Extraversion and performance: A cognitive-energetical approach

Please check the document version of this publication:

Contents:

Extraversion and performance: A cognitive-energetical approach

Fren T.Y. Smulders [*], Ewout H. Meijer

*Department of Psychology, Experimental Psychology, Maastricht University, P.O. Box 616,
6200 MD Maastricht, The Netherlands*

Abstract

Various personality theories specify that extraversion is related to a low level of arousal. The aim was to relate extraversion to the mechanisms in Sanders' (1983) cognitive-energetical model of choice-reaction time (RT): arousal, activation, and effort. Stimulus degradation and time-uncertainty were manipulated during a long task given to extreme introverts ($N = 22$) and extraverts ($N = 21$). In mean RTs, there was only weak evidence for a stronger slowing during the task in extraverts than in introverts. However, an analysis of the RT-distribution demonstrated a remarkable slowing across time of RTs at the high end of the RT-distribution to degraded stimuli in extraverts, suggesting that arousal is lower in extraverts than in introverts. Extraversion had no such effect on activation. The study of the whole reaction time distribution is also important because in many real-life monitoring tasks, especially if visibility is degraded, the risks may not depend so much on mean RT, but rather on the realistic maximum RT.
© 2007 Elsevier Ltd. All rights reserved.

Keywords: Personality; Extraversion; Cognitive performance; Arousal; Degradation; Time-on-task; Foreperiod; RT-distribution

---

[*] Corresponding author. Tel.: +31 43 3881909; fax: +31 43 3884196.
E-mail address: F.Smulders@psychology.unimaas.nl (F.T.Y. Smulders).

1. Introduction

Extraversion (*E*) has been postulated as a biologically-based dimension of personality by Eysenck (1967), and is also a dimension in more recent descriptions of personality (Costa & McCrae, 1985). The question whether a higher score on *E* is associated with worse performance (or more decrement) in certain tasks or conditions is interesting both from a theoretical and an applied viewpoint. The theoretical importance derives from Eysenck's conception that individual differences in extraversion are based on arousal. From an applied viewpoint, consistent individual differences in performance in specific tasks or conditions might provide a tool for selection for specific jobs.

Research in this area has predominantly focused on vigilance performance. A meta-analysis by Koelega (1992) mildly supported Eysenck's predictions, but also found many null-results. Koelega noted that effects on sustained reaction time (RT) performance have received much less attention (see also Matthews & Gilliland, 1999). The latter is surprising because there exists a body of literature relating arousal-mediated variables to choice RT that is adequately explained by a cognitive-energetical model (Sanders, 1983, 1998).

The cognitive-energetical model (Sanders, 1983, 1998) integrates the energetical mechanisms that have been put forward by Pribram and McGuinness (1975) and the theory of processing stages (Sternberg, 1969). Importantly, it specifies how energetical mechanisms affect processing stages and so produce the performance effects of suboptimal states such as after sleep loss or the intake of psychopharmaca. Basically, it proposes an 'arousal' and an 'activation' mechanism. Arousal was conceived by Pribram and McGuinness as a phasic response to input, and activation as a tonic readiness to respond. These mechanisms give energetical supply to specific processing stages, and if the supply falls short, the stages take longer to complete. In RT, the result is an increase in the effect of a task variable that affects the same stage, leading to an interaction between the state and the task variable. A separate 'effort' mechanism may compensate for these adverse effects on performance, but it tends to do so mainly in the beginning of a task. Thus, the model specifies that if a suboptimal energetic state is present, its adverse effects on performance will initially be masked by compensatory effort. Furthermore, when adverse effects eventually show up, one can tell whether they concern arousal or activation by probing specific processing stages through selected task variables.

The original Eysenck (1967) explanation of extraversion, and also later formulations of it (Eysenck & Eysenck, 1985) involved a one-dimensional arousal concept, but the cognitive-energetical model involves multiple mechanisms. This raises the question what to predict regarding the effect of extraversion in the cognitive-energetical model: which mechanism(s) should be involved? Sanders (1998, p. 441) hypothesized that introverts have a higher level of both arousal and activation,[1] but do not differ from extraverts with regard to investing effort. Others have proposed a control theory of arousal, in which differences in both effort and arousal play a role (Brocke, Tasche, & Beauducel, 1996, 1997; M.W. Eysenck, 1988). The locus of extraversion-related differences in the

---

[1] Eysenck (1967, 1990) also referred to 'activation', but the term referred to autonomic activity in response to emotion-producing stimuli. This concept was related to the N (neuroticism) dimension, and is not relevant to the present discussion.

cognitive-energetical model is best regarded as an empirical issue. The present study was set up to provide relevant data.

