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Evidence for a general factor of behavioral activation system sensitivity

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Abstract

Individual differences in one's propensity to engage the *behavioral activation system* (BAS) and *behavioral inhibition system* (BIS) have primarily been studied with Caver and White's (1994) BIS/BAS scale. Whereas, Carver and White identified the BIS as a unidimensional scale, they identified three separable BAS group factors - drive, fun seeking, and reward responsiveness - which Carver urged against combining into a BAS total score. Despite this, a BAS total score has been used extensively although researchers have yet to test whether a BAS general factor exists and, if so, whether a BAS total score can be interpreted as primarily being a measure of the general factor. The current study observed that the best fitting BAS factor model of those we tested was a hierarchical model with three group facets and a general factor. This model was largely invariant across both sex and race/ethnicity. We show, for the first time, that a general factor accounts for the majority of the variance in BAS total scores. Due to the superior fit of the hierarchical model and variance accounted for by the general factor, we conclude that researchers are psychometrically justified in using a BAS total score.

Introduction

Human behavior and psychological experience is largely driven by the pursuit of rewards and the evasion of threats. These fundamental drives underlie the *behavioral activation system* (BAS) and *behavioral inhibition system* (BIS) respectively. Individual differences in one's propensity to engage these systems have often been studied with Carver and White's (1994) BIS/BAS scales. With 5,400 citations the BIS/BAS scales have revealed important insights into the motivational underpinnings of cognition (e.g., Harmon-Jones, Gable, & Price, 2012), attention (e.g., Gable & Harmon-Jones, 2008), instrumental learning (e.g.,

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Zinbarg & Mohlman, 1998), emotion (e.g., Carver & Harmon-Jones, 2009, Gable & Poole, 2014), interpersonal relationships (e.g., Impett, Peplau, & Gable, 2005), self-control (e.g., Crowell, Kelley, & Schmeichel, 2014; Schmeichel & Crowell, 2016), and mood disorders (e.g. Alloy, Olino, Freed, & Nusslock, 2016), among other phenomena. Whereas, Carver and White identified the BIS as a unidimensional scale, they identified three separable BAS group factors which Carver urged against combining into a BAS composite score. Specifically, he stated, "I do not encourage combining the BAS scales, however, because they do turn out to focus on different aspects of incentive sensitivity" (Carver, 2007). However, the empirical literature reveals that Carver's urging has largely gone unheeded in contemporary research. For example, a PsycInfo search of empirical papers published in 2017 revealed 70 used the BAS and a majority ($N = 45$, 64.3%) either used the total score exclusively or in conjunction with subscale scores. Despite the popularity of the total score, researchers have yet to explore whether a BAS total score has adequate psychometric properties.

An important psychometric property of a total score derived from a multidimensional scale is whether it can be interpreted as primarily being a measure of a single construct (McDonald, 1999; Zinbarg, Revelle, Yovel & Li, 2005). Unfortunately, researchers have yet to test whether a BAS general factor exists and, if so, whether a BAS total score can be interpreted as primarily being a measure of a single construct - the general factor. Similarly, in the absence of testing whether a BAS general factor exists, it is also unknown at present whether BAS subscale scores can be interpreted as primarily being measures of their corresponding group factors (versus the general factor).

Reinforcement sensitivity theory and the development of the BIS/BAS scale

The BIS/BAS scales are the most widely utilized individual difference measure based on Jeffrey Gray's reinforcement sensitivity theory. Gray's (1972, 1981) early work conceptualized motivational differences along two personality dimensions: *anxiety*, which reflects sensitivity of the aversive motivation system, and *impulsivity*, which reflects sensitivity of the appetitive motivation system. He referred to the system that produces anxiety in response to relevant cues as the *behavioral inhibition system* (BIS; Gray, 1990). This system is sensitive to signals of negative consequences, such as punishment or nonreward, and tends to *inhibit* behavior to try to avoid these consequences. The motivation is thus aversive; the individual (passively) avoids something they do not want. On the other hand, he referred to the system that promotes impulsivity in response to relevant cues as the *behavioral approach system* (Gray, 1990). This system is sensitive to signals of positive consequences (e.g. reward, nonpunishment), and tends to activate behavior to try to attain these consequences. Gray (1987) hypothesized these two systems to be two orthogonal constructs along which individuals will demonstrate varying levels of sensitivity.

Despite the popularity and influence of Gray's theory, a proper measure for BIS/BAS sensitivity was lacking for over 20 years. Researchers in the 1970s and 1980s relied heavily on previously developed measures of conceptually similar personality traits. For example, BAS was often assessed with measures of extraversion (e.g. Larsen & Ketelaar, 1991) or impulsivity (e.g. Diaz & Pickering, 1993), whereas BIS was typically measured with measures of neuroticism (e.g. Larsen & Ketelaar, 1991). Eventually, scales directly inspired by Gray were developed (e.g., MacAndrew & Steele 1991; Cloninger 1987) although they were not widely used due to both theoretical and psychometric flaws (see Carver & White, 1994).

Carver and White (1994) sought to design a self-report instrument to more accurately reflect Gray's theory by accounting for the motivation direction rather than the affective state (e.g., anxiety, elation) underlying behavior. In their scale, BIS reflects a concern or worry about receiving punishment (e.g. "I feel worried when I think I have done poorly at something"). The BAS includes items reflecting goal striving (e.g., "I go out of my way to get things I want"), reward responsivity (e.g., "When I get something I want I feel excited and energized"), novelty seeking (e.g., "I'm always willing to try something new if I think it will be fun"), and impulsivity (e.g., "I often act on the spur of the moment").

