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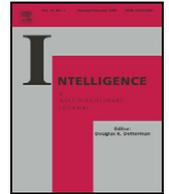
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The relationship between intelligence and creativity: New support for the threshold hypothesis by means of empirical breakpoint detection

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ARTICLE INFO

Article history:

Received 1 August 2012
Received in revised form 12 March 2013
Accepted 14 March 2013
Available online xxxx

Keywords:

Threshold hypothesis
Intelligence
Creativity
Segmented regression
Breakpoint detection

ABSTRACT

The relationship between intelligence and creativity has been subject to empirical research for decades. Nevertheless, there is yet no consensus on how these constructs are related. One of the most prominent notions concerning the interplay between intelligence and creativity is the threshold hypothesis, which assumes that above-average intelligence represents a necessary condition for high-level creativity. While earlier research mostly supported the threshold hypothesis, it has come under fire in recent investigations. The threshold hypothesis is commonly investigated by splitting a sample at a given threshold (e.g., at 120 IQ points) and estimating separate correlations for lower and upper IQ ranges. However, there is no compelling reason why the threshold should be fixed at an IQ of 120, and to date, no attempts have been made to detect the threshold empirically. Therefore, this study examined the relationship between intelligence and different indicators of creative potential and of creative achievement by means of segmented regression analysis in a sample of 297 participants. Segmented regression allows for the detection of a threshold in continuous data by means of iterative computational algorithms. We found thresholds only for measures of creative potential but not for creative achievement. For the former the thresholds varied as a function of criteria: When investigating a liberal criterion of ideational originality (i.e., two original ideas), a threshold was detected at around 100 IQ points. In contrast, a threshold of 120 IQ points emerged when the criterion was more demanding (i.e., many original ideas). Moreover, an IQ of around 85 IQ points was found to form the threshold for a purely quantitative measure of creative potential (i.e., ideational fluency). These results confirm the threshold hypothesis for qualitative indicators of creative potential and may explain some of the observed discrepancies in previous research. In addition, we obtained evidence that once the intelligence threshold is met, personality factors become more predictive for creativity. On the contrary, no threshold was found for creative achievement, i.e. creative achievement benefits from higher intelligence even at fairly high levels of intellectual ability.

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1. Introduction

1.1. The relationship between intelligence and creativity

Although empirical creativity research can meanwhile look back on a scientific tradition of over 60 years of investigation, it is still unclear how the concepts of creativity and intelligence relate to each other (Kaufman & Plucker, 2011). Sternberg and O'Hara (1999) provide a general framework for researchers encompassing five possible relationships: Intelligence and

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creativity can either be seen as a subset of each other, they may be viewed as coincident sets, they can be seen as independent but overlapping sets, and lastly as completely disjoint sets.

Though there exists evidence in favor of each of these perspectives (Kaufman & Plucker, 2011), several influential models of intelligence treat creativity as a lower order factor of intelligence (e.g., divergent production in Guilford's structure-of-intellect model; Guilford, 1967), retrieval ability in Carrol's three-stratum model (Carrol, 1993), or imaginativeness in the Berlin model of intelligence structure (Bucik & Neubauer, 1996; Jäger, 1982). These models thus assume a substantial correlation between creativity and intelligence. Guilford (1967) was one of the first to discover that this correlation may vary at different levels of cognitive ability: He found a positive linear relationship in the lower to average IQ range while there was no correlation at above-average levels of intelligence. Guilford concluded that "the pattern of bivariate distribution of the cases suggests that although high IQ is not a sufficient condition for high DP [divergent production] ability, it is almost a necessary condition" (p. 168). The notion that high intellectual ability is a necessary condition for high creativity has become popular as "threshold hypothesis".

1.2. Creativity

Creativity is a concept of individual differences which is intended to explain why some people have higher potential to provide new solutions to old problems than others. It leads us to change the way we think about things and is conceived as the driving force that moves civilization forward (Hennessey & Amabile, 2010). Creativity is usually examined at different conceptual levels. One of the most general distinctions to be made is the one between creative potential as opposed to creative achievement (Eysenck, 1995). Creative potential refers to the individual's ability to generate something novel and useful (Sternberg & Lubart, 1999) and reflects a normally distributed trait (Eysenck, 1995). In turn, creative achievement refers to the actual realization of this potential in terms of real-life accomplishments (such as having made a scientific discovery, written a novel etc.; cf., Carson, Peterson, & Higgins, 2005). Although different authors use different terminologies such as Little-C vs. Big-C (cf., Kaufman & Beghetto, 2009) to describe this dichotomy, it seems that the underlying taxonomy is the same.

Creative potential is usually assessed by means of tests that measure divergent thinking ability (Runco, 2010) such as the Torrance Test of Creative Thinking (TTCT; Torrance, 1966), the Guilford tests (Wilson, Guilford, & Christensen, 1953), or the Wallach and Kogan tests (Wallach & Kogan, 1965). Divergent thinking (DT) is hereby defined as "the kind that goes off in different directions" (Guilford, 1959, p. 381). Accordingly, divergent thinking tests involve open problems for which a variety of possible solutions can be found. A widely used DT task is the alternate uses task in which participants are instructed to find creative uses for everyday objects (for example: brick – "use for karate demonstration" etc.) (Kaufman, Plucker, & Baer, 2008). DT tests can be scored with respect to different criteria usually involving ideational fluency, i.e. the quantity of ideas produced, and/or originality, i.e. the quality of ideas. However, these scores are commonly found to be correlated to an extent that their discriminative validity has been questioned (Hocevar,

1979; Michael & Wright, 1989; Silvia et al., 2008). This is especially true when a summative originality scoring is employed where originality may directly increase with the number of ideas (i.e., ideational fluency). However, alternative scorings of ideational originality, which control for fluency by either dividing originality by fluency or by considering a constant number of ideas, no longer show this problem (Benedek, Mühlmann, Jauk, & Neubauer, 2013; Hocevar, 1979; Silvia et al., 2008).

Creative achievement is commonly assessed by means of self-reports such as biographical questionnaires in which participants indicate their achievements across diverse domains (e.g., literature, music, or theatre). A popular example is the Creative Achievement Questionnaire (CAQ; Carson et al., 2005). The CAQ and related measures were found to have good psychometric properties (Silvia, Wigert, Reiter-Palmon, & Kaufman, 2012) and successfully discriminate between more and less creative persons (Vellante et al., 2011). Moreover, intelligence significantly predicts CAQ scores (Carson, Peterson, & Higgins, 2003; Kéri, 2011).

Meta-analytic findings suggest that the correlation between creative potential and intelligence generally is around $r = .20$ (Kim, 2005). Besides its relationship to intelligence, personality correlates of creative potential have been extensively studied. The most consistent and significant finding is that creative potential is positively related to openness to experiences (cf., Batey & Furnham, 2006; Feist, 2010). Openness is thought to reflect an "investment trait" relevant to creative potential (Chamorro-Premuzic & Furnham, 2005). Moreover, openness can be associated with actual creative achievement (King, Walker, & Broyles, 1996). Open people are imaginative and curious, which forms a good basis for creative endeavors across all domains. On the contrary, the relationship to other personality traits such as conscientiousness or neuroticism strongly depends on the investigated domain. While conscientiousness may be promotive of scientific creativity, artistic creativity is related to emotional instability (Batey & Furnham, 2006).

1.3. The threshold hypothesis

The basic idea behind the threshold hypothesis is that high creativity requires high or at least above-average intelligence. At this, above-average intelligence is thought to form a necessary but not a sufficient condition for high creativity (Guilford, 1967). More specifically, it is assumed that there exists a threshold in intelligence which is usually set to an IQ of 120. While creativity should be limited by intelligence below this threshold, differences in intelligence should be no longer relevant to creativity above it. Accordingly, the threshold hypothesis predicts a correlation between measures of creativity and IQ only in low to average IQ samples, whereas there should be no correlation in groups of higher IQ.

Studies investigating the threshold hypothesis focused predominantly on the relationship between intelligence and creative potential rather than creative achievement (for reviews see Kaufman & Plucker, 2011; Kim, 2005). Early studies investigating the relationship between intelligence and creativity showed that highly creative individuals are also of higher intelligence (Barron, 1963, 1969; Getzels & Jackson, 1962). Fuchs-Beauchamp, Karnes, and Johnson (1993) investigated the threshold hypothesis in preschoolers and found correlations

between intelligence and creative potential ranging from $r = .19$ to $r = .49$ for a subsample with an IQ below 120. In a subsample above that level, none of the coefficients exceeded $r = .12$. In secondary school children, a significant correlation between intelligence and creative potential of $r = .30$ was found while no significant correlations emerged when gifted children were selected (Yamamoto, 1964). In a later study, correlations of $r = .50$ and $r = .20$ were reported below and above an IQ threshold of 120, respectively (Yamamoto, 1966). Recently, a threshold effect was found using measures of verbal and figural creative potential in a sample of adolescents and adults (Cho, Nijenhuis, van Vianen, Kim, & Lee, 2010). Correlations between intelligence and creative potential of up to $r = .40$ were observed in an average IQ sample while correlations in the higher IQ sample equaled zero. Sligh, Conners, and Roskos-Ewoldsen (2005) reported a slight threshold effect for crystallized intelligence while an inverse threshold effect was found for fluid intelligence.

However, other studies did not spot a threshold effect (Kim, 2005; Preckel, Holling, & Wiese, 2006; Runco & Albert, 1986; Wallach & Kogan, 1965). Preckel et al. (2006) investigated the threshold hypothesis in a sample of about 1300 gifted and normal schoolchildren. They found correlations between processing capacity and ideational fluency ranging from $r = .3$ to $r = .4$ at all levels of cognitive ability. After controlling for speed of information processing, the correlations of intelligence and ideational fluency were markedly reduced, but still no group differences were found. Thus, the results did not support the threshold hypothesis.

A meta-analysis estimated mean correlations below and above an IQ of 120 to be $r = .20$ and $r = .23$, respectively, and therefore rejected the threshold hypothesis (Kim, 2005). Correlations between the two constructs were markedly lower when the type of creativity test was taken into account as a moderator: Like in an early study of Wallach and Kogan (1965), non-speeded tests were practically uncorrelated with intelligence.

Turning from creative potential to creative achievement, no evidence for an intelligence-threshold was found in recent investigations: In a large-scale longitudinal study of intellectually gifted youth, Scholastic Aptitude Test scores of age 13 were used to predict creative real-life outcomes in a 20 year follow-up. Individual differences in the upper range of intellectual ability predicted creative occupational accomplishments (Wai, Lubinski, & Benbow, 2005) as well as achievement in the arts and science (Park, Lubinski, & Benbow, 2007). Moreover, intellectual ability was found to predict scientific creativity even within groups of equal qualification (Park, Lubinski, & Benbow, 2008). Thus, individual differences in intelligence are highly relevant to real-life achievement not only in the general population (e.g., Kéri, 2011) but also within high-ability groups.

1.4. Methodological considerations for investigating the threshold hypothesis

Recently, Karwowski and Gralewski (2013) tested the threshold hypothesis in light of different methodological considerations. The