Two task variables were selected whose effects can be linked to arousal and activation, and the task was given to extreme introverts and extraverts. The task variable whose effect is specifically sensitive to low arousal is stimulus degradation, interacting strongly with induced lack of sleep and with sleep medication, but not with amphetamine (Frowein, 1981, Frowein, Gaillard, & Varey, 1981; Sanders, Wijnen, & Arkel van, 1982; Steyvers, 1987; Steyvers & Gaillard, 1993). The associated processing stage is stimulus encoding.

The task variable whose effect is specifically sensitive to activation is uncertainty regarding the moment of stimulus onset ('time-uncertainty'), manipulated through the time between a warning and an imperative stimulus, the foreperiod. A short, fixed foreperiod enables preparation for the upcoming stimulus. The resulting decrease in RT is typically interpreted as a speeding of a central motor stage (motor adjustment; Sanders, 1983, 1998). With a long or variable foreperiod such preparation cannot be maintained (Gottsdanker, 1975). The effect of time-uncertainty is augmented by sleep loss, and then again reduced by a dose of amphetamine (Frowein, Reitsma, & Aquarius, 1981). It was concluded that time-uncertainty has an effect on a motor stage receiving energetical supply from the activation mechanism.

As noted, a suboptimal energetic state of arousal or activation may be masked by compensatory effort in the beginning of a task. If so, an interaction between extraversion and either task variable will only show up at the end of a long task, when effort is low. To investigate the moderating effect of effort, the factor time-on-task was included in the design, and effects on the distribution of reaction times were studied. Time-on-task is a variable that interacts with many state variables (e.g., Wilkinson, 1969). Typically, adverse effects of state variables are small in the beginning of a task, to increase after that, and reach an asymptotic level after about 10 min (Mackworth, 1964). Sanders (1983, 1998) argued against an explanation of time-on-task effects in terms of arousal. One reason is that after the decrement, performance usually remains at the lowered level for a long period, and does not further decrease. Second, time-on-task effects are similar for arousal decreasing and increasing variables: also the effect of noise is larger during the later part of a work spell, which is unexpected if it were added to a decreasing arousal level. Finally, the decrement is often absent in everyday settings, when subjects may find no reason to invest extra effort in the beginning of the work period, because they are not continuously monitored. Altogether, whereas the state of arousal may be too high or too low during the entire task, effort tends to compensate for this deficient state in the beginning, resulting in a time-on-task effect. Steyvers and Gaillard (1993) showed that a short interruption near the end of their task had the effect of restoring performance to a level close to the start level. They showed that this improvement was due to a regain of effort rather than arousal or activation. We inserted a similar interruption near the end of the task.

A little explored variable is relative speed of RT, which involves a comparison of experimental effects at relatively fast trials to effects at the upper end of the distribution. Both sleep loss effects (Sanders et al., 1982) and their increase over time (Lisper & Kjellberg, 1972; Smulders, Kenemans, Jonkman, & Kok, 1997) are much larger at the upper end of the RT-distribution. Furthermore, Sanders and Hoogenboom (1970) found time-on-task effects only in the slowest RT deciles. It appears that energetical variables in general have strongly variable effects across individual trials, and are thus small or absent at the lower end of the RT-distribution and more pronounced at

the upper end (Sanders, 1983). A plausible cause for this increased variability is variation in effortful compensation of suboptimal states.

In overview, effect sizes of stimulus degradation and time-uncertainty can presumably be used as indicators of low arousal and low activation, respectively. If extraversion has an effect on one of these mechanisms, this should ultimately show in an interaction between extraversion and the corresponding factor. Given the dynamics of effortful compensation, that will be near the end of the task, and for responses that are relatively slow.

2. Method

2.1. Participants

University students were selected based on their extreme *E* score on the EPQ-RA (Sanderman, Arrindell, Ranchor, Eysenck, & Eysenck, 1995), administered in majority during two screenings (total *N* = 370). The average *E* score was 7.7 (SD = 2.75, range 0–12), and scores were distributed in such a manner that the maximal score for extreme introverts (*N* = 25) was set to 5, and the minimal score for extreme extraverts (*N* = 30) was set to 11 to get two sizeable groups that were willing to participate and could be reached again. One participant had a EPQ-RSS lie score larger than 8, and 11 failed to recognize the degraded stimuli (>20% errors) even after extended practice (see procedure). These were excluded.[2] For the remaining introverts (*N* = 22, mean age 19.2 yr, 13 female), the average *E* score was 3.6 (SD = 1.4, range 0–5); for the extraverts (*N* = 21, 20.3 yr, 14 female), the average *E* score was 11.7 (SD = 0.5, range 11–12). The age difference was not significant ($t(41) = 1.4$, $p = .18$). All participants had (corrected-to) normal vision, signed an informed consent form, and received course credits. Permission was obtained from the local ethics committee.