After initial item generation (Study 1) and testing (Study 2), Carver and White (1994) concluded that a 4-factor structure best fit the data which included one BIS factor and three BAS factors – Drive, Reward Responsivity, and Fun Seeking. The drive subscale reflected goal striving tendencies, reward responsivity reflected positive reactions to the receipt of rewards, and fun seeking reflected a blend of novelty seeking and impulsivity. These scales initially showed good test-retest reliability at eight weeks and both convergent and discriminant validity. Finally, in two subsequent studies Carver and White (1994) found that BIS and BAS predicted behavioral reactions to aversive (e.g., punishment) and appetitive (e.g., reward) stimuli respectively.

Factor Structure of the BIS/BAS Scales

The factor structure of the BAS, as determined by Carver and White (1994), has been widely replicated (Jorm et al., 1998; Heubeck, Wilkinson, & Cologon, 1998; Leone, Perugini, Bagozzi, Pierro, & Mannetti, 2001; Campbell-Sills, Liverant, & Brown, 2004; Franken, Muris, & Rassin, 2005; Müller, & Wytykowska, 2005; Cooper, Gomez, & Aucote, 2007; Yu, Branje, Keijsers, & Meeus, 2011). Although there have been a number of studies that replicate the factor structure of the BAS, many studies have failed to do so (Cogswell, Alloy, van Dulmen, & Fresco 2006; Smillie, Jackson, and Dalgleish; Heym, Fergueson & Lawrence, 2008; Poythress, et al., 2008; Beck, Smits, Claes, Vandereycken, & Bijttebier, 2009; Dissabandara, Loxton, Dias, Daglish, & Stadlin, 2012; Pagliaccio et al., 2016; Gray, Hanna, Gilleb, & Rushe, 2016). The research reviewed above focused on the factor structure of both the BIS and the BAS. Other researchers have focused specifically on the factor structure of the BIS (e.g. Heym, Ferguson, & Lawrence; 2008), none have specifically focused on a hierarchical structure to the BAS as we do in the current research.

Beyond factor structure another important, yet often ignored, psychometric property is measurement invariance. Measurement invariance refers to whether a given instrument (i.e. BAS) measures the same latent dimensions (i.e. approach motivation) across groups. Invariance across groups or categories should be explicitly tested because if invariance does not hold, we cannot use the measure to quantify differences across groups. For example, imagine we have a measure of aggression that has been shown to tap two factors in women: physical aggression and relational aggression. If this same measure is unidimensional in men, we cannot validly use this measure to quantify sex differences in physical and relational aggression (given that the instrument is not measuring these two latent variables in men in the first place). Such differences may arise because different populations perceive or react to items differently so that the same constructs are not being measured in these groups (McDonald, 1999). Alternatively, imagine the measure taps two factors with the same items loading onto the same factors in both sexes but there are sex differences in the factor loadings (i.e., the slope of the regression of the item on the factor) and/or intercepts (i.e., the expected item response when the trait equals zero). Such differences would also complicate the use of the measure to quantify sex differences in physical and relational aggression. For these reasons, psychometric experts have recommended that it is important to test the invariance of every measure (e.g., Horn & McArdle, 1992; Widaman, Ferrer & Conger, 2010).

Some studies have asked whether the factor structure of the BIS/BAS scales, as conceived by Carver and White (1994), is invariant across different demographic factors. For example, invariance has been observed across countries – namely the United States, the United Kingdom, and Italy (Leone, Perugini, Bagozzi, Pierro, & Mannetti, 2001). Invariance has also been observed across sex (Campbell-Sills, Liverant, & Brown, 2004), age group (Cooper, Gomez, & Aucote, 2007) and racial groups (Demianczyk, Jenkins, Henson, & Conner, 2014). Although Demianczyk and colleagues (2014) observed invariance they had to modify Carver and White's original structure to do so (see the Discussion for a more in depth treatment of this issue). Considering past research has identified sex, ethnicity, and race as key variables for invariance testing *and that we identified a factor structure that has not previously appeared in the literature*, we sought to test invariance across these groups in the current study.

But how might measurement invariance (or non-invariance) manifest in the current context? Two unlikely possibilities are non-invariance in either the number of factors or the strength of the factor loadings. Either of these forms of non-invariance suggest that the latent concepts (i.e., approach motivation and its facets) mean the same thing across groups. Given that approach motivation is an evolutionarily old process (e.g., Schneirla, 1959), it seems unlikely that if non-invariance did manifest it would do so in either of these two ways. A more likely possibility is non-invariant intercepts. This type of non-invariance may reflect measurement bias whereby contextual factors like culture or sex are systematically influencing how individuals' respond to BAS items. For example, the same assertive/agentic behavior that is praised in a man is often criticized in a woman (e.g., Eagly & Karau, 2002; Williams & Tiedens, 2016). These differing gender norms might cause women to be less likely to endorse BAS items with an assertive/agentic component thereby causing non-invariant intercepts.

Is there a BAS general factor?

As reviewed above, despite the many studies that have been conducted on the factor structure of the BIS and BAS, none of the these studies tested whether the BAS might be most accurately conceptualized as having a hierarchical structure with one general factor in addition to several group factors. This may be due to Carver's direct discouragement of combining the BAS subscales discussed above. Regardless of the reason for this state of affairs, there is no psychometric support for the use of a BAS total score. Despite this, many papers compute BAS total scores and thus, at least implicitly, assume a general factor that accounts for the majority of the variance in BAS total scores. Indeed, highly influential theories in affective science (e.g., Harmon-Jones, Gable, & Peterson, 2010; Coan & Allen, 2003) and clinical psychology (e.g., Alloy & Abramson, 2010; Harmon-Jones & Allen, 1997) presume a general factor underlying the BAS. In other words, highly influential work in psychological science using the BAS uses a total score and presumes a strong general factor. In addition, the use of BAS subscales presumes that the subscales are better measures of BAS group factors than a BAS general factor. Thus, there appears to be a discrepancy between how the BAS is often used in practice and the current psychometric evidentiary base for the BAS.

