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Agentic extraversion as a predictor of effort-related cardiovascular response

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Abstract

The present study examined an extraversion-based extension of the integrative model of cardiovascular effort regulation by Wright and Kirby (2001). This model explains cardiovascular effort-reactivity in terms of task difficulty, ability appraisal, and success importance. Aggregate measures of cardiovascular variables (alpha-adrenergic, beta-adrenergic, and cholinergic activation components) were used to measure extraversion-based differences in effort. Subjects performed a sequential letter task (n-back verbal working memory task) with four levels of difficulty. Agentic extraverts (*n* = 10) appraised their ability and happiness as significantly higher than introverts (*n* =10). Introverts showed the expected shark-fin shaped pattern of effort-related cardiovascular reactivity for the alpha-adrenergic and cholinergic activation components. Effort decreased after the moderately difficult 2-back task. Results provide first evidence for an extraversion-based extension of the model and are discussed with regard to mood and resource allocation as possible mechanisms.

Keywords: agentic extraversion, effort, task engagement, active coping, activation components, beta-adrenergic activation, alpha-adrenergic activation, cholinergic activation

Introduction

Mental effort investment has been introduced as an energetical supply mechanism that serves to achieve cognitive goals (Mulder, 1986). The mobilization of mental effort is seen as a compensatory strategy (Hockey, 1997) or an active coping mechanism (Obrist, 1981) subserving the achievement of goals under increasingly difficult task conditions or other psychological stressors. Besides performance measures, self-reports, and measures of the N100 and P300 amplitude (e.g., Beauducel et al., 2006), somatovisceral parameters have been employed to assess mental effort (Gendolla and Richter, 2005). In contributing to the explanation of effort-related somatovisceral responses, the present paper focuses on the investigation of the integrative model of cardiovascular reactivity presented by Wright and Kirby (2001). Since habitual individual differences of effort-related somatovisceral responses are not a main focus of the "Wright-Kirby model", we here propose an extraversion-based extension together with broader physiologically-informed measures of cardiovascular parameters. After a brief description of the model, we probe the relevance of extraversion, more specifically, the agency facet of extraversion, in the context of effort-related cardiovascular responses.

The Integrative Wright-Kirby Model of Cardiovascular Reactivity (2001)

The integrative model[i] specifies conditions under which individuals ought to invest more or less effort in a task and offers a framework for predicting effort-related cardiovascular responses. According to this model, predictors of effort-related cardiovascular responses are (a) the difficulty of a task, (b) the appraised ability to cope with it, and (c) the importance of successful performance. This latter determinant reflects "the upper bound of what people would be willing to do to succeed" in a given task (Wright and Kirby, 2001, p. 260) and defines whether potential success is worth the effort. In general, effort is assumed to rise with task difficulty up to the point where (a) difficulty is appraised as too high and success as impossible or (b) effort is no longer justified by the benefit variables need, incentive value, and outcome expectancy.

Implications for effort reactivity are as follows. First, individuals with low compared to high ability appraisal compensate for their assumed ability deficit by investing more effort; therefore they show stronger cardiovascular responses at least as long as success is deemed possible and worthwhile. Second, individuals with low compared to high ability appraisal withhold their effort at a lower objective difficulty level, because task demands exceed their perceived ability. Individuals with high ability appraisal should stay engaged, try harder and show stronger cardiovascular responses until they too consider success as excessively difficult or costly to achieve, at which point they should disengage as well. Remarkably, when task difficulty is extremely high, effort and cardiovascular responses will be low regardless of ability appraisal or success importance. Hence, task difficulty and effort expenditure are related by a non-monotonic, shark-fin shaped function, which is shifted more towards higher task difficulty levels for high than low ability appraisal individuals.

Briefly, the integrative model implies that with increasing task difficulty effort and cardiovascular responses follow a shark-fin shaped function. As long as success seems possible, effort increases proportionally with difficulty but drops sharply at higher objective difficulty levels depending on the individual's appraised ability to meet the challenge.

Extraversion and Effort Regulation

Several authors have addressed extraversion-based differences in effort reactivity (e.g., Beauducel et al., 2006). However, within the integrative model the potential influence of extraversion on effort has not yet been investigated. But an elaboration of the integrative model has related mood to effort investment. In the mood-behavior-model, Gendolla (2000) argued that mood is a diagnostic information used for challenge-related judgments. Indeed, inducing positive vs. negative mood, Gendolla and colleagues (2001) demonstrated that individuals in a positive mood appraised their ability as higher than individuals in a negative mood. Furthermore, individuals in a positive mood displayed less effort than those in a negative mood.

Extraversion has been related to positive mood (Depue and Collins, 1999; Larsen, 2000) and confidence in achieving goals (Pearce-McCall and Newman, 1986). According to Depue and Collins (1999), agentic extraversion can be characterized as a motivational disposition comprising social dominance, enthusiasm, energy, assertiveness, ambitiousness, reward sensitivity, and achievement striving. Consequently, agentic extraverts can be expected to be more optimistic about their own ability and to face task demands more fully than agentic introverts. Thus, up to the point of introverts' disengagement agentic extraverts should spend less effort than agentic introverts and stay engaged even when the task gets too difficult for introverts (see Figure 1).

Please insert Figure 1 about here

Cardiovascular Reactivity

Obrist (1981) postulated that effort engages beta-adrenergic activation. However, cardiovascular variables such as diastolic and systolic blood pressure or heart rate, which have often been used as effort indicators (e.g., Annis et al., 2001; Wright et al., 1997; Wright et al., 1994), are not targets of beta-adrenergic activation alone or even predominantly so. Autonomic receptor blockade studies have consistently demonstrated that heart rate increases with a rise in beta-adrenergic tone and a withdrawal of cholinergic tone, whereas systolic blood pressure increases with a rise in both alpha- and beta-adrenergic tone (Berry et al., 1959; Nelson et al., 1984). Stemmler (1993; 2003) has shown that these "activation components" can be estimated from a larger array of autonomic variables. Using these index variables, a purer picture of the type of activation elicited by a specific effort-inducing task can be obtained.

While progress in measuring activation components could more clearly describe effort related cardiovascular activity, conceptual distinctions between different aspects of effort related processing could help predict when to expect more of a beta-adrenergic or alpha-adrenergic cardiovascular pattern of response. In describing two distinct patterns of somatovisceral activation, Schneiderman and McCabe (1989) proposed an active coping or mental effort pattern which should be mainly beta-adrenergic, and a passive coping, vigilance or sensory intake pattern which should be mainly alpha-adrenergic. Thus, in tasks involving both mental work and sensory intake, a sizable amount of vigilance and a passive coping tendency—such as when high task difficulty opposes further effort to succeed—a combination of alpha- and beta-adrenergic activation would be expected. Indeed, increases in alpha-adrenergic tone have been reported during effort expenditure (Blascovich and Tomaka, 1996), in achievement situations promising incentives (e.g., Waldstein et al., 1997), and quite often during mental arithmetic tasks (e.g., Krantz and Manuck, 1984).

Two aspects become apparent from this discussion: (1) Previous studies on the Wright-Kirby model investigated single variables as effort indicators but (2) did not systematically relate to alpha-adrenergic, beta-adrenergic, and cholinergic activation. Instead of single cardiovascular variables, a larger sample of variables would be useful for making inferences about cardiovascular activation components and subsequently about the mechanisms underlying previously observed physiological ability and difficulty effects. Consequently, we employed a larger sampling of variables indicative of alpha-adrenergic, beta-adrenergic, and cholinergic activation to investigate their status as effort indicators (see Method section). Previous studies have investigated the role of activation components predominantly in the context of emotions (Stemmler, 2003; Stemmler et al., 2007). Here we are employing the concept of activation components for the first time in the context of effort reactivity.

Tasks for the Investigation of Cardiovascular Effort

For over a decade Wright and colleagues have studied effort and cardiovascular responses as a function of ability appraisal, task difficulty, and success importance. Studies reporting somatovisceral parameters mostly used cognitive tasks with two or three difficulty levels, for example, math problems (Wright et al., 1994) or memory tasks (Wright et al., 1997). For cognitive tasks with three difficulty levels,[ii] Annis et al. (2001) and Wright et al. (1994) reported a shark-fin shaped pattern of cardiovascular reactivity in low-ability, but a linear pattern in moderate- or high-ability groups. A reason for this discrepancy could be that task difficulty levels were not large enough for the high-ability group; to be sure, the Wright-Kirby model predicts a shark-fin shaped pattern of effort also for the latter group. To increase the chances of finding the predicted effort pattern in both groups, in this study we employed a cognitive task with four difficulty levels.