2.2. Task and stimuli

Each trial started with four dots demarcating the area where the imperative stimulus would appear, and, at fixation, a cue indicating the foreperiod for 250 ms. The cue was either the digit '1', indicating that the imperative stimulus would appear one second later (fixed), or a question mark, indicating that the foreperiod was variable between 500 and 11,500 ms, following to a 'non-aging' distribution to minimize the possibility to prepare for the imperative stimulus (Gottsdanker, Perkins, & Aftab, 1986). A soft, but clearly audible tone (665 Hz, 55 dBa) was added to direct participants' attention to the cue. Imperative stimuli, presented for 750 ms, were arrow-shaped dot patterns ('<' or '>', 4.2 * 7.5 cm), surrounded by a frame (9 * 13 dots, 9 * 12.5 cm). Participants were instructed to quickly but accurately press their left (right) index finger resting on a left (right) button when the arrow pointed to the left (right). Half the arrows were degraded by moving 20 dots from the frame to random positions surrounding the arrow. To prevent easy recognition

---

[2] More extraverts (nine) than introverts (three) were excluded, suggesting that recognition of degraded stimuli was especially difficult to extraverts. Although we do not regard this as strong evidence, it is consistent with the overall interpretation of the data (see results): a specific (arousal-related) weakness in stimulus encoding in extraverts.

of specific patterns, there were 20 degraded versions. After 1750 ms the response was evaluated. If it was correct, a 250 ms intertrial interval started immediately, else, the Dutch word for 'error' appeared for 500 ms, first. In all, there were eight trial types (2: intact/degraded stimulus ×2: fixed/variable foreperiod ×2: left/right arrow), repeated in randomized order 46 times during a long period preceding a short interruption, and nine times after that.

2.3. Procedure

Participants sat in a dimly-lit sound-shielded cubicle at 1 m from a monitor. They started with 10 short practice blocks, each ending in feedback of mean RT and amount of errors. During these blocks, each trial was followed by feedback of RT, facilitating performance optimization. The practice blocks could be restarted if participants had difficulty recognizing the degraded stimuli. To promote performance decrements, all RT feedback was removed during the experimental blocks (Steyvers, 1987), and participants handed in their watch to deprive them of time-markers. The long block lasted 27 min. Then the task paused, and the experimenter entered the cubicle to ask the participant if all was still well, and announce the final short task period (5 min).

3. Results

Separate analyses were performed for performance decrement during the long block and the effect of the task interruption. After that, effects at different parts of the RT-distribution will be reported. RTs of incorrect responses were discarded.

3.1. Long block

3.1.1. Mean RT

Average reaction times during the long block were submitted to ANOVA with the factors hand (left, right), stimulus-quality (sq: intact, degraded), foreperiod (fp: fixed, variable), time-on-task (tot), and extraversion-group (E). Time-on-task effects were tested using a planned linear trend across three periods of 9 min (totl).[3] The (small) effects of the factor hand on RT and accuracy were uninteresting and are not reported. Fig. 1a displays the average RTs. Responses were slower to degraded (474 ms) than to intact (403 ms) stimuli, $F(1, 41) = 290.9$, $p < .001$, $\eta_p^2 = .88$, and also slower with variable (468 ms) than with fixed (409 ms) foreperiod, $F(1, 41) = 202.8$, $p < .001$, $\eta_p^2 = .83$. The effect of stimulus degradation was larger in variable than in fixed foreperiod trials (sq ∗ fp: $F(1, 41) = 42.7$, $p < .001$, $\eta_p^2 = .51$), an effect that increased during the task (sq ∗ fp ∗ totl: $F(1, 41) = 4.8$, $p < .05$, $\eta_p^2 = .10$). Also, the effect of foreperiod increased during the task (fp ∗ totl: $F(1, 41) = 15.2$, $p < .001$, $\eta_p^2 = .27$). There was no

---

[3] A planned linear contrast was appropriate, because it was expected that a waning of compensatory effort leads to a simple increase in RT across time (strictly: a non-decreasing function). Koelega (1992, pp. 253–254) noted the greater power of this linear trend analysis in investigating extraversion × time effects in comparison to ANOVA with correction for violations of the sphericity assumption.