The current study addresses this discrepancy in three ways. First, we compared the fit of BAS factor models represented by one factor or three group factors (as in Carver & White, 1994) with a hierarchical model that includes a general factor and three group factors. Second, we also estimated the proportion of variance in BAS total scores accounted for by a general factor – coefficient omega$_{\text{hierarchical}}$ (ω_h; McDonald, 1999; Zinbarg et al., 2005). Third, because past psychometric studies have infrequently asked whether the BAS has a similar factor structure across groups (e.g., age, sex, and race/ethnicity, country of origin) we also tested whether the factor structure of the hierarchical model is invariant across both sex and race/ethnicity. Collectively, these analyses offer one of the most rigorous psychometric investigations of the BAS to date.

Method

Participants and Procedure

Recruitment Strategy.—Participants were recruited for screening into the Brain, Motivation and Personality Development (BrainMAPD) project via informational flyers placed in the Los Angeles and Chicago areas. All interested participants completed a series of screening measures, including the Behavioral Activation Scale and the Behavioral Inhibition Scale, at either the University of California, Los Angeles (*N* = 901, 36.6%), or Northwestern University (*N* = 1,560, 63.4%). The data from all participants completing those screening measures, regardless of their inclusion in the BrainMAPD study itself, were used for analysis in the present work. Therefore, the sample size for this study is far larger than that of the BrainMAPD study. Data, scripts, and materials are available on the Open Science Framework: https://osf.io/zw9ut.

Initial Screening.—Our web-based screening questionnaire was completed by 2,461 participants from 15 to 67 years old (*M* = 19.68, *SD* = 3.34). Approximately two-thirds of the sample was female (*N* = 1,672, 67.9%), approximately one-third male (*N* = 784, 31.9%), with some participants not reporting their sex (*N* = 5, 0.2%).

We asked about race and ethnicity in a manner consistent with NIH guidelines (see https://grants.nih.gov/grants/guide/notice-files/not-od-15-089.html). First, participants are asked whether or not they identified as Hispanic/Latino. Hispanic was defined as a person of

Cuban, Mexican, Puerto Rican, Cuban, South or Central American, or other Spanish culture or origin, regardless of race. In the current study the majority of participants identified as non-Hispanic (*N* = 1902, 77.3%) whereas the minority of participants identified as Hispanic (*N* = 519, 22.7%) and 40 participants (1.6%) did not report their ethnicity.

Next, participants were asked to report on their racial background. The racial breakdown of the sample was as follows: White (*N* = 1,165, 47.34%), Asian (N = 623, 25.31%), Black (N = 185, 7.52%), and American Indian or Alaskan Native (N = 32, 1.30%). Participants were identified as multi-racial if they selected more than one racial background regardless of ethnicity (*N* = 171, 6.95%). Finally, 285 participants (11.58%) did not report their race.

Materials.—The BAS includes three subscales which focus on different aspects of approach motivation. The 4-item *drive subscale* indexes behavioral persistence ("I go out of my way to get things I want"). The 4-item *fun-seeking subscale* indexes sensation seeking ("I crave excitement and new sensations") and impulsivity ("I often act on the spur of the moment"). The 5-item reward responsivity subscale indexes positive responses to real ("When I see an opportunity for something I like I get excited right away") or anticipated ("It would excite me to win a contest") rewards.

Study Design.—The goal of the present study was to test competing models of the structure of the BAS using Carver and White's (1994) measure. The competing models of BAS structure tested are depicted in Figure 1 and were as follows: 1) a one factor model, 2) an oblique three group factor (Drive, Reward Responsivity and Fun Seeking) model, 3) an orthogonal three group factor model, and (4) a four-factor hierarchical model with a general factor and three group factors (Drive, Reward Responsivity and Fun Seeking). This last model was specified such that all factors included in the model were orthogonal with each other (thus conforming to what some call the bi-factor model and what we, following McDonald, 1999, call the hierarchical model). We next sought to evaluate whether the preferred model above was invariant across sex, ethnicity, and race. In all models, the items were designated as continuous.[1]

First we tested competing confirmatory factor analysis (CFA) models of the factor structure of the BAS using Mplus version 7.4 (Muthen & Muthen, 1998-2010). It has long been recognized that CFA provides the most rigorous approach to test the assumption of measurement invariance (Marsh & Hocevar, 1985). Moreover, CFA is also the most rigorous approach for comparing competing factor models that have been identified on an a priori basis (Bollen, 1989; Gorsuch, 1983; Brown, 2006). As in Pinsof et al. (2009), we used three fit indices. For the first, the comparative fit index (CFI), an acceptable level of model fit was defined as CFI greater than or equal to 0.9. For the second, the root mean square error of approximation (RMSEA), an acceptable level of model fit was defined as RMSEA less than or equal to 0.06. For the third, the standardized root mean square residual (SRMR), an

[1]Because the BAS items are rated on a 4-point scale and thus non-normality of the data is likely, all models were also conducted with the items designated as categorical. In no case was the improvement in model fit large enough to justify the use of the significantly more complex, categorical model – therefore, for the sake of parsimony, we retained the continuous models and did not report on the categorical models. The categorical model scripts and output files are available on the OSF.

acceptable level of model fit was defined as SRMR less than or equal to 0.08. These fit criteria are based on the recommendations of Hu and Bentler (1999).

Then, to better understand the hierarchical factor structure of the BAS as well as the type of construct invariance characterizing the BAS, we tested both configural and metric invariance across sex, ethnicity, and race. Configural invariance analyses test the extent to which the factor structure is invariant across groups and constrain neither the factor loadings nor the intercepts. Metric invariance analyses constrain the loadings to be equal across groups but allow the intercepts to be freely estimated. When compared to configural invariance models, metric invariance models examine whether or not the factor loadings are invariant across groups. Finally, scalar invariance, the most stringent form of structural invariance, constrains both the unstandardized factor loadings and the intercepts to be equal across groups. When compared to metric invariance models, scalar invariance models examine whether or not the intercepts are invariant across groups. Invariance across sex, ethnicity, and race was tested at these three levels of invariance. In each set of analyses, the configural invariant model was compared to the metric invariant model and the metric invariant model was compared to the scalar invariant model using a variety of fit criteria. Differences in model fit were tested not only by whether the chi square difference test was significant but also, as has become increasingly frequent in invariance testing (e.g., Putnick & Bornstein, 2016), by a) the difference in CFI values was greater that 0.01 (Cheung & Rensvold, 2002), and b) the difference in RMSEA and SRMR was greater than 0.015 (Chen, 2007).