Overview and Predictions

The goals of the current investigation were twofold. First, we wanted to examine whether agentic extraversion can be integrated into the Wright-Kirby model of cardiovascular reactivity. Second, we wanted to gauge cardiovascular effects of task difficulty and extraversion-related differences in ability appraisal with activation components that are expected to map more accurately the underlying physiological systems.

As agentic extraversion is at least moderately correlated with positive affect (Depue and Collins, 1999), individuals with high compared to low agentic extraversion should report more positive affect and -- in line with the mood-behavior-model -- in a performance task should appraise their ability as higher. Regardless of extraversion, ability appraisal should linearly decrease with increasing task difficulty (Wright and Kirby, 2001).

For task performance measures (reaction time and accuracy) we expected a difficulty-contingent decline in performance. Agentic extraverts should display a smaller performance decrement than introverts (Lieberman and Rosenthal, 2001).

Our primary hypothesis concerning cardiovascular reactivity was based on the assumption that introverts and extraverts would show a shark-fin shaped trend pattern of cardiovascular reactivity as predicted by the Wright-Kirby model. Agentic introverts should demonstrate disengagement at a lower objective level of task difficulty than extraverts (see Figure 1). Since we could not know in advance whether the highest level of task difficulty would be large enough to induce effort withdrawal also in agentic extraverts, we expected one of two patterns of results. (1) If levels of task difficulty were appropriately large, extraverts should show a shark-fin shaped pattern of effort with effort decrement occurring at a higher level of objective task difficulty than for introverts (see Figure 1). (2) If levels of task difficulty were not large enough, extraverts should show an increasing linear trend of effort reactivity across levels of difficulty. Because agentic extraverts are expected to have a higher ability appraisal, their effort expenditure should be below that of introverts. This assertion should be true for task difficulty levels below the introverts' point of disengagement.

Method

Participants

To select extreme groups of extraverted and introverted participants we recruited N = 507 male volunteers by flyers on the university campus and on bulletin boards. They filled out the Marburg Agentic Extraversion scale (MAE; for details see below). Participants scoring above the median in each of the three subscales of the MAE (Well-Being: Md = 6.0; Achievement: Md = 1.5; Social Potency: Md = 3.0) constituted the extraverted extreme group, whereas participants with scores below or equal to the median in all three scales constituted the introverted extreme group. With respect to total Extraversion scores (sum of the three subscales) these extreme groups constituted the upper and lower terciles of the Extraversion score distribution.

Participants included in this study were randomly sampled from these extreme groups.[iii] They were right-handed male university or high school students in Marburg, Germany, and between 18 and 40 years old. Exclusion criteria were consumption of psychotropic substances, chronic or acute illness, intake of medication affecting the circulation, and mental disorders as verified by a brief diagnostic interview (Margraf, 1997) based on DSM-IV criteria. The 20 normotensive male volunteers (Table 1) received 45 Euros (approximately 55 USD) for approximately five hours of participation.

Please insert Table 1 about here

Trait Variables

Depue, Luciana, Arbisi, Collins, and Leon (1994) recommended the Positive Emotionality scale of the Tellegen Multidimensional Personality Questionnaire (MPQ, Tellegen and Waller, 1997) for measuring agentic extraversion. The MAE is an economical German version of this scale. It contains three positively correlated 10-item scales that correspond to the three MPQ primary scales most relevant to positive emotionality: Well-being, Achievement, and Social Potency (see Tellegen and Waller, 1997). We found previously (unpublished observation) that scores in these three MAE scales correlated highly with the respective MPQ primary scales ($r > .85$). The sum of the three scales constituted our aggregate measure of agentic extraversion. The internal consistency of the three short scales was high in the initial sample of $N = 507$ volunteers (Cronbach's $\alpha \geq .81$), as was the consistency of the aggregate measure (Cronbach's $\alpha = .87$). Other assessments included the German version of the Eysenck Personality Questionnaire – Revised (EPQ-R, Ruch, 1999) to assess neuroticism and psychoticism (see Table 1), and the Culture Fair Test 3 (CFT 3, Cattell and Weiß, 1971) to control for differences in fluid intelligence as a possible confound of n-back performance.

The Sequential Letter Task (N-Back Task)

We employed a letter variant of the n-back task which has previously been used to study working memory (e.g., Lieberman and Rosenthal, 2001). Letters (color: white, font: Times New Roman, font size: 60 points, background color: black) successively appeared on a display for 500 ms. Participants responded to each letter by pressing one of two buttons on a response box (one button for targets, the other for non-targets). Following each letter, a black screen was presented for 1,650 ms followed by a 350 ms auditory feedback ("right", "wrong", "too slow"). Slow reactions were defined as responses beyond the 90^{th} percentile of the individual reaction time distribution during the last 50 practice trials. Directly after feedback, the next letter was presented. Each trial lasted 2.5 s.

In the 0-back condition (Task Difficulty: very easy) participants responded to a single target letter ("Q"). In the 1-back condition (Task Difficulty: easy) the target was any letter identical to the preceding one. In the 2-back (Task Difficulty: moderate) and 3-back condition (Task Difficulty: difficult) the target was any letter identical to the one presented two or three trials before, respectively. All n-back conditions were blocked and included 60 practice trials followed by 120 experimental trials. Each block lasted 7.5 min.

Setting and Apparatus

The experiment was conducted in two adjacent rooms. The experimental room (4 x 3.4 m) had no window, was air-conditioned (22 °C), sound-attenuated, and had a largely non-technical appearance. Participants sat comfortably in a reclined position. In front of their seat a table was placed with a 15-in. flat screen monitor and a response box (XQMS, Frankfurt/Main, Germany). Further equipment included a microphone and two loudspeakers. In an adjacent room the following equipment was placed: a Cardiodynagraph (Diefenbach, Frankfurt/Main, Germany) impedance cardiogram (ICG), a 16-channel Biopac system (Biopac Systems, Goleta, USA) with couplers for pulse volume (PPG100), electrocardiogram (ECG100c), and amplification of the ICG signal (DA100), a Dinamap Pro 100 (Critikon, Tampa, USA) blood pressure monitor, two Power Macintosh G3 microcomputers performing data recording, data visualization, and data storage under LabView 5.0 software (National Instruments, Austin, USA) and a PC running experimental control software (Presentation 0.5, Neurobehavioral Systems, Albany, USA). The experimental and the monitoring rooms were separated by two doors, which were closed during the experiment. Whenever necessary, communication with participants was secured by intercom.

Design and Procedure

Design. A 2 (Agentic Extraversion: high, low) x 4 (Task Difficulty: very easy, easy, moderate, difficult) factorial design was used with Agentic Extraversion as a between-subjects and Task Difficulty as a within-subjects factor. To control for sequence effects, the presentation order of task difficulty levels was balanced across participants according to a Latin Square.

Procedure. After written informed consent was obtained, participants filled out the EPQ-R and completed the CFT 3. Afterwards electrodes and transducers were attached. Then the experimental session started between 11 a.m. and 2 p.m. with an explanation of the task and an assessment of state affect (see below). Furthermore, participants could receive a reward if their performance in the task exceeded a pre-defined criterion. The experimental session lasted about 1.5 hours. Participants were given the opportunity to familiarize with the n-back task and to ask questions. The experimenter reminded participants to sit quietly in order to prevent artifacts and left the room.

The experiment started with a 10-minute rest period. Participants were instructed to relax while keeping their eyes open. At the end of the rest period self-report items were presented (see below). Then four experimental blocks followed. Each block comprised one difficulty level of the n-back task, the presentation of self-report items, and performance feedback. The experimenter briefly entered the room to provide feedback and handed out the promised reward if the participant had passed the criterion. To receive a reward (in addition to the participation fee), at least 50% of the responses to target and non-target trials had to be correct. Rewards were popular sweets each worth about 1 Euro. Participants were told that the reward directly depended on their performance, but the criterion was not revealed. Following the last experimental block, further self-report items of emotion, motivation, and performance were presented. Finally, participants were unhooked, led to another room for a brief post-experimental interview, debriefed, paid, and dismissed.

Dependent Variables and Data Reduction

Rating scales. Following the rest period and each task block participants performed a 9-point intensity rating on two unipolar (0 = "not at all applicable", 8="very applicable") and a 9-point bipolar scale (4—0—4, 4 = "very applicable, 0 = "not applicable") tagged by one to four descriptive adjectives.[iv] The scales were selected to capture (a) positive affect assessed via a happiness scale (happy/gay/cheerful/delighted), (b) motivational aspects such as interest (bored/indifferent/dull vs. curious/interested/motivated) and importance of success. Furthermore, participants performed a retrospective rating of ability appraisal and effort expended on two 11-point scales (0-10).