Fig. 1. (a) Mean reaction time in introverts and extraverts as a function of stimulus degradation (intact, degraded), foreperiod (fixed, variable), and time-on-task (tot1, tot2, tot3: consecutive 9-min periods in block 1, followed by a short interruption, and then block2, bl2). (b) Mean reaction time in the same groups as a function of time-on-task. Data were collapsed across the levels of the other factors.

main effect of extraversion, $F < 1$, but Fig. 1b depicts a pattern in the RTs that is suggestive of a greater increase in RT across time in extraverts than in introverts (and a drop back after the task interruption, see below). This pattern resulted in an almost significant interaction between extraversion and time-on-task, E * totl: $F(1, 41) = 3.8$, $p = .057$, $\eta_p^2 = .085$. The distributional analysis will shed more light on this effect.

3.1.2. Accuracy

Log-transformed percentage-correct data (Dickman & Meyer, 1988) were submitted to the same analysis as the RTs. Responses were more accurate to intact (97.8%) than to degraded (91.8%) stimuli, $F(1, 41) = 56.3$, $p < .001$, $\eta_p^2 = .58$. There was an interaction between stimulus-quality and foreperiod, $F(1, 41) = 7.9$, $p < .01$, $\eta_p^2 = .16$. Fig. 2 suggests that for intact stimuli, reactions were less accurate with a fixed than with a variable foreperiod, whereas for degraded stimuli the pattern was opposite. Extraversion had no significant effects on accuracy (main effect: $F(1, 41) = 1.5$, $p = .23$, $\eta_p^2 = .04$). The same analyses on raw percent-correct yielded essentially identical results.

3.2. Task interruption

3.2.1. Mean RT and accuracy

Fig. 1 depicts also the effects of the task interruption. These effects were analyzed by replacing the factor time-on-task in the first ANOVA with a factor 'block' with two levels: the last period of block1 (tot3) and block2. The only significant effect of the interruption was that responses in trials with a variable foreperiod speeded up more than with a fixed foreperiod (fp * block: $F(1, 41) = 8.9$, $p < .01$, $\eta_p^2 = .18$). The same ANOVA, run on log-transformed percentage-correct yielded no significant effects.

3.3. Distributional analyses

RT distributions were characterized by computing for each participant, time period and condition, five 20% quantiles ($q1–q5$, fast-to-slow, Ratcliff, 1979). This method can still be used when the number of RTs per cell is relatively small (10–20). Effects at different parts of the distribution were studied by adding the factor 'quantile' (q) to the overall ANOVA. In view of our hypotheses,
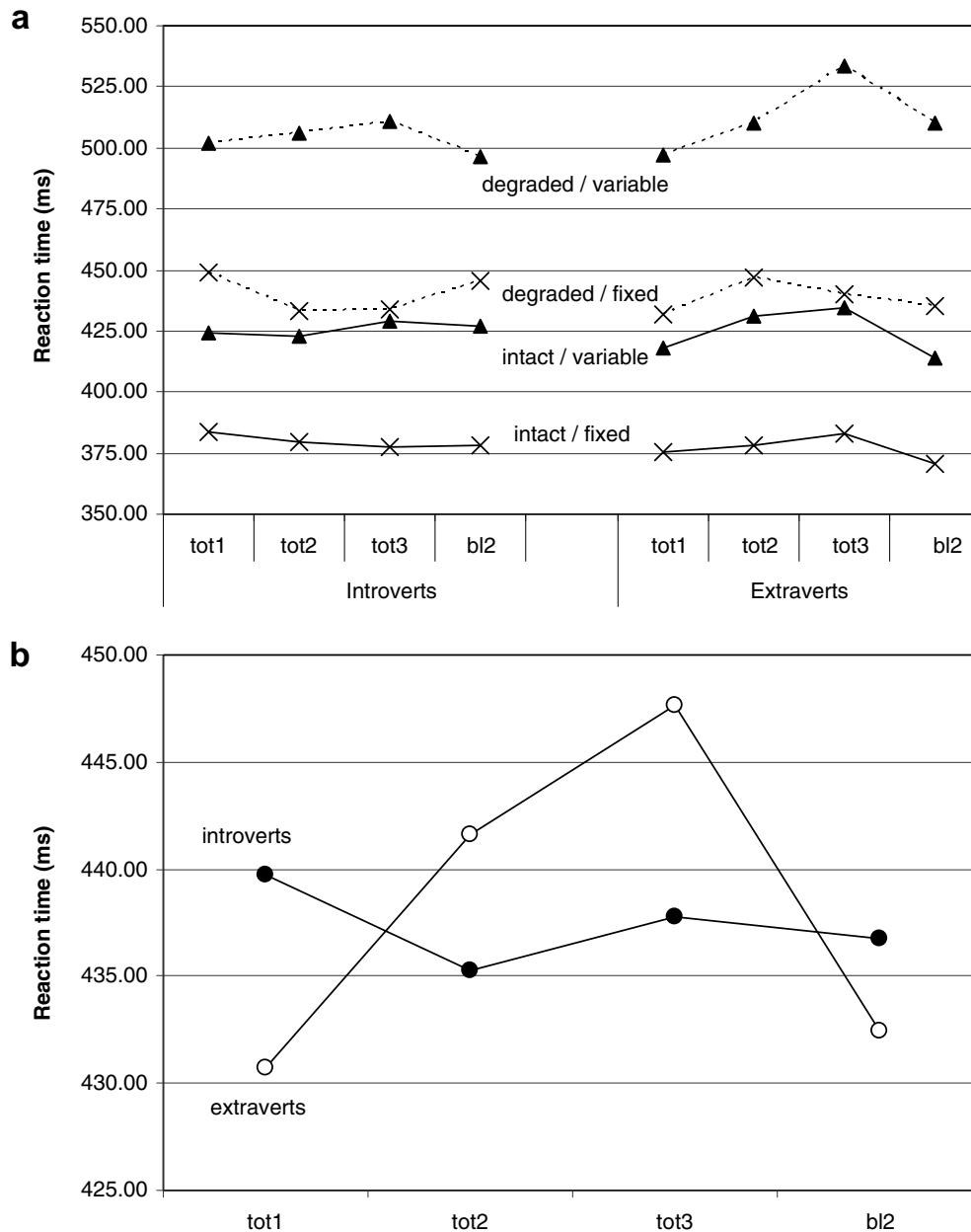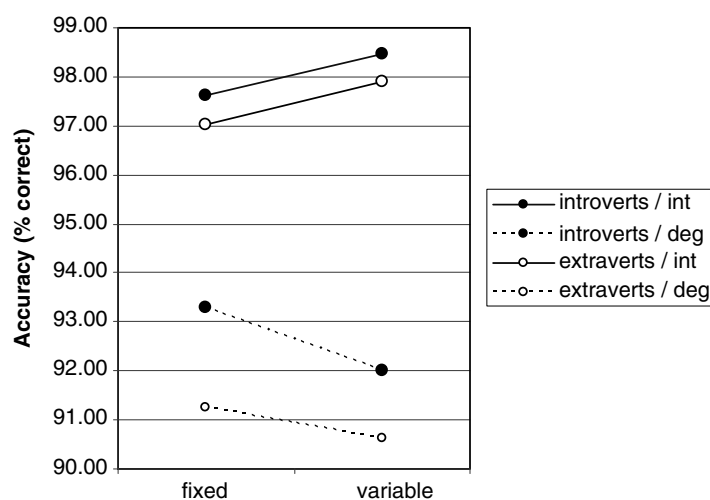