Results

Testing the structure of the BAS

The one-factor model—In the one-factor model, the BAS items all loaded onto one general factor (with no facets or group factors). This model had poor fit, χ^2 (65) = 1709.99, $p < .001$, CFI = .76, RMSEA = .102, SRMR = .07.

The three-factor models.—We tested two different three-factor models in which all of the BAS items loaded onto one of three group factors identified by Carver and White (1994; Drive, Reward Responsivity, and Fun Seeking). In the first model, the three BAS group factors were constrained to be orthogonal to one another. This model is likely to strike the reader as highly implausible and was only tested for the sake of comparison – since we intended to test a hierarchical factor structure, the inclusion of an orthogonal group factor model was necessary to be able to test whether the inclusion of a general factor accounts for a significant proportion of the variance in the model (Gorsuch, 2013). As expected, the orthogonal three-factor model demonstrated poor fit, χ^2 (65) = 1902.99, $p < .001$, CFI = .73, RMSEA = 0.110, SRMR = .16.

However, the oblique three-factor model, in which the three group factors were allowed to correlate, demonstrated acceptable fit, χ^2 (62) = 748.47, $p < .001$, CFI = .90, RMSEA = 0.067, SRMR = .05. As long as the three factors were allowed to correlate, as Carver and White (1994) would suggest, we are able to replicate the original factor structure of the BAS.

Four-factor hierarchical model.—Finally, we tested a four-factor hierarchical model in which each of the BAS items loaded both on a general factor *and* on one of the three group factors (Drive, Reward Responsivity, and Fun Seeking). This model demonstrated good fit, χ^2 (52) = 473.64, p < .001, CFI = .94, RMSEA = 0.058, SRMR = .04. This model fit best across all three indices and fit significantly better than any of the other models, *ps* < .001. In addition to the differences in model fit being statistically significant, comparison of the Bayesian Information Criteria (BIC), a parsimony-adjusted fit measures for which smaller values are better, shows that the hierarchical model had a lower BIC (56589.83) than the one-factor model (57724.78), the three-factor orthogonal model (57724.78), and the three-factor oblique model (56786.66), again supporting that it is the best fitting model of the models tested here. The standardized factor loadings for the four-factor hierarchical model can be found in Table 1.

The significant increment in model fit compared with the orthogonal three factor model indicates that the general factor accounts for a significant proportion of the variance beyond that which can be accounted for by the three group factors alone. Additionally, the squared correlation between the total score and the general factor (ω_h), revealed that approximately 68.3% of the variance in BAS total scores is attributable to the general factor, lending support for the interpretability and coherence of total scale scores.

Likewise, the significant increment in fit compared with the one factor model indicates that the three group factors account for a significant proportion of the variance beyond that which can be accounted for by the general factor alone. Given this, we examined the general factor saturation (i.e., the squared correlation between the subscale score and the general factor) and group factor saturation (i.e., the squared correlation between the subscale score and its corresponding group factor) for each of the three BAS subscales. For drive, 30.4% of the variance in drive subscale scores is attributable to the drive factor whereas 46.7% of the variance in drive subscale scores is attributable to the general factor. For reward responsivity, 27.0% of the variance in drive subscale scores is attributable to the Reward Responsivity factor whereas 41.0% of the variance in reward responsivity subscale scores is attributable to the general factor. For fun seeking, 30.1% of the variance in fun seeking subscale scores is attributable to a Fun Seeking factor whereas 38.2% of the variance in reward responsivity subscale scores is attributable to the general factor.

The significant increment in fit compared with the oblique three factor model might indicate that the items have direct associations with the general factor rather than associations with the general factor that are mediated by the group factors as specified in a higher-order representation of the oblique group factor model (Yung, Thissen & McLeod, 1999). However, this interpretation is controversial as Murray & Johnson (2013) argued that comparisons conceptually identical to this one are biased in favor of the hierarchical model. Indeed, we acknowledge that the question of whether items have direct associations with the general factor rather than associations with the general factor that are mediated by the group factors is a thorny one. Fortunately, however, this question is not central to our primary aims. We used the hierarchical model not because we believe it to be conceptually superior to the higher-order model but rather because it allows for a clean decomposition of variance due to a general factor versus variance due to group factors. Next, we tested the invariance of this model across sex, race, and ethnicity.

Structural Invariance of the BAS

Invariance across sex.—To test for invariance across sex, male participants (*N* = 780, 32.0%) were compared to female participants (*N* = 1656, 68.0%). 4 participants did not report their sex and were excluded from analyses. The configural invariant model showed good fit, χ^2 (104) = 533.37, p < .001, CFI = .94, RMSEA = 0.058 [.053, .063], SRMR = .04, BIC = 56918.61, suggesting that a similar factor structure was present for both men and women. The metric invariant model also showed good fit, χ^2 (130) = 564.33, p < .001, CFI = .94, RMSEA = 0.052 [.048, .057], SRMR = .04, BIC = 56746.83. Furthermore, the metric invariant model did not show a significant decrement in fit in any of the comparison measures when compared to the configural invariant model, $\Delta\ \chi^2$ (26) =30.97, p = 0.230, ΔCFI = 0.001, ΔRMSEA = 0.006, ΔSRMR = 0.006, suggesting that the loadings did not significantly differ between men and women. Scalar invariance testing across sex also showed good fit, χ^2 (139) = 590.54, p < .001, CFI = .93, RMSEA = 0.052 [0.047, 0.056], SRMR = .04, BIC = 56702.85. Though the scalar invariant model showed a significant decrement in fit from the metric invariant model according to the χ^2 difference test, $\Delta\ \chi^2$ (9)=26.07, p = 0.002, the difference in the other comparison measures suggested inconsequential differences between the two models, ΔCFI = 0.003, ΔRMSEA = 0.000, ΔSRMR = 0.000. Therefore, though the differences in intercepts between men and women are statistically significant, the differences are small and likely inconsequential. Finally, ω_h, revealed that approximately 67.6% of the variance in BAS total scores is attributable to the general factor in men and 68.2% in women suggesting that a total score is interpretable and meaningful across sexes.

