associated with PAA before, during, and after physical activity such as attentional focus to pleasant or unpleasant stimuli (e.g., Tian & Smith, 2011) and cognitive appraisal differences related to gender, fitness, and activity status (e.g., Rose & Parfitt, 2010) are likely important for PAA change and physical activity adherence. Another viable area involves expectancies about the impact of physical activity on well-being (e.g., Anderson & Brice, 2011). Expectations are often mediated by changes in behavior and expectancy theory can account for any effect for which a person can develop an expectation, including the affective benefits of physical activity. Expectancies play a central part in placebo effects (Stewart-Williams, 2004) and investigators are encouraged to spend more effort understanding the role of placebo effects (if any) in the relationship between physical activity and PAA. Testing expectations, however, requires creative research designs to minimize experimenter bias.

Researchers should continue to explore individual differences. For example, "grit" defined as perseverance and passion for long-term goals (Duckworth, Peterson, Matthews, & Kelly, 2007) might correlate with PAA during and after physical activity and be related to intentions within the theory of planned behavior (Ajzen, 1991) or behavioral regulation constructs in self-determination theory (Deci & Ryan, 2000). Individual differences relative to an affective "home base" (Kuppens, Oravecz, & Tuerlinckx, 2010) could also shed light on activity-related PAA response variability.

Genetic factors likely influence voluntary physical activity and health outcomes and are perhaps a source of variation in affective responses to physical activity (de Geus & de Moor, 2008). Preliminary research suggests increased activity-related PAA might in part depend on variations in dopamine systems (Simonen et al., 2003) or brain-derived neurotrophic factor (BDNF), a gene possibly related to physical activity and activity-associated PAA (Bryan, Hutchison, Seals, & Allen, 2007). Understanding gene-by-physical activity interactions is undoubtedly an important future research topic.

Finally, researchers should replicate the important findings reviewed in this chapter to firmly establish the reliability of the results. As aptly noted by Hunter (2001), scientific progress in any field not only depends on new ideas but also requires a database of facts and replicated studies help establish scientific facts. A meta-analysis on the effect of aerobic activity on in-task PAA could now provide a constructive addition to the literature. There is also a need for more studies on the effect of weight training on PAA.

## Conclusion

Positive activated affect (PAA) is a subjective mental state of positive energy and engagement. PAA is related to health and well-being. Aerobic physical activity increases self-reported PAA in aerobic activity groups compared to non-activity control groups (Reed & Buck, 2009; Reed & Ones, 2006). Several conditions result in consistent and generalizable increases in post-activity PAA including when pre-activity PAA is lower than average and with lower-intensity aerobic activity sessions of 10 to 35 minutes. A variety of aerobic physical activity programs appear to increase PAA. An important conceptual issue is whether PAA is fundamentally a function of valence and arousal or a scientific natural kind. Cognitive and individual difference variables along with genetic factors are suggested as productive research areas for further understanding the effect of aerobic physical activity on PAA.

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