Fig. 2. Mean accuracy in introverts and extraverts as a function of stimulus degradation (int: intact; deg: degraded) and foreperiod (fixed, variable).
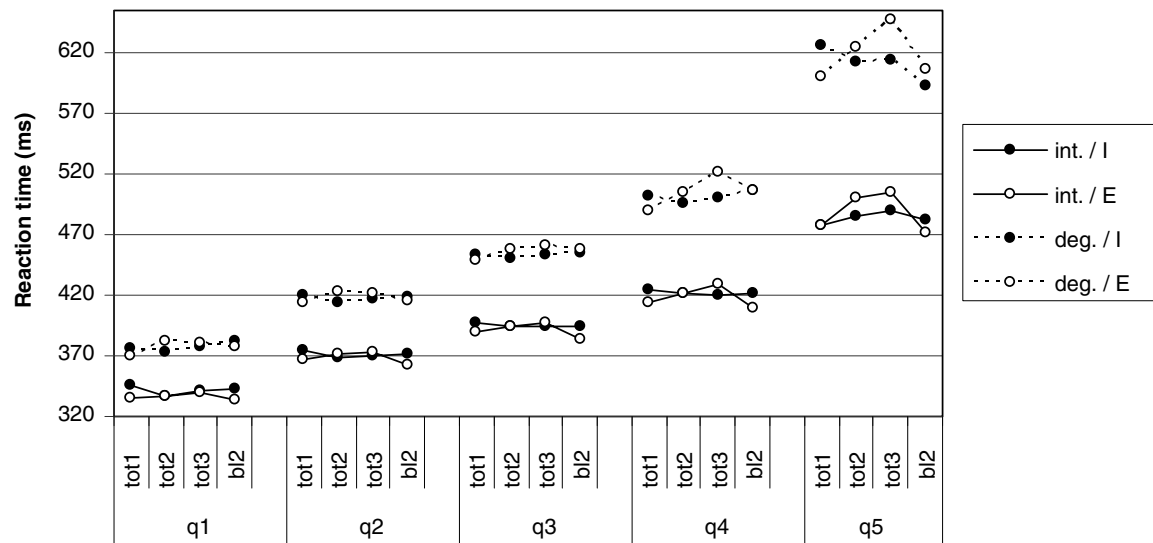
Fig. 3. The effects of extraversion (I = introvert, E = extravert) on reaction time as a function of time-on-task (tot1, tot2, tot3: consecutive 9-min periods in block 1, followed by a short interruption, and then block 2, bl2), reaction time-quantile (20%-bins $q1$–$q5$) and stimulus degradation (int.: intact; deg.: degraded).