Invariance across ethnicity.—To test for invariance across ethnicity, non-Hispanic participants (*N* = 1902, 77.3%) were compared to Hispanic participants (*N* = 519, 22.7%). The 40 participants (1.6%) who did not report their ethnicity were excluded from this analysis. The configural invariance model showed good fit, χ^2 (104) = 514.60, p < .001, CFI = 0.94, RMSEA = 0.057 [.052, .062], SRMR = .04, BIC = 56263.64, suggesting that a similar factor structure was present across groups (see Table 2). The metric invariant model also showed good fit, χ^2 (130) = 578.70, p < .001, CFI = .93, RMSEA = 0.053 [0.049, 0.058], SRMR = .05, BIC = 56125.14. Though the metric invariant model showed a significant decrement in fit from the configural invariant model according to the χ^2 difference test, $\Delta\ \chi^2$ (26)=64.09, p < 0.001, the difference in the other comparison measures suggested inconsequential differences between the two models, ΔCFI = 0.005, ΔRMSEA = 0.004, ΔSRMR = 0.01. Therefore, though the differences in loadings between Hispanic and non-Hispanic individuals are statistically significant, the differences are small and likely inconsequential. Finally, the scalar invariance model also showed good fit, χ^2 (139) = 590.42, p < .001, CFI = .93, RMSEA = 0.052 [0.048, 0.056], SRMR = .047, BIC = 56066.74. Furthermore, the scalar invariant model did not show a significant decrement in fit in any of the comparison measures when compared to the metric invariant model, $\Delta\ \chi^2$ (9) =11.73, p = 0.230, ΔCFI = 0.001, ΔRMSEA = 0.001, ΔSRMR = 0.001, suggesting that the intercepts did not significantly differ between Hispanic and non-Hispanic individuals.

Additionally, ω_h revealed that the majority of the variance in BAS total scores is attributable to the general factor across both Hispanic (70.89%) and non-Hispanic participants (67.24%), suggesting that a total score is similarly meaningful across ethnic groups.

Invariance across race.—Next, to test for invariance across race we compared White (N = 1,165, 47.34%), Asian (N = 623, 25.31%), Black (N = 185, 7.52%), and multi-racial participants (N = 171, 6.95%). Participants who identified as American Indian or Alaskan Native (N = 32, 1.30%) were excluded due to insufficient group size. The 285 participants (11.58%) who did not report their race were also excluded. The configural invariance model showed good fit, χ^2 (209) = 640.66, p < .001, CFI = 0.93, RMSEA = 0.062, [.057, .068], SRMR = .04, BIC = 50087, suggesting that a similar factor structure was present across racial groups (see Table 3). The metric invariant model showed acceptable fit, χ^2 (287) = 870.19, p < .001, CFI = .90, RMSEA = .062 [.057, .066], SMRM = .07, BIC = 50498.31. The metric invariant model fit significantly worse than the configural invariant model by most of the comparison measures, $\Delta\ \chi^2$ (78) =229.53, p < 0.001, ΔCFI = 0.025, ΔRMSEA = 0.000, ΔSRMR = 0.026, suggesting that some of the loadings were significantly and meaningfully different between racial groups. As shown in Table 2, however, this appears to apply to a relatively small number of the loadings. Thus, of the 78 pairs of comparisons between loadings in one of the non-White groups and in the White group, the differences were greater than or equal to .20 in only 8 of them and greater than or equal to .30 in only 1 of them. Therefore, whereas some loadings were significantly and meaningfully different across groups, the vast majority of these differences were small.

Finally, the scalar invariant model across race also showed acceptable fit, χ^2 (314) = 939.44, p < .001, CFI = .90, RMSEA = 0.061, SRMR = .07. Though the scalar invariant model showed a significant decrement in fit from the metric invariant model according to the χ^2 difference test, $\Delta\ \chi^2$ (27)=66.25, p < 0.001, the difference in the other comparison measures suggested inconsequential differences between the two models, ΔCFI = 0.006, ΔRMSEA = 0.001, ΔSRMR = 0.004. Therefore, though the differences in intercepts between racial groups are statistically significant, the differences are small and likely inconsequential. Additionally, ω_h revealed that the majority of the variance in BAS total scores is attributable to the general factor across racial groups: White (68.89%), Black (62.88%), Asian (67.90%), and multi-racial (67.24%), suggesting that a total score is similarly meaningful across groups.

Discussion

The current study observed that the best fitting BAS factor model of those we tested was a hierarchical model with three group facets and a general factor and that this model was largely invariant across sex, ethnicity, and race. We show, for the first time, that a general factor accounts for the majority of the variance in BAS total scores. For a total score to be interpretable, a general factor has to account for at least 50% of the total score variance (Revelle, 1977). By accounting for 62.88% to 70.89% of the variance in BAS total scores depending on the sex, ethnicity, and race of participants, the current study suggests that a BAS total score is interpretable across groups. Due to the superior fit of the hierarchical model and total score variance accounted for by the general factor, we conclude that researchers are psychometrically justified in using a BAS total score.