Performance variables. Performance variables were reaction time of correct responses and accuracy. All responses faster than 200 ms were excluded from data analysis. For further details on performance parameters, see Wacker et al. (2006).

Cardiovascular variables. Nineteen parameters were derived from the cardiovascular recordings. Electrode sites for ICG and the electrocardiogram (ECG) were rubbed with a mild abrasive gel (Every, GVB-geliMED, Germany) and cleansed with alcohol to ensure electrode impedances below 10 kΩ. Disposable Ag/AgCl surface electrodes (VivoMed, 8 mm sensor diameter; Servoprax, Wesel, Germany) were used. Our custom software package BodyVision 2.0 written in LabView 5.0 was used for offline visualization, artifact rejection, parameterization, and averaging of all somatovisceral signals.

The ECG was recorded from the right forearm and the left vs. right leg. The signal was sampled at 1000 Hz, amplified by 1000, filtered with a high-pass of 0.5 Hz and a lowpass of 35 Hz. The following seven parameters were extracted: *heart period* (HP, in milliseconds), *heart period variability* (calculated as the mean square of successive heart period differences; in milliseconds squared), *T-wave amplitude* and *P-wave amplitude* (in millivolts), *S-T-segment* (amplitude of the ECG-curve at a point 80 ms past the J-point, which was defined as the first point with a null potential after the S-peak; in millivolts), *PQ-time* (end of P-wave to Q-wave; in milliseconds), and relative *QT-time* (QTLC = T-wave-end - Q-wave-start + 0.154 x [1000 - HP], in milliseconds, see Andrassy et al., 2003).

The ICG was recorded with nine spot electrodes following the recommendations of Woltjer et al. (1996) and Raaijmakers et al. (1998). One electrode was placed on the forehead, two laterally on the neck, and two further electrodes were attached to the thorax laterally at the processus xiphoideus level. Four electrodes were attached on the abdomen equally spaced in a semi-circle. The dZ/dt-signal was amplified by 10, filters set to AC, and sampled at 1000 Hz. Parameterization was performed with BodyVision 2.0 on the ensemble average triggered by the R-wave within each data recording. The B-notch was defined as the intersection of a straight line fixed at the E-wave maximum and the dZ/dt-signal preceding the E-wave. The straight line had a slope of 80% of the maximum E-wave slope. This B-notch determination was used due to the frequent problems in locating the B-notch.

Eight parameters were derived: *ejection speed* (ES, amplitude of E-wave; in Ohms per second), *left ventricular ejection time* (LVET, time between B-notch and X-point; in milliseconds), *RZ-time* (time between R-wave of ECG and E-wave maximum in ICG; in milliseconds), *Heather-index* (ES x 1000 / RZ-time; in Ohms per second squared), *preejection period* (Q-wave in ECG to B-notch in ICG; in milliseconds). *Stroke volume* (SV, in milliliters) was estimated using the formula of Kubicek et al. (1966; 0.135 x [L / Z0] ^ 2 x LVET x ES, with L = distance of inner electrodes). *Cardiac output* (cardiac output = [SV x 60000 / HP] / 1000; in liters per minute) and *total peripheral resistance* (estimated from mean blood pressure and cardiac output; in dyn x sec x cm^{-5}) were estimated accordingly.

Systolic and *diastolic blood pressure* (in mmHg) were measured by a non-invasive automatic inflation system (Dinamap Pro 100; oscillometric measurement method) with the cuff attached at the right arm. Peripheral pulses were detected at the volar surface of the distal phalanx of the left middle finger using a photoplethysmograph (TSD 100, Biopac). The signal was amplified by 100 with filters set to AC at a sampling rate of 1000 Hz. BodyVision 2.0 was used for parameterization yielding *pulse volume amplitude* (in arbitrary units) and *pulse transit time* (time between R-wave of ECG and systolic peak in the pulse signal; in milliseconds).

Data recording. Physiological data were obtained during eleven periods, each of 60 s duration. Recordings were obtained during the first, fifth, and ninth minute of the rest period, during the fourth minute of each task block (trials 40 to 65 of the 120 experimental trials) and its ensuing 1-min waiting period before reward feedback. BodyVision produced average values resulting in a 19 (cardiovascular variables) x 20 (participants) x 11 (1-min periods) raw data matrix used for preprocessing.

Preprocessing of physiological data. Outlier detection and transformations were performed with JMP 5.01 statistical software (SAS Institute Inc., 1995). Outliers were set to missing data. Missing data were replaced by estimates using the overall statistical model which specified Extraversion x 11 Data Recordings (empirical best linear unbiased prediction-algorithm, PROC MIXED, SAS Institute Inc., 1997). Overall, 3.9% of missing physiological data were replaced. Highest rates of missing data (11%) were observed for systolic and diastolic blood pressure due to movement artifacts during measurement. Subsequent statistical analysis was restricted to data recorded while participants completed the task.

Calculation of activation components. To gauge autonomic nervous system influences, we formed three autonomic activation components, which captured alpha-adrenergic, beta-adrenergic, and cholinergic activity. Variables were selected according to their responsiveness to specific autonomic blockades (see Stemmler, 2003, p. 237, Table 12.2), standardized across all participants and data recordings and then linearly combined as follows:

alpha-adrenergic = heart period + systolic blood pressure + diastolic blood pressure + total peripheral resistance + stroke volume – pulse transit time – pulse volume amplitude.

beta-adrenergic = pulse volume amplitude – PQ-time – heart period + QT-time – S-T-segment – T-wave amplitude + P-wave amplitude – left ventricular ejection time – preejection period – stroke volume + cardiac output + Heather-index – RZ-time + systolic blood pressure – diastolic blood pressure – total peripheral resistance – pulse transit time.

cholinergic[v] = PQ-time + heart period + ST-segment + T-wave amplitude + left ventricular ejection time – cardiac output – systolic blood pressure – diastolic blood pressure + heart period variability + pulse transit time – P-wave amplitude.

Statistical data analysis. For performance and cardiovascular variables we analyzed data from within task blocks and for self-report ratings obtained immediately after task blocks using SAS 6.12 statistical software (SAS Institute, 1997). Analysis of covariance (ANCOVA) was used to control for differences between extraversion groups in EPQ-R Neuroticism, EPQ-R Psychoticism, and CFT 3 (Table 1). For cardiovascular data, the baseline level from the fifth minute of the rest period was used as an additional covariate in order to derive change scores, to control for random group differences in pre-task arousal levels, and to increase statistical power by reducing physiological between-subjects variance.[vi] In SAS PROC MIXED, the error variance-covariance matrix for the repeated factor Task Difficulty was specified as completely general (TYPE=UN option) and allowed for heterogeneous error variances in the Extraversion groups (GROUP option).

Experimental hypotheses regarding cardiovascular variables were tested with specific trend analyses. Contrast coefficients of -0.25, 0.25, 0.75, and -0.75 for the 0-, 1-, 2- and 3-back task, in that order, were specified to capture the shark-fin shaped trend pattern of cardiovascular effort reactivity (see Figure 1) and to test for (a) extraversion-based differences in this trend (interaction effect Trend x Extraversion) and for (b) the occurrence of this trend within each Extraversion group. Hypotheses regarding performance data were tested with linear trends (contrast coefficients: -2, -1, 1, 2). *P*-values are presented at a two-tailed alpha-level of .05. Effect sizes ($r_{contrast}$) for repeated measures factors were computed according to Furr and Rosenthal (2003); otherwise, Cohen´s *d* was calculated.

Results

Preliminary Analyses

Manipulation checks on four rating scales were conducted to clarify whether participants were sufficiently motivated to pursue the n-back task and whether the manipulation of task difficulty was successful (see Table 2).

Please insert Table 2 about here

Correlations among the rating scales were low to moderate and thus allowed their independent interpretation. Participants evaluated their ability to succeed and the importance of success as moderate. In addition, they reported investing some effort to solve the task and not being happy. However, agentic extraverts reported being happier and more able to master the tasks than introverts, Extraversion main effect: $F(1, 15) = 7.75, 14.84$, $p < .05$, $d = 1.44, 1.99$, respectively (see Figure 2 a). Ability appraisal decreased from the 0-back (very easy) to the 3-back (difficult) task, Task Difficulty main effect: $F(3, 54) = 16.73$, $p < .05$, $d = 1.83$; linear trend: $t(54) = 6.72$, $p < .01$, with high ability appraisal at the lowest and low ability appraisal at the highest difficulty level (Figure 2 b). Groups did neither differ in self-rated success importance nor effort.