the effects of the factor quantile were most simply and adequately described by a planned linear contrast (ql).[4]

3.3.1. Long block

All the task effects found on mean RT were significant here too, but relevant are interactions with the factor quantile. Both stimulus-quality and foreperiod effects were larger at the high end of the RT-distribution than at the low end, $F(1, 41) = 143.4$, $\eta_p^2 = .78$, and 57.1, $\eta_p^2 = .58$, respectively, both $p < .001$. Also their positive interaction was stronger at the high end, $F(1, 41) = 32.7$, $p < .001$, $\eta_p^2 = .44$. As noted, especially the combination of time-on-task and quantile effects indicates energetical effects. An increase in RT across time was stronger for slower responses (totl * ql: $F(1, 41) = 4.3$, $p < .05$, $\eta_p^2 = .094$). Suggesting a decreasing activation level, the latter was more pronounced with a variable than with a fixed foreperiod (fp * totl * ql: $F(1, 41) = 5.6$, $p < .05$, $\eta_p^2 = .12$), but this effect did not depend on E (E * fp * totl * ql: F(1, 41) = 1.1, $p = .30$, $\eta_p^2 = .026$). In contrast, extraversion had specific effects on RTs at the high end of the distribution that depended on stimulus degradation and time-on-task, E * totl * sq * ql: $F(1, 41) = 5.3$, $p < .05$, $\eta_p^2 = .11$. Fig. 3 shows that in the faster quantiles ($q1$–$q3$), RT hardly increased during the task in any group or condition. In $q4$ and $q5$, however, there were marked increases, especially for extraverts' responses to degraded stimuli. Separate analyses per quantile indeed revealed a significant E * sq * totl interaction in $q5$, $F(1, 41) = 5.1$, $p < .05$, $\eta_p^2 = .11$ ($q1$–$q3$: $F(1, 41) < 1$; $q4$: $F(1, 41) = 1.8$, $p = .19$, $\eta_p^2 = .042$). Within $q5$, for degraded, but not for intact

---

[4] The considerations in selecting a planned linear contrast are similar to those described in footnote 3, replacing the factor 'time-on-task' by 'quantile'.

stimuli, there was a significant interaction between extraversion and time-on-task, $F(1, 41) = 6.8$, $p < .05$, $\eta_p^2 = .14$; and $F(1, 41) < 1$, respectively.

3.3.2. Task interruption effects

The factor quantile was added to the ANOVA used for the analysis of interruption effects on mean RT. Fig. 3 shows that, in higher quantiles, there was a greater reduction in RT after the interruption than in lower quantiles (ql * block: $F(1, 41) = 6.8$, $p < .05$, $\eta_p^2 = .14$). No other effects reached significance.

4. Discussion

We aimed to identify differences between extreme introverts and extraverts in the energetical mechanisms postulated in the cognitive-energetical model of Sanders (1983, 1998). It was hypothesized that an effect on arousal or activation would only become apparent when compensatory effort had declined, i.e. at the end of the task, at the high end of the RT-distribution. Indeed, in mean RTs, there was only weak evidence for more increment during the task in extraverts than in introverts, but an analysis of the RT-distribution demonstrated a strong slowing of RTs near the end of the long block at the high end of the distribution to degraded (as compared to intact) stimuli in extraverts. Specifically, in the highest RT-quantile, for degraded stimuli, RT decreased during the task from 627 to 613 ms in introverts, but increased from 600 to 648 ms in extraverts. This pattern is revealing: it appears that only when compensatory effort is low (near the end of the long block, at the high end of the RT-distribution), extraverts' performance is especially low on degraded stimuli. This increase in the effect of stimulus degradation implies a deficient arousal supply to the stimulus encoding stage. Hence, the results embody positive evidence that the arousal mechanism falls short of energetical supply in extraverts. Foreperiod effects also increased during the task, especially for slow responses, but this did not depend on extraversion. This suggests that activation was indeed affected during the task, but apparently to the same extent in introverts and extraverts.