The superiority of a model with a significant contribution from a general factor is theoretically consistent with Gray's original conceptualization of the BAS as a unitary system driving appetitive motivation. Furthermore, the facets that are present in addition to the general factor are consistent with other research illustrating the heterogeneity of reward striving (e.g., Berridge & Robinson, 2003; Carver & White, 1994). Thus, the results of the current study highlight both the unity (general factor) and diversity (group factors) of approach motivation as measured by the BAS.

The results of the current study suggest that researchers should pay attention to BAS total scores when considering the role of individual differences in the behavioral approach system in predicting cognitive, emotional, and behavioral reactions to appetitive stimuli. Although we report that much of the variance in BAS total scores is attributable to a general factor, the three group factors or facets of the BAS did account for a significant proportion of the variance in BAS items beyond that which can be accounted for by the general factor alone. Thus, we do not suggest that future researchers abandon a subscale approach to studying the BAS. Rather, the results of the current work strongly suggest that future researchers are justified in incorporating a total score in addition to subscale scores (or using some other psychometric method for teasing apart the effects of the general factor from those of the group factors) when using the BAS scale to investigate the behavioral approach system. Moreover, our analysis of ω_h for the subscales revealed that each of the general factor accounted for more variance in each of the three subscales (38.2% – 46.7%) than their corresponding group factors (27.0% – 30-4%) suggesting that the group factors are at least as saturated with variance due to the general factor as with their corresponding group factor. This suggests that the results of past research involving any given subscale score may be due to the general factor rather than to the corresponding group factor. Moving forward, we advise that future researchers interested in BAS subscale scores parse the variance of the general factor from that of the group factors in their analyses. One possibility for doing so is to use a hierarchal measurement model for the BAS similar to the one we used in the current paper. Alternatively, researchers using observed subscale scores can regress outcomes of interest onto the subscales entered as a set into a hierarchical multiple regression. In this later approach, it may be that the subscales as a set make a significant contribution to predicting the outcome in the absence of significant regression coefficients for any of the three subscale scores. In this case, it would suggest that the association between BAS and that outcome is due to the general factor.

The results of the current study have implications for research domains in which the BAS has been widely utilized. For example, the BAS has been often used in research linking approach motivation to left-lateralized patterns of frontal brain activity (e.g., Coan & Allen, 2003; Harmon-Jones, Gable, & Peterson, 2010; Harmon-Jones & Gable, 2018). However, recent studies (e.g., Gable, Mechin, Hicks, & Adams, 2015) and meta-analytic evidence (e.g., Wacker, Chavanon, & Stemmler, 2010) suggest that the association between approach-related traits (e.g., behavioral approach system, extraversion) and frontal asymmetry is weaker than commonly assumed. One possible reason for these findings is inconsistencies in the measurement of BAS. By highlighting a hierarchical structure to the BAS, the results of the current work can be used to more precisely interrogate the associations between BAS sensitivity and asymmetric frontal cortical activity.

The current study also has two key implications for cross-cultural research using the BAS. First, the results reported here suggest that the BAS can be used to test for quantitative differences in approach motivation as a function of sex, ethnicity, and race among English-speaking samples of the racial and ethnic groups we studied. Second, the results reported here suggest that the BAS can be used in heterogeneous samples – both in terms of sex, race, and ethnicity. The current research replicates past research revealing invariance across sex (Campbell-Sills, Liverant, & Brown, 2004). Like past research we also observed invariance across racial groups (e.g., Demianczyk et al., 2014). However, this previous research had to modify Carver and White's original measure to do so. As they note, "most of the modification that were needed to obtain fit were cross-loading multiple observed variables onto multiple factors" (Demianczyk et al., 2014., p. 492). It is often the case that items with cross-loadings in non-hierarchical models have the strongest loadings on a hierarchical general factor in a hierarchical representation of the factor structure[2]. Thus, if they used a hierarchical model like the current study, they likely would have obtained evidence of invariance for it. Demianczyk and colleagues also tested for invariance among White, Black, and Asian participants as we did in the current research. We extend this work by testing for invariance across these groups in a hierarchical model and also including a multi-racial group. We then show for the first time that a hierarchical factor structure of the BAS is invariant across both race and ethnicity. Whereas invariance across race and ethnicity is understudied and replications of our results are needed, the potential of the hierarchical model of the BAS to be used in heterogeneous populations is promising.

The BAS has been translated into a number of languages including Spanish (Perczek, Carver, Price, & Pozo-Kaderman, 2000), German (Strobel, Beauducel, Debener, & Brocke, 2001), French (Caci, Deschaux, & Baylé, 2007), Dutch (Franken, Muris, & Rassin, 2005), Polish (Müller & Wytykowska, 2005), and Portuguese (Moreira, Almeida, Pinto, Segarra, & Barbosa, 2015) among others. As in research using the BAS in English-speaking samples, research in non-English speaking samples has yet to explore the hierarchical factor structure of the BAS as in the current research. As a result, it remains unclear whether the BAS general factor is present and meaningful to the same degree in non-English speaking samples. Future research should test this possibility. Along these same lines, the BAS has also been used in a number of populations including children (e.g., Muris, Meesters, de Kanter, & Timmerman, 2005), offenders (e.g., Poythress et al., 2008), eating disorder patients (e.g., Beck et al., 2009), drug addicts (e.g., Dissabandara et al., 2012), and those with anxiety and mood disorders (e.g., Campbell-Sills et al., 2004). Future work should also explore whether the BAS general factor is present and meaningful in these groups as well.

[2]The logic for this argument follows from a Schmid-Leiman (S-L) transformation of a higher-order representation into a hierarchical one in which an item's loading on the general factor in the hierarchical representation is derived by a two-step process: (1) for each group factor it loads on, multiply the item's loading on the group factor times that group factor's loading on the higher-order factor and (2) summing all of those products across the various group factors it loads on. So, if an item loads on only one group factor with a loading of .6 and that factor loads .6 on the higher-order factor then the S-L transformation generates a general factor loading of $.6 \times .6 = .36$. If you add a cross-loading on a second group-factor of say .4 and that second group factor loads .5 on the higher-order factor then the S-L transformation generates a general factor loading of $(.6 \text{ X } .6) + (.4 \times .5) = .56$.