Please insert Figure 2 about here

Independent sample *t*-tests confirmed that during the resting phase agentic extraverts and introverts did not differ in alpha-adrenergic, beta-adrenergic, or cholinergic activation. Paired *t*-tests indicated a significant change of cardiovascular activity from the resting phase to the 0-back task for the alpha-adrenergic and the cholinergic activation component, $t(19) = 2.55, -3.03$, $p < .05$, $d = 1.14, 1.36$, respectively, but not so for the beta-adrenergic activation component (see Table 3).

Please insert Table 3 about here

Activation Components: Agentic Extraversion and Task Difficulty

All three activation components displayed a shark-fin shaped trend pattern across task difficulty levels, $t(54) = 2.40, 2.16, -2.88$, $p < .05$, for alpha-adrenergic, beta-adrenergic, and cholinergic activation components, in that order. Extraverts and introverts differed in the trend of the alpha-adrenergic activation component, Extraversion x Trend interaction: $t(54) = 2.14$, $p < .05$ (see Table 4). Introverts had a stronger increase of alpha-adrenergic activation across task difficulty levels than extraverts (see Figure 3). Follow-up tests within each Extraversion group revealed that for agentic introverts, the shark-fin shaped trend was significant for the alpha-adrenergic and the cholinergic activation components. For agentic extraverts, none of the activation components showed a significant shark-fin shaped trend (Table 4), neither was there a linear increase in adrenergic activation as alternatively hypothesized, but instead an increase in the cholinergic activation component from the 0-back to the 3-back task, $t(54) = 2.92$, $p < .05$, actually indicating an increasing *deactivation*.

Please insert Table 4 and Figure 3 about here

In order to detect where in the trend of agentic introverts the sharp decrease of effort-related activity occurred, we compared successive task difficulty levels using a Bonferroni-corrected significance level ($p < .017$). A significant change occurred from the 2- to the 3-back task in the alpha-adrenergic and cholinergic activation components, $t(54) = 2.96, -2.85$, $p < .017$, respectively. Thus, in agentic introverts cardiovascular effort investment decreased after the moderate 2-back task (see Figure 3). A comparable analysis for extraverts did not reveal significant changes, $t(54) = 0.02, 0.08, 1.12$ for 0- vs. 1-back, 1- vs. 2-back and 2- vs. 3-back, $p > 0.27$.

Differences between agentic extraverts and introverts for task difficulty levels below the introverts' point of disengagement, that is, below the difficult 3-back task, were found in the alpha-adrenergic and the cholinergic activation components for the moderate 2-back task, $t(54) > 2.47$, $p < .05$, and in addition in the cholinergic activation component for the easy 1-back task, $t(54) = 2.33$, $p < .05$. For the alpha-adrenergic activation component the latter effect just missed significance, $t(54) = 1.90$, $p = 0.06$. Throughout these comparisons, introverts had larger activations than extraverts.

Additional Results

To facilitate a comparison with previous empirical work on the integrative model, we also analyzed Heather-index, preejection period, and systolic blood pressure. ANCOVA revealed a significant effect of Extraversion on the shark-fin shaped trend for systolic blood pressure, Extraversion x Trend interaction: $t(54) = 2.15$, $p < .05$. This effect was mostly due to agentic introverts, who tended to show -- comparable to the alpha-adrenergic component but less pronounced -- the predicted shark-fin shaped pattern, $t(54) = 1.82$, $p < .08$. Results for preejection period and Heather-index were similar, but not significant. Extraversion-based differences below the introverts' point of disengagement were observed for systolic blood pressure in the 2-back task, where introverts had a higher blood pressure than extraverts, $t(54) = 2.38$, $p < .05$.

Reaction times of correct responses on target and non-target trials increased linearly across task difficulty levels, while the number of correct responses decreased, $t(54) = 6.59$, -14.81, $p < .05$, $r_{\text{contrast}} = .80$, .95, respectively. Agentic extraverts showed a significantly smaller linear increase of reaction times than introverts, $t(54) = -2.37$, $p < .05$, $r_{\text{contrast}} = .55$ (see Figure 4).

Please insert Figure 4 about here

Discussion

The present paper aimed at testing Wright and Kirby's integrative model (2001) and an extraversion-based extension of it. The integrative model explains effort in terms of task difficulty, ability appraisal, and success importance. In this study, task difficulty was experimentally manipulated. Hypotheses derived from the Wright-Kirby model were confirmed for ability appraisal and happiness in agentic introverts and extraverts. Predictions concerning cardiovascular reactivity were confirmed for agentic introverts in the alpha-adrenergic and cholinergic activation components.

Evidence for the Integrative Model

Ability appraisal decreased linearly with increasing difficulty. At the very easy (0-back) task, ability appraisal was highest, and lowest at the most difficult (3-back) task. Ability appraisal has been discussed as an important predictor of vigor and perseverance of effort invested to meet task demands (Kukla, 1972; Meyer, 1987). This was also supported by the present results. The drop of appraised ability with increasing task difficulty also demonstrated that with the sequential letter task the induction of different levels of difficulty was successful. These results fit the predictions of the integrative model.

Wright and Kirby (2001) postulated that with increasing task difficulty a shark-fin shaped pattern of effort may be observed: Effort increases up to a point beyond which a successful processing of the task is appraised as impossible and disengagement occurs. Our results confirm this shark-fin shaped trend pattern for the total sample in all three activation components and demonstrate an increase of adrenergic activity and a decrease of cholinergic activity up to a moderate task difficulty. This general trend attests to our participants' motivation to engage in the task. In the difficult task a decrease of adrenergic activity and an increase of cholinergic activity indicated disengagement.

Remarkably, the linearly decreasing trend across task difficulty levels for ability appraisal and the shark-fin shaped trend pattern for cardiovascular reactivity indicates a partial dissociation between an already diminishing ability appraisal and an increasing cardiovascular effort expenditure at a moderate task difficulty. That is, while participants appraised their ability for a successful task execution already as low, an increased cardiovascular activation probably served as a compensatory mechanism.

Evidence for an Extraversion-based Extension of the Wright-Kirby Model

Apart from task difficulty, ability appraisal, and success importance previous studies investigated further predictors of effort. Trait variables such as dispositional optimism (Wright and Franklin, 2004) and state variables such as ego involvement (Gendolla and Richter, 2005), mood (Gendolla et al., 2001), or self-reported ability (e.g., Annis et al., 2001; Wright et al., 1994) were employed as putative predictors of effort. However, the relevance of trait dimensions for effort has rarely been addressed so far. To our knowledge, this is the first study to extend and validate the Wright-Kirby model with respect to extraversion.

One possible mechanism by which agentic extraversion could impact ability appraisal and effort expenditure is suggested by the mood-behavior model (Gendolla, 2000). According to this model, mood can influence effort expenditure by boosting one's ability appraisal. Compared to individuals in a positive mood, individuals in a negative mood make less optimistic evaluations, appraise their ability as lower, and consequently judge subjective task demands as higher. At low levels of objective task difficulty they try harder and invest more effort. At higher levels of task difficulty they evaluate task demands as excessively difficult and withhold effort at a lower level of objective task difficulty. This results in displaced shark-fin shaped functions of (cardiovascular) effort for individuals in a negative versus positive mood. These groups can be roughly equated with introverts and extraverts, since positive mood and extraversion are positively associated (Larsen, 2000). For example, a meta-analysis by Lucas and Fujita (2000) reported an average correlation of 0.37 between extraversion and pleasant affect.

We actually found that across all levels of task difficulty agentic introverts reported less happiness and a lower ability appraisal than agentic extraverts. The accompanying findings for cardiovascular effort were also concordant with the predictions: Agentic introverts increased their effort up to the point of disengagement, which for the alpha-adrenergic and cholinergic activation component resulted in the predicted shark-fin shaped trend. Most importantly, for low levels of task difficulty introverts mobilized significantly more cardiovascular effort -- in alpha-adrenergic and cholinergic activation components-- than extraverts.

In contrast, extraverts did not display difficulty-related changes in effort mobilization, their trend pattern simply consisted of a linear deactivation from the 0- to the 3-back task as indicated by the cholinergic activation component. This finding could be due to insufficient task difficulty or poorly graded difficulty levels. Extraverts' positive estimation of their ability to meet the task demands and to obtain the announced reward might have dampened any pronounced effort investment up until the 2-back task. The 3-back task might have induced deactivation because it quickly was found too hard to succeed in it.