It should be noted that the present measures of energetical mechanisms are indirect because they depend on affected processing stages. Using a more direct approach, Brocke et al. (1996, 1997) used electroencephalographic (EEG) indicators of energetical mechanisms, finding support for a control theory of arousal that specifies that extraversion concerns both effort and arousal. Using similar measures, Beauducel, Brocke, and Leue (2006) found support for the role of effort. A combination of these approaches would entail measuring EEG in the present task, and might lead to convergence, supporting the validity of both approaches.

It was predicted that a decline in performance during the long task would be followed by a restoration after the interruption. Fig. 3 suggests that indeed after the interruption, the group difference for degraded stimuli/slow responses was diminished, but this effect did not attain the level of significance. One reason may be that the period after the interruption was short, so that only few RTs were available, decreasing the power to detect restoration.

Foreperiod predictability had some interesting effects on performance. First, when foreperiods were unpredictable, effects of degradation were enlarged. This interaction contrasts with earlier findings of additivity (e.g. Frowein & Sanders, 1978), and suggests that preparation

for a stimulus may not be limited to motor processes (Sanders, 1980), but also concerns stimulus encoding.[5] The nature of preparation effects on RT has long been debated (Posner, 1978). Indeed, more recently, psychophysiological data demonstrated effects of preparation on processes that preceded motor stages (Müller-Gethmann, Ulrich, & Rinkenauer, 2003). One difference between our manipulation of time-uncertainty and the one used in studies finding additive effects with stimulus degradation, is that we mixed levels of time-uncertainty within a block of trials, rather than between blocks (Frowein & Sanders, 1978), or even between subjects (Stoffels, van der Molen, & Keuss, 1985). This mixing precludes confounding by non-specific differences between blocks or subject groups, and may have increased sensitivity to perceptual effects. Secondly, for intact (as compared to degraded) stimuli, there were more errors with fixed than with variable foreperiods. Likely, preparation resulted in a gain in speed at the cost of errors (Posner, 1978). Interestingly, this effect was smaller for degraded stimuli (Fig. 2 suggests: absent or even the opposite). A difference in preparation for intact and degraded stimuli is impossible, since they were randomly mixed. Likely, there is a decrease in the efficiency of stimulus encoding with unpredictable foreperiods that leads to both the increase in degradation effect on RT, and to increased errors in its output.

In conclusion, effects of extraversion on the decrement of performance during a long task appear not to be limited to d' and hits in vigilance tasks, but can also be found on choice RT. Still, the differences were strong only in circumstances that maximize sensitivity to low arousal. It is revealing that a task of almost half an hour is needed to find an effect, especially for degraded stimuli, but only on the speed of the 20% slowest responses. The specific interaction with degradation suggests that arousal but not activation is affected. Studying the reaction time distribution is also important from an applied viewpoint. In many real-life monitoring tasks, especially if visibility is degraded, the risks may not depend so much on mean RT but rather on the realistic maximum RT.

Acknowledgements

References

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

Brocke, B., Tasche, K. G., & Beauducel, A. (1996). Biopsychological foundations of extraversion: Differential effort reactivity and the differential P300 effect. *Personality and Individual Differences, 21*, 727–738.

---

[5] Theoretically, this opens the possibility that the foreperiod effect is not specifically sensitive to activation, but also to arousal. However, since the interaction that exemplifies the effect of extraversion on arousal ($E *$ stimulus-quality $*$ time-on-task $*$ quantile) was not moderated by foreperiod, nor was there a significant E $*$ foreperiod $*$ time-on-task $*$ quantile interaction, it remains likely that the two four-way interactions reflect different energetical mechanisms, i.e. arousal (affected by extraversion) and activation (unaffected).

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.

Costa, P. T., & McCrae, R. R. (1985). *The NEO personality inventory*. Odessa, FL: Psychological Assessment Resources.

Dickman, S. J., & Meyer, D. E. (1988). Impulsivity and speed-accuracy tradeoffs in information processing. *Journal of Personality and Social Psychology, 54*, 274–290.

Eysenck, H. J. (1967). *The biological basis of personality*. Springfield, IL: Thomas.

Eysenck, H. J. (1990). Biological dimensions of personality. In L. Pervin (Ed.), *Handbook of personality, theory and research* (pp. 244–276). New York: Guilford Press.

Eysenck, M. W. (1988). Individual differences, arousal, and monotonous work. In L. Peonard (Ed.), *Vigilance: Methods, models, and regulation* (pp. 111–118). Frankfurt: Lang.

Eysenck, H. J., & Eysenck, M. W. (1985). *Personality and individual differences: A natural science approach*. New York: Plenum Press.

Frowein, H. W. (1981). Selective effects of barbiturate and amphetamine on information processing and response execution. *Acta Psychologica, 47*, 105–115.