Despite growing interest in reproducibility, the role of measurement issues in reproducible science has been less appreciated (see Fried & Flake, 2018). An important psychometric property of a total score derived from a multidimensional measure is whether it can be interpreted as primarily being a measure of a single construct (McDonald, 1999; Zinbarg et al., 2005). Ignoring this psychometric property can lead to false positives and failures to replicate. For example, research on Type-A personality and cardiovascular disease long assumed a general factor (Type-A personality) predicted risk for coronary artery disease (Friedman & Rosenman, 1959; Rosenman et al., 1970; Jenkins, Rosenman, & Zyzanski 1974; Rosenman, Brand, Sholtz, & Friedman 1976; Haynes, Feinlab, & Kannel, 1980). However, recent studies find no association between Type-A personality and cardiovascular health (e.g., Kuper, Marmot, & Hemmingway, 2005; Bunker et al, 2003). One possibility for this pattern of results is that early work treated Type-A personality as unidimensional while recent research has found that Type-A personality is better conceptualized as a multidimensional construct (Edwards, Baglioni, & Cooper, 1990). Consistent with this viewpoint, the hostility facet of Type-A personality rather than a general factor predicts cardiovascular health outcomes (Dembroski & Cost, 1987; Myrtek, 2001; Chida & Steptoe, 2009). Thus, research on Type-A personality and cardiovascular health was improved by considering the utility of total score derived from a multidimensional scale. In the interest of producing robust findings, researchers should pay special attention to the interpretability of total scores derived from multidimensional scales as doing so may help clarify and prevent failures to replicate findings. The results of the current study highlight the feasibility of this approach.

Limitations and Conclusion

Carver once said, “I do not encourage combining the BAS scales, however, because they do turn out to focus on different aspects of incentive sensitivity” (Carver, 2007). We take this quote to imply that the general factor of BAS does not have explanatory value above and beyond the subscale scores and that the subscales do not share enough variance related to incentive sensitivity for a total score to be meaningful. In the current paper we show that the four-factor hierarchical model, which includes the three subscales and a general factor, has better fit indices than other models, suggesting that both the general factor and subscale scores have explanatory value. Furthermore ω_h in this model supports the notion that the general factor explains a large proportion of the variance in BAS total scores, lending additional support for the explanatory importance of the general factor and the coherence of a total score.

However, just because we can extract a meaningful general factor does not mean it is the most useful unit of analysis – it only means it is a *valid* unit of analysis. Perhaps a more compelling argument for the general factor scoring (i.e., total score) than model fit or value of ω_h would be in its ability to account for important outcomes. For example, one would need to show that for a given purpose, such as predicting a specific outcome, the general factor adds unique predictive information that is not gleaned from the group/lower-order factors. Future studies should test this possibility to determine whether the general factor is indeed useful in predicting outcomes above and beyond the group/lower-order.

A second limitation of the current research is that our sex, race, and ethnic composition is not representative of the US population. As a result, the factors that accounted for self-selection into our sample might have impacted the results in unknown ways. That is, our results might only generalize to the population of those willing to participate in research. Mitigating the seriousness of this limitation is the fact that future research using the BAS is likely going to be limited to the same population. Thus, whereas we cannot speak to whether there are sex or ethnic/racial differences in the structure of approach motivation in the general population, the present results do suggest that such differences are likely to be small among the population willing to participate in research studies similar to ours. Future studies with more representative samples are warranted to determine whether or not the factor structure we observed holds in those samples as well.

A third limitation of the current study concerns the measurement of BIS. The larger project from which this data was taken was not specifically designed to test the psychometric properties of the BIS/BAS scales and thus the BIS scale was not included. As a result, we are unable to give a complete picture of the psychometric properties of behavioral inhibition and approach. Although previous research has observed that the BIS is also not unidimensional (Neal & Gable, 2017; Heym et al., 2008) to date a hierarchical factor structure of the BIS has yet to be explicitly tested. Future research should simultaneously test for a hierarchical structure on both the BIS and BAS scales in the same representative sample.

In conclusion, the current work suggests that the best fitting BAS factor model of those we tested was a hierarchical model with three group facets and a general factor. This model was largely invariant across both sex and race/ethnicity. Contrary to the advice of its developer, we show, for the first time, that a general factor accounts for the majority of the variance in BAS total scores such that BAS total scores are interpretable. We hope that this work will pave a new path forward in research on the behavioral approach system.

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Highlights

- We compared the fit of four factor models of Carver and White’s BAS scale.
- The best fitting model was hierarchical with 3 group factors and a general factor.
- This model was largely invariant across sex, ethnicity, and race.
- A general factor accounts for the majority of the variance in BAS total scores.
- Researchers are psychometrically justified in using a BAS total score.

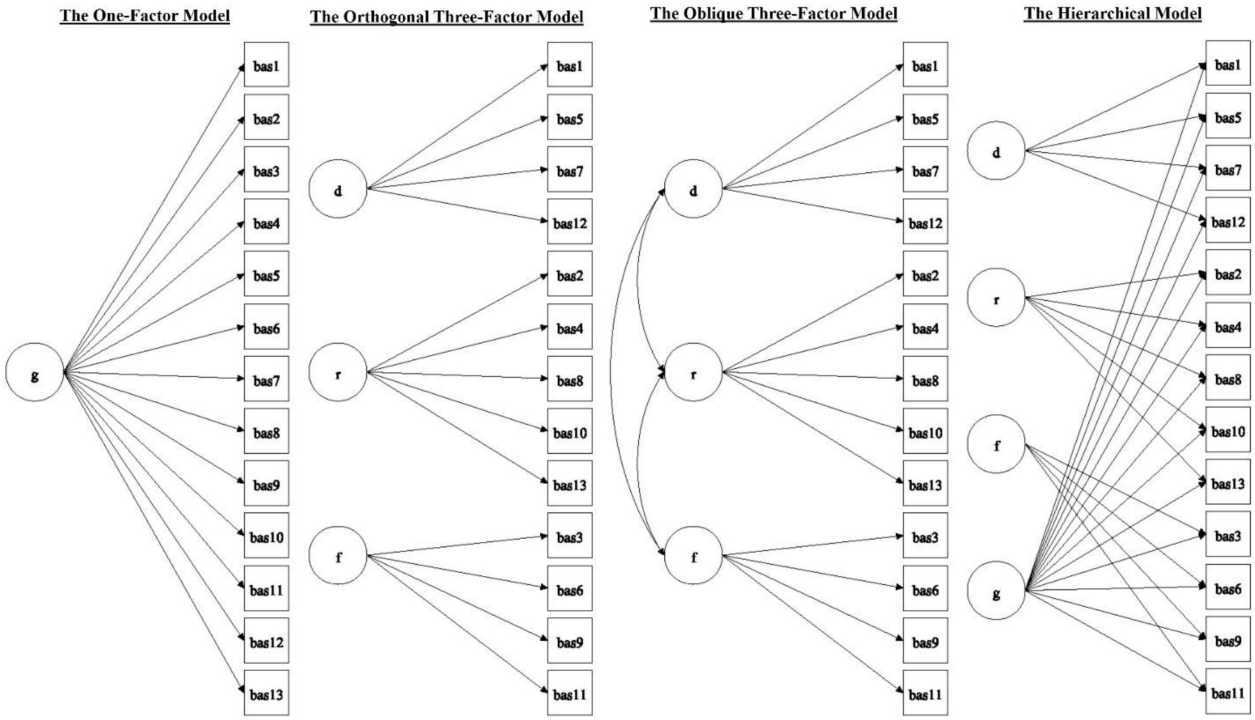

Figure 1.

Schematic diagrams of the four models tested in the current study. The models depicted from left to right are: 1) a one factor model, 2) an orthogonal three group factor model. 3) an oblique three group factor model, (4) a four-factor hierarchical model with a general factor and three group factors. ***Note:*** g – General Factor; d – Drive Subscale; r – Reward Responsivity Subscale; f – Fun Seeking Subscale.

Table 1.

Standardized factor loadings for the hierarchical model in the full sample.

Item	Item Text	GF	D	RR	FS
1	I go out of my way to get things I want.	0.37	0.55		
2	When I'm doing well at something I love to keep at it.	0.26		0.30	
3	I'm always willing to try something new if I think it will be fun.	0.41			0.30
4	When I get something I want, I feel excited and energized.	0.43		0.43	
5	When I want something I usually go all-out to get it.	0.49	0.65		
6	I will often do things for no other reason than that they might be fun.	0.35			0.57
7	If I see a chance to get something I want I move on it right away.	0.61	0.24		
8	When I see an opportunity for something I like I get excited right away.	0.57		0.25	
9	I often act on the spur of the moment.	0.47			0.36
10	When good things happen to me, it affects me strongly.	0.43		0.40	
11	I crave excitement and new sensations.	0.53			0.31
12	When I go after something I use a "no holds barred" approach.	0.58	0.25		
13	It would excite me to win a contest.	0.38		0.34	

Note: GF – General Factor; D – Drive Subscale; RR – Reward Responsivity Subscale; FS – Fun Seeking Subscale

Table 2.

Standardized factor loadings for the configural invariant models for ethnicity.

	Hispanic				Non-Hispanic			
Item	**GF**	**D**	**RR**	**FS**	**GF**	**D**	**RR**	**FS**
1	0.42	0.34			0.36	0.56		
2	0.33		0.28		0.22		0.31	
3	0.45			0.24	0.39			0.34
4	0.32		0.41		0.44		0.43	
5	0.51	0.83			0.48	0.67		
6	0.41			0.28	0.33			0.62
7	0.56	0.17			0.62	0.24		
8	0.52		0.36		0.58		0.21	
9	0.48			0.09	0.46			0.41
10	0.38		0.43		0.43		0.41	
11	0.53			0.50	0.52			0.31
12	0.63	0.03			0.58	0.28		
13	0.32		0.44		0.39		0.30	

Table 3.

Standardized factor loadings for the configural invariant models for race

	White				Asian				Black				Multiracial			
Item	**GF**	**D**	**RR**	**FS**	**GF**	**D**	**RR**	**FS**	**GF**	**D**	**RR**	**FS**	**GF**	**D**	**RR**	**FS**
1	0.39	0.50			0.38	0.62			0.12	0.65			0.40	0.45		
2	0.26		0.18		0.21		0.48		0.19		0.43		0.26		0.09	
3	0.40			0.34	0.38			0.30	0.41			0.91	0.41			0.25
4	0.48		0.33		0.39		0.46		0.36		0.56		0.44		0.39	
5	0.52	0.63			0.52	0.62			0.29	0.78			0.37	0.82		
6	0.32			0.5	0.36			0.55	0.54			0.08	0.37			0.65
7	0.63	0.23		9	0.65	0.12			0.36	0.42			0.61	0.35		
8	0.57		0.20		0.53		0.32		0.54		0.47		0.62		0.10	
9	0.43			0.4 3	0.51			0.42	0.57			−0.21	0.48			0.49
10	0.44		0.45		0.37		0.35		0.42		0.39		0.38		0.72	
11	0.50			0.34	0.52			0.22	0.72			0.05	0.52			0.35
12	0.59	0.19			0.61	0.26			0.31	0.47			0.66	0.34		
13	0.37		0.33		0.32		0.40		0.34		0.28		0.43		0.27	

Note: GF – General Factor; D – Drive Subscale; RR – Reward Responsivity Subscale; FS – Fun Seeking Subscale