In addition to mood as a source of our extraversion effects the differential reinforcement sensitivity of agentic introverts and extraverts might have contributed to our findings. Gray and McNaughton (2000) proposed fundamental emotion-motivation brain systems that regulate motivated behavior. The Behavioral Approach System (BAS) responds to appetitive stimuli and is functionally akin to the system Depue and Collins (1999) proposed to underlie agentic extraversion. The Behavioral Inhibition System (BIS), in contrast, is a conflict detection and resolution device. Recent neurobehavioral findings have shown the importance of the BIS and BAS for feedback and error processing (see e.g. Amodio et al., 2008). In line with this work, it could be argued that agentic introverts, who arguably have a more active BIS, were more responsive to the negative task feedback ("wrong", "too slow") and made a definite effort to succeed. The more BAS-guided agentic extraverts probably focused more on the positive feedback ("right"), which signaled the adequateness of their effort investment, and sped up their responses.

Another approach for the explanation of extraversion-based differences is provided by the concept of resource allocation (Beauducel et al., 2006; Brocke et al., 1997). Introverts have been reported to outperform extraverts in long-lasting monotonous tasks and to allocate their resources more effectively than extraverts (e.g., Beauducel et al., 2006). However, in a task like ours, extraversion-based differences in resource allocation might manifest themselves differently. N-back tasks require -- especially with increasing processing demands -- various cognitive processes (e.g., directing attention, updating, sequencing, inhibiting; see Cohen et al., 1997; Owen et al., 2005), flexible resource allocation, and an optimal timing of these processes for a successful completion. Recent studies have demonstrated extraversion-based differences in working memory functioning (e.g., Chavanon et al., 2007; Lieberman and Rosenthal, 2001; Wacker et al., 2006) that are probably related to dopaminergically based differences in cognitive control modes (see Braver, Gray and Burgess, 2007) or multitasking capability (see Wacker et al., 2006). This type of differential resource allocation and utilization could be a reason for the strong cardiovascular effort investment in agentic introverts: Introverts were in need to compensate for a biologically founded, suboptimal working memory “set-up”.

Successful Validation of Activation Components

The Wright-Kirby model was tested here primarily by using aggregate measures of cardiovascular reactivity (i.e., activation components) as dependent variables. Psychophysiologists have for long propagated a multivariate assessment strategy (e.g., Davis, 1957; Fahrenberg, 1987; Lacey, 1967), because activation processes are not unitary. Caccioppo and Tassinary (1990) recommended a broad sampling of somatovisceral variables, because somatovisceral variables seldom map one-to-one to psychological processes. Stemmler (1992, 1993) proposed to combine somatovisceral variables into physiologically meaningful parameters.

In the present study the activation components were sensitive to changes in effort regulation across task levels, and the alpha-adrenergic activation component was particularly apt at demonstrating significant differences in agentic introverts and extraverts. Thus, the present study provides clear evidence for the usefulness of activation components to investigate cardiovascular effort. This is in accordance with Blascovich and coworkers’ (e.g. Blascovich et al., 2003; Blascovich and Tomaka, 1996) claim for a broader sampling of cardiovascular variables to investigate challenge and threat appraisals. Blascovich and colleagues pointed to the fact that these appraisal types are related to complex sympathetic, parasympathetic, and endocrine influences, which are unlikely captured by single cardiovascular variables. Despite some critical methodological aspects of this model (Wright and Kirby, 2003) the biopsychosocial model supports the idea of a broader sampling of cardiovascular reactivity and suggests a promising differentiation of appraisal types, which appear to be relevant also for effort investment.

Furthermore, our findings extend Obrist's (1981) suggestion that effort is related exclusively to beta-adrenergic activation by showing the importance of cholinergic and alpha-adrenergic activation. This result is supported by Waldstein and colleagues (1997), who also reported alpha-adrenergic activation in an incentive-related performance situation. Moreover, Schneiderman and McCabe (1989) reported an alpha-adrenergic activation in tasks that require vigilance. In the present task incentives were provided when responses were fast and correct. Although our task was not a vigilance task, sustained attention was required to deal with it successfully. In line with Waldstein et al. (1997) and Schneiderman and McCabe (1989), the present task exhibited a context for alpha-adrenergic activation.

A review of the literature shows that systolic blood pressure is the physiological variable to best support the integrative model. It is noteworthy that systolic blood pressure enters into all three linear combinations forming the activation components. The pattern of results observed for systolic blood pressure was similar to but less pronounced than the one we found for alpha-adrenergic activation. Importantly, this finding does not necessitate a new interpretation of previous findings on systolic blood pressure, because this variable can be interpreted as a cardiovascular variable representing the net effect of different regulatory influences. Activation components are estimates of just these influences and are able to highlight the source of activations more succinctly and reliably than single variables.

Limitations and Future Issues

The interpretation of the present results is limited by the fact that we investigated exclusively male participants. To increase the generalizability of our results future studies should also include female participants. This is advisable, because previous studies related cardiovascular effort to sex differences (e.g., Wright et al., 1997). Compared to previous studies of cardiovascular effort (e.g., Annis et al., 2001) the statistical power of our study is restricted due to the small sample size, although extreme group selection acted to enhance power. Incentive motivation has not been systematically varied in this study. A simultaneous manipulation of incentive and task difficulty could further clarify extraversion-based differences in effort investment and, moreover, the motivational basis of agentic extraversion (Depue and Collins, 1999).

Conclusion

In summary, the implications of the present study are threefold. First, agentic extraversion (Depue and Collins, 1999) emerged as a further valid predictor of cardiovascular responses within the integrative model provided by Wright and Kirby (2001). Second, the sequential letter task with its four levels of difficulty in agentic introverts was able to provoke changes of effort investment as hypothesized in the shark-fin shaped trend pattern of cardiovascular responses. Third, our results demonstrate that activation components are promising indicators of mental effort in incentive-related achievement situations.

References

Andrassy, G., Szabo, A., Dunai, A., Simon, E., Nagy, T., Trummer, Z., Tahy, A., Varro, A., 2003. Acute effects of cigarette smoking on the QT interval in healthy smokers. American Journal of Cardiology 92, 489-492.

Amodio, D.M., Master, S.L., Yee, C.M., & Taylor, S.E., 2008. Neurocognitive components of the behavioral inhibition and activation systems: Implications for theories of self-regulation. Psychophysiology 45, 11-19.

Annis, S., Wright, R.A., Williams, B.J., 2001. Interactional influence of ability perception and task demand on cardiovascular response: Appetitive effects at three levels of challenge. Journal of Applied Biobehavioral Research 6, 82-107.

Beauducel, A., Brocke, B., Leue, A., 2006. Energetical bases of extraversion: Effort, arousal, EEG, and performance. International Journal of Psychophysiology 62, 212-223.

Berry, N.J., Thompson, H.K., Miller, D.E., McIntosh, H.D., 1959. Changes in cardiac output, stroke volume, and central venous pressure induced by atropine in man. American Heart Journal 58, 204-213.

Blascovich, J., Mendes, W.B., Tomaka, J., Salomon, K., Seery, M., 2003. The robust nature of the biopsychosocial model challenge and threat: A reply to Wright and Kirby. Personality and Social Psychology Review 7, 234-243.

Blascovich, J., Tomaka, J., 1996. The biopsychosocial model of arousal regulation. In: Zanna, M.P. (Ed.), Experimental social psychology. Academic Press, New York, pp. 1-51.

Braver, T.S., Gray, J.R., Burgess, G.C., 2007. Explaining the many variations in working memory: dual mechanisms of cognitive control. In: Conway, A., Jarrold, C, Kane, M., Miyake, A., Towse, J. (Ed.), Variation of Working Memory. Oxford University Press

Brocke, B., Tasche, K.G., Beauducel, A., 1997. Biopsychological foundations of extraversion: Differential effort reactivity and state control. Personality and Individual Differences 22, 447-458.

Cacioppo, J.T., Tassinary, L.G., 1990. Inferring psychological significance from physiological signals. American Psychologist 45, 16-28.

Cattell, R.B., Weiß, R.H., 1971. Grundintelligenztest Skala 3 (CFT 3) [Culture Fair Intelligence Test, Scale 3]. Georg Westermann Verlag, Braunschweig.

Chavanon, M.-L., Wacker, J., Leue, A., Stemmler, G., 2007. Evidence for a dopaminergic link between working memory and agentic extraversion: An analysis of load-related changes in EEG alpha 1 activity. Biological Psychology 74, 46-59.

Cohen, J.D., Perlstein, W.M., Braver, T.S., Nystrom, L.E., Noll, D.C., Jonides, J., Smith, E.E., 1997. Temporal dynamics of brain activation during a working memory task. Nature 386, 604-608.

Davis, R.C., 1957. Response patterns. Transactions of the New York Academy of Sciences 19, 731-739.

Depue, R.A., Collins, P.F., 1999. Neurobiology of the structure of personality: Dopamine, facilitation of incentive motivation, and extraversion. Behavioral and Brain Sciences 22, 491-569.

Depue, R.A., Luciana, M., Arbisi, P., Collins, P., Leon, A., 1994. Dopamine and the structure of personality: relation of agonist-induced dopamine activity to positive emotionality. Journal of Personality and Social Psychology 67, 485-498.

Fahrenberg, J., 1987. Theory in psychophysiology: The multi-component analysis of psychophysiological reactivity. Journal of Psychophysiology 1, 9-11.

Fridlund, A.J., Cacioppo, J.T., 1986. Guidelines for human electromyographic research. Psychophysiology 23, 567-589.

Furr, R.M., Rosenthal, R., 2003. Repeated-measures contrasts for "multiple-pattern" hypotheses. Psychological Methods 8, 275-293.

Gendolla, G.H., 2000. On the impact of mood on behavior: An integrative theory and a review. Review of General Psychology 4, 378-408.

Gendolla, G.H., Abele, A.E., Krüsken, J., 2001. The informational impact of mood on effort mobilization: a study of cardiovascular and electrodermal responses. Emotion 1, 12-24.

Gendolla, G.H., Richter, M., 2005. Ego involvement and effort: Cardiovascular, electrodermal, and performance effects. Psychophysiology 42, 595-603.

Gray, J.A., & McNaughton, N. (2000). *The neuropsychology of anxiety*. Oxford: University Press.

Hockey, G.R.J., 1997. Compensatory control in the regulation of human performance under stress and high workload; a cognitive-energetical framework. Biological Psychology 45, 73-93.

Krantz, D.S., Manuck, S.B., 1984. Acute psychophysiologic reactivity and risk of cardiovascular disease: A review and methodological critique. Psychological Bulletin 96, 435-464.

Kubicek, W.G., Karnegis, J.N., Patterson, R.P., Witsoe, D.A., Mattson, R.H., 1966. Development and evaluation of an impedance cardiac output system. Aerospace Medicine 37, 1208-1212.

Kukla, A., 1972. Foundations of an attibutional theory of performance. Psychological Review 79, 454-470.

Lacey, J.I., 1967. Somatic response patterning and stress: Some revisions of activation theory. In: Appley, M.H., Trumbull, R. (Eds.), Psychological stress. Appleton-Century-Crofts, New York, pp. 14-37.

Larsen, R.J., 2000. Toward a science of mood regulation. Psychological Inquiry 11, 129-141.

Lieberman, M.D., Rosenthal, R., 2001. Why introverts can't always tell who likes them: Multitasking and nonverbal decoding. Journal of Personality and Social Psychology 80, 294-310.

Lucas, R.E., Fujita, F., 2000. Factors influencing the relation between extraversion and pleasant affect. Journal of Personality and Social Psychology 79, 1039-1056.

Margraf, J., 1997. Mini-DIPS Kurz-Interview bei psychischen Störungen [Short version of the DIPS – Diagnostic interview of mental disorders]. Springer, Berlin.

McEvoy, L.K., Smith, M.E., Gevins, A., 1998. Dynamic cortical networks of verbal and spatial working memory: Effects of memory load and task practice. Cerebral Cortex 8, 563-574.

Meyer, W.-U., 1987. Perceived ability and achievement-related behavior. In: Halisch, F., Kuhl, J. (Eds.), Motivation, intention, and volition. Springer, Berlin, pp. 73-86.

Mulder, G., 1986. The concept and measurement of mental effort. In: Hockey, G.R.J., Gaillard, A.W.K., Coles, M.G.H. (Eds.), Energetics and human information processing. Martinus Nijhoff, Dodrecht

Nelson, G.I., Silke, B., Hussain, M., Verma, S.P., Taylor, S.H., 1984. Rest and exercise hemodynamic effects of sequential alpha1-adrenoceptor (tirmazosin) and beta-adrenoceptor (propranolol) antagonism in essential hypertension. American Heart Journal 108, 124-131.

Obrist, P.A., 1981. Cardiovascular psychophysiology. Plenum, New York.

Owen, A.M., McMillan, K.M., Laird, A.R., Bullmore, E., 2005. N-back working memory paradigm: a meta-analysis of normative functional neuroimaging studies. Human Brain Mapping 25, 46-59.

Pearce-McCall, D., Newman, J.P., 1986. Expectation of success following noncontingent punishment in introverts and extraverts. Journal of Personality and Social Psychology 50, 439-446.

Raaijmakers, E., Faes, T.J., Goovaerts, H.G., Meijer, J.H., de Vries, P.M., Heethaar, R.M., 1998. Thoracic geometry and its relation to electrical current distribution:

consequences for electrode placement in electrical impedance cardiography. Medical & Biological Engineering & Computing 36, 592-597.

Ruch, W., 1999. Die revidierte Fassung des Eysenck Personality Questionnaire und die Konstruktion des deutschen EPQ-R bzw. EPQ-RK [The Eysenck Personality Questionnaire – Revised and the construction of German standard and short versions EPQ-R and EPQ-RK]. Zeitschrift für Differentielle und Diagnostische Psychologie 20, 1-24.

SAS Institute Inc., 1995. JMP statistics and graphic guide, version 3.1. SAS Institute Inc., Cary, NC.

SAS Institute Inc., 1997. SAS/STAT Software: Changes and Enhancements through Release 6.12. SAS Institute Inc., Cary, NC.

Schneiderman, N., McCabe, P.M., 1989. Psychophysiologic strategies in laboratory research. In: Schneiderman, N., Weiss, S.M., Kaufmann, P.G. (Eds.), Handbook of research methods in cardiovascular behavioral medicine. Plenum, New York, pp. 349-364.

Stemmler, G., 1992. Differential Psychophysiology: Persons in situations. Springer, New York.

Stemmler, G., 1993. Receptor antagonists as tools for structural measurement in psychophysiology. Neuropsychobiology 28, 47-53.

Stemmler, G., 2003. Methodological considerations in the psychophysiological study of emotion. In: Davidson, R.J., Goldsmith, H.H., Scherer, K.R. (Eds.), Handbook of affective science. Oxford University Press, New York, pp. 225-255.

Stemmler, G., Aue, T., Wacker, J., 2007. Anger and fear: Separable effects of emotion and motivational direction on somatovisceral responses. International Journal of Psychophysiology 66, 141-153.

Stemmler, G., Heldmann, M., Pauls, C.A., Scherer, T., 2001. Constraints for emotion specificity in fear and and anger: the context counts. Psychophysiology 38, 275-291.

Tellegen, A., Waller, N.G., 1997. Exploring personality through test construction: Development of the Multidimensional Personality Questionnaire (MPQ). In: Briggs, S.R., Cheek, J.M. (Eds.), Personality measures: Development and evaluation. JAI Press, Greenwich, CT, pp. 23-42.

Wacker, J., Chavanon, M.-L., Stemmler, G., 2006. Investigating the dopaminergic basis of extraversion in humans: A multilevel approach. Journal of Personality and Social Psychology 91, 171-187.

Wacker, J., Stemmler, G., 2006. Agentic extraversion modulates the cardiovascular effects of the dopamine D2 agonist bromocriptine. Psychophysiology 43, 372-381.

Waldstein, S.R., Bachen, E., Manuck, S.B., 1997. Active coping and cardiovascular reactivity: A multiplicity of influences. Psychosomatic Medicine 59, 620-625.

Woltjer, H.H., Arntzen, B.W., Bogaard, H.J., de Vries, P.M., 1996. Optimalisation of the spot electrode array in impedance cardiography. Medical and Biological Engineering and Computing 34, 84-87.

Wright, R.A., Franklin, J., 2004. Ability perception determinants of effort-related cardiovascular response: mood, optimism, and performance resources. In: Wright, R.A., Greenburg, J., Brehm, S.S. (Eds.), Motivational analyses of social behavior: Building on Jack Brehm's contributions to psychology. Lawrence Erlbaum, Hillsdale, NJ, pp. 187-204.

Wright, R.A., Kirby, L.D., 2001. Effort determination of cardiovascular response: An integrative analysis with applications in social psychology. In: Zanna, M.P. (Ed.), Advances in experimental social psychology. Academic Press, San Diego, CA, pp. 255-307.

Wright, R.A., Kirby, L.D., 2003. Cardiovascular correlates of challenge and threat appraisals: A critical examination of the biopsychosocial analysis. Personality and Social Psychology Review 7, 216-233.

Wright, R.A., Murray, J.B., Storey, P.L., Williams, B.J., 1997. Ability analysis of gender relevance and sex differences in cardiovascular response to behavioral challenge. Journal of Personality and Social Psychology 73, 405-417.

Wright, R.A., Wadley, V.G., Pharr, R.P., Butler, M., 1994. Interactive influence of self-reported ability and avoidant task demand on anticipatory cardiovascular responsivity. Journal of Research in Personality 28, 68-86.

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Footnotes

[i] Studies of cardiovascular reactivity often use the terms effort, active coping, and task engagement synonymously (e.g., Obrist, 1981; Wright and Kirby, 2001). Throughout this article we are using the term effort. We define effort as the use of mental resources intended to satisfy a motive, which is preceded and accompanied by adjustments in the cardiovascular system.

[ii] Annis and colleagues used a recognition memory task with six levels of task difficulty; however, collapsing the data across the lower two, middle two, and higher two difficulty levels, these authors again analyzed just three task levels.

[iii] The present sample constitutes the placebo group of a larger pharmacological study in which dopamine D2 agonists and antagonists were administered. Data from the D2 agonist and antagonist conditions are reported elsewhere (Wacker et al., 2006; Wacker and Stemmler, 2006).

[iv] Several additional self-report items were presented. They are, however, not relevant to the present hypotheses.

[v] High cholinergic activity is related to parasympathetic activation (i.e., high deactivation). Thus, low scores of cholinergic activity indicate activation.

[vi] As participants in several variables displayed signs of activation in the first and the last data recording during rest, the second recording was considered the most appropriate baseline reference.

Table 1

Means (Standard Deviations) and Effect Sizes of Sample Characteristics

Characteristic	Agentic Extraverts	Agentic Introverts	*t*(18)	Cohen's *d*
Age	24.4 (3.03)	23.1 (3.87)	0.84	0.38
BMI	23.6 (2.08)	22.4 (1.91)	1.31	0.61
MAE	20.5 (3.82)	-4.3 (6.09)	10.93***	5.01
EPQ-R Extraversion	18.9 (3.18)	12.6 (5.40)	3.18**	1.47
EPQ-R Neuroticism	5.0 (3.71)	11.5 (5.74)	2.96**	1.38
EPQ-R Psychoticism	8.0 (4.45)	12.0 (3.97)	2.12*	0.95
CFT 3	25.2 (3.46)	28.3 (3.06)	2.12*	0.95

Note. BMI = Body mass index. CFT 3 = Culture Fair Test. EPQ-R = Eysenck Personality Questionnaire – Revised. MAE = Marburg Agentic Extraversion. * $p < .05$. ** $p < .01$. *** $p < .001$ (two-tailed).

Table 2

Descriptive Statistics of Rating Scales

	Effort[a]	Ability appraisal[a]	Success importance[b]	Happiness
Effort	1.00	.41	.59**	.09
Ability appraisal		1.00	.47*	.54**
Success importance			1.00	.28
M	7.59	5.84	4.86	2.76
SEM	0.39	0.31	0.48	0.40

Note. Intercorrelations, means, and standard errors of the rating scales averaged across task difficulty levels. $N = 20$. [a] Eleven-point rating scale (scale midpoint is 5). [b] Nine-point rating scale (scale midpoint is 4). * $p < .05$. ** $p < .01$ (two-tailed).

Table 3

Unadjusted Means (Standard Deviations) of Cardiovascular Activation Components During Resting Phase and 0-back Task

	Agentic Extraverts		Agentic Introverts	
	Resting	0-back task	Resting	0-back task
Alpha-adrenergic	-0.12 (0.80)	0.18 (0.86)	-0.58 (0.63)	0.18 (0.72)
Beta-adrenergic	-0.38 (2.28)	-0.16 (2.05)	-0.05 (0.86)	0.36 (1.48)
Cholinergic	0.37 (1.57)	-0.09 (1.82)	0.60 (0.77)	-0.36 (1.06)

Table 4

Contrasts for Shark-Fin Shaped Trend in Cardiovascular Activation Components

	Trend x Extraversion		Trend in Agentic Extraverts		Trend in Agentic Introverts	
	t	$r_{contrast}$	t	$r_{contrast}$	t	$r_{contrast}$
Alpha-adrenergic	2.14*	.76	0.24	.07	2.78*	.68
Beta-adrenergic	0.97	.30	1.09	.34	1.87	.53
Cholinergic	-1.38	.52	-1.04	.33	-3.10*	.72

Note. *df* (of *t*-values) = 54. *df* (for $r_{contrast}$ coefficients) = 9. * $p < .05$.

Figure Captions

Figure 1. Expected cardiovascular effort across task difficulty levels (0 = very easy, 1 = easy, 2 = moderate, 3 = difficult) for agentic introverts and extraverts.

Figure 2. Adjusted means and standard errors of (a) happiness (9-point scale) and (b) ability appraisal (11-point scale) across task difficulty levels (0 = very easy, 1 = easy, 2 = moderate, 3 = difficult) for agentic introverts and extraverts.

Figure 3. Adjusted means and standard errors of activation components across task difficulty levels (0 = very easy, 1 = easy, 2 = moderate, 3 = difficult) for agentic introverts and extraverts.

Figure 4. Adjusted means and standard errors of reaction time for correct responses across task difficulty levels (0 = very easy, 1 = easy, 2 = moderate, 3 = difficult) for agentic introverts and extraverts.

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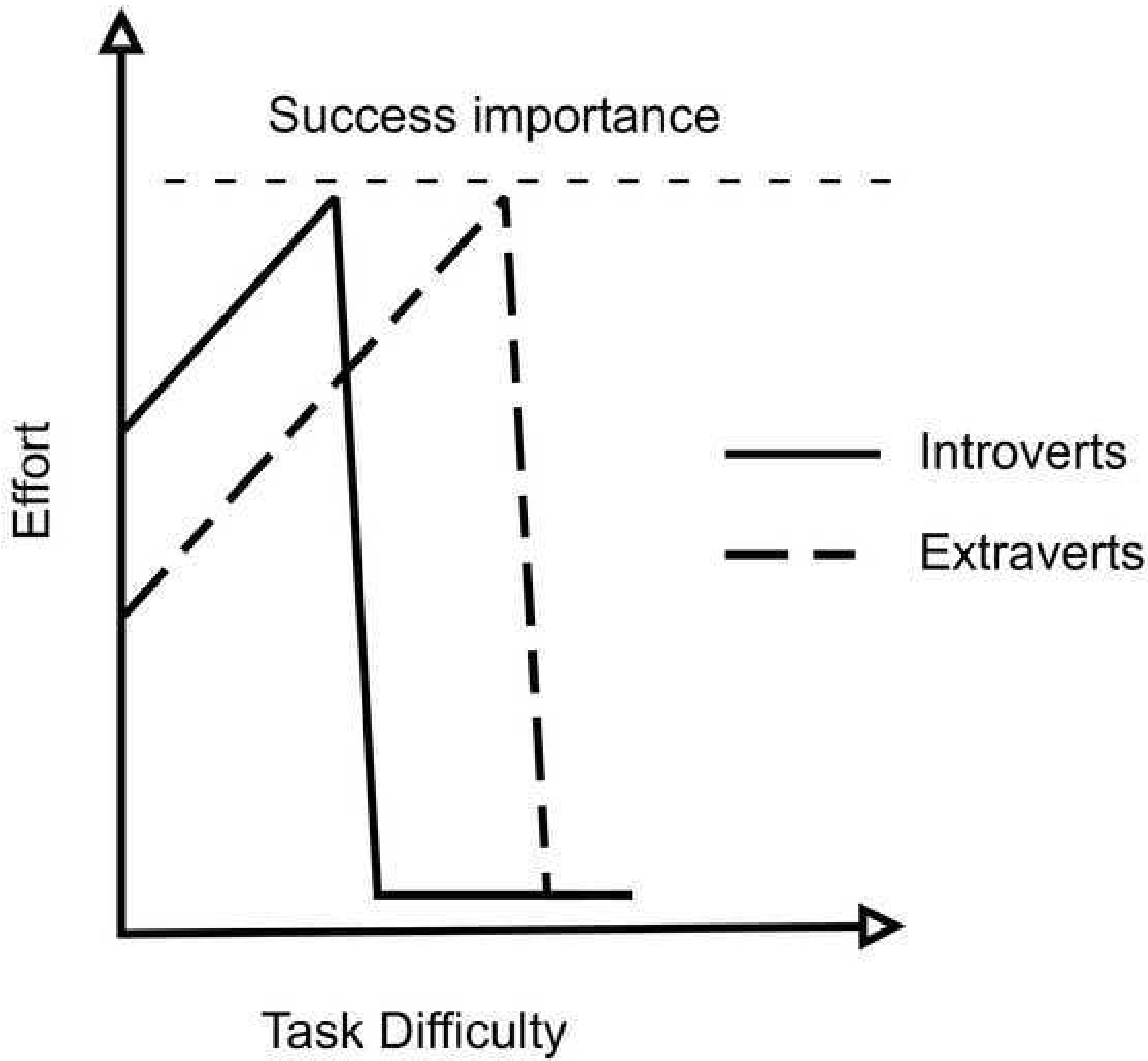

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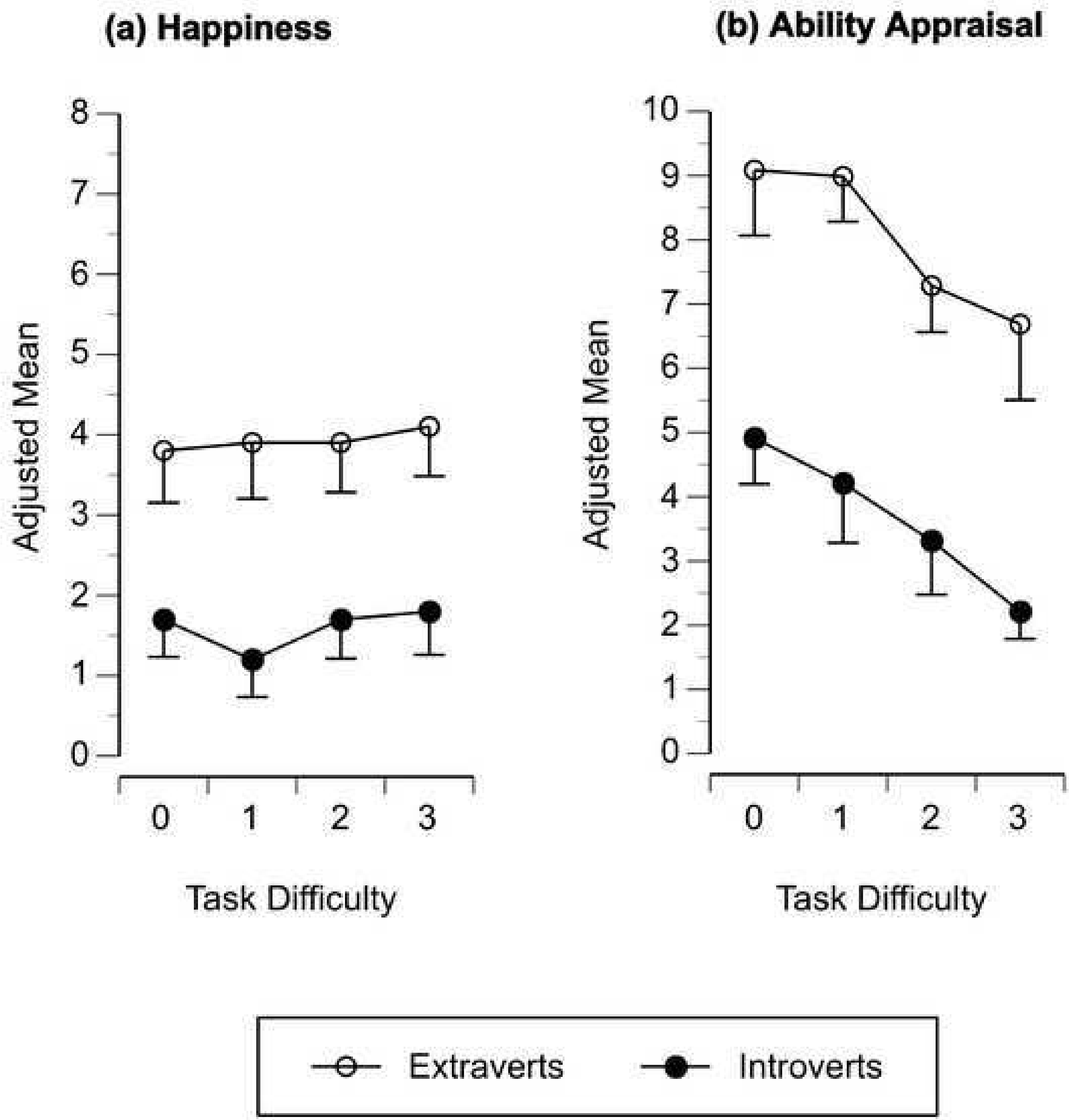

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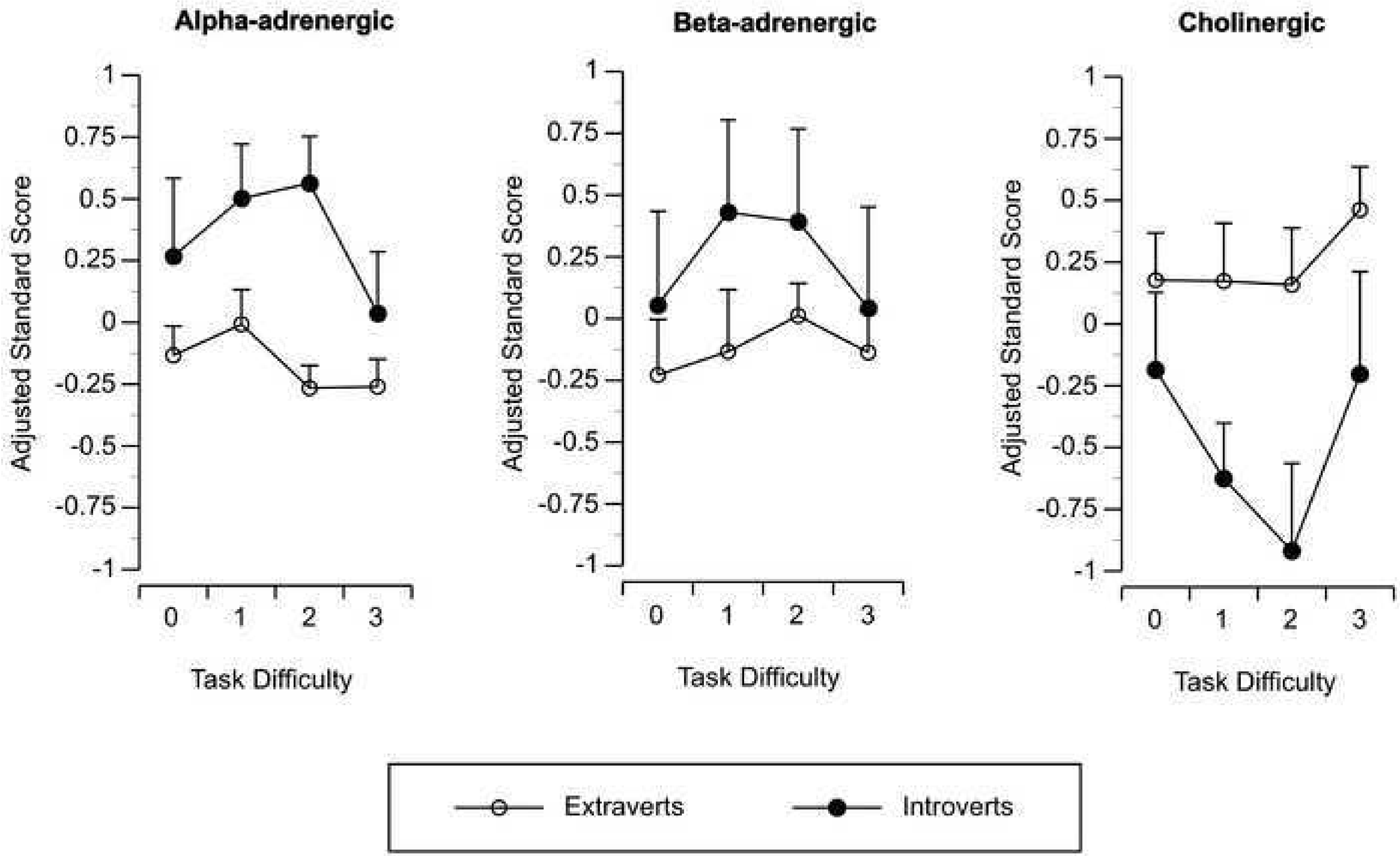

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