Frowein, H. W., & Sanders, A. F. (1978). Effects of visual stimulus degradation, *S–R* compatibility, and foreperiod duration on choice reaction time and movement time. *Bulletin of the Psychonomic Society, 12*, 106–108.

Frowein, H. W., Gaillard, A. W., & Varey, C. A. (1981). EP components, visual processing stages, and the effect of a barbiturate. *Biological Psychology, 13*, 239–249.

Frowein, H. W., Reitsma, D., & Aquarius, C. (1981). Effects of two counteracting stresses on the reaction process. In J. Long & A. D. Baddeley (Eds.). *Attention and Performance* (Vol. 9). Hillsdale, NJ: Lawrence Erlbaum.

Gottsdanker, R. (1975). The attaining and maintaining of preparation. In P. M. A. Rabbitt & S. Dornic (Eds.). *Attention and Performance* (Vol. V, pp. 59–74). London: Academic Press.

Gottsdanker, R., Perkins, T., & Aftab, J. (1986). Studying reaction time with nonaging intervals: An effective procedure. *Behavior Research Methods, Instruments and Computers, 18*, 287–292.

Koelega, H. S. (1992). Extraversion and vigilance performance: 30 years of inconsistencies. *Psychological Bulletin, 112*, 239–258.

Lisper, H. O., & Kjellberg, A. (1972). Effects of 24-hour sleep deprivation on rate of decrement in a 10-minute auditory reaction time task. *Journal of Experimental Psychology, 96*, 287–290.

Mackworth, J. F. (1964). Performance decrement in vigilance, threshold, and high-speed perceptual motor tasks. *Canadian Journal of Psychology, 18*, 209–223.

Matthews, G., & Gilliland, K. (1999). The personality theories of H.J. Eysenck and J.A. Gray: A comparative review. *Personality and Individual Differences, 26*, 583–626.

Müller-Gethmann, H., Ulrich, R., & Rinkenauer, G. (2003). Locus of the effect of temporal preparation: Evidence from the lateralized readiness potential. *Psychophysiology, 40*, 597–611.

Posner, M. I. (1978). *Chronometric explorations of mind*. Hillsdale, NJ: Erlbaum.

Pribram, K. H., & McGuinness, D. (1975). Arousal, activation, and effort in the control of attention. *Psychological Review, 82*, 116–149.

Ratcliff, R. (1979). Group reaction time distributions and an analysis of distribution statistics. *Psychological Bulletin, 86*, 446–461.

Sanderman, R., Arrindell, W. A., Ranchor, A. V., Eysenck, H. J., & Eysenck, S. B. G. (1995). *Het meten van persoonlijkheidskenmerken met de Eysenck personality questionnaire (EPQ): Een handleiding (the measurement of personality characteristics with the Eysenck personality questionnaire (EPQ): A manual)*. Groningen: Northern Centre for Healthcare Research.

Sanders, A. F. (1980). Some effects of instructed muscle tension on choice reaction time and movement time. In R. S. Nickerson (Ed.). *Attention and performance VIII* (Vol. 3, pp. 59–75). Cambridge, Massachusetts: Bolt Beranek and Newman, Inc.

Sanders, A. F. (1983). Towards a model of stress and human performance. *Acta Psychologica, 53*, 61–97.

Sanders, A. F. (1998). *Elements of human performance: Reaction processes and attention in human skill*. NJ: Erlbaum.

Sanders, A. F., & Hoogenboom, W. (1970). On the effects of continuous active work on performance. *Acta Psychologica, 33*, 414–431.

Sanders, A. F., Wijnen, J. L. C., & Arkel van, A. E. (1982). An additive factor analysis of the effects of sleep loss on reaction processes. *Acta Psychologica, 51*, 41–59.

Smulders, F. T. Y., Kenemans, J. L., Jonkman, L. M., & Kok, A. (1997). The effects of sleep loss on task performance and the electroencephalogram in young and elderly subjects. *Biological Psychology, 45*, 217–239.

Sternberg, S. (1969). The discovery of processing stages: Extensions of Donders' method. *Acta Psychologica, 30*, 276–315.

Steyvers, F. J. J. M. (1987). The influence of sleep deprivation and knowledge of results on perceptual encoding. *Acta Psychologica, 66*, 173–187.

Steyvers, F. J., & Gaillard, A. W. (1993). The effects of sleep deprivation and incentives on human performance. *Psychological Research, 55*, 64–70.

Stoffels, E. J., van der Molen, M. W., & Keuss, P. J. (1985). Intersensory facilitation and inhibition: Immediate arousal and location effects of auditory noise on visual choice reaction time. *Acta Psychologica, 58*, 45–62.

Wilkinson, R. (1969). Some factors influencing the effect of environmental stressors upon performance. *Psychological Bulletin, 72*, 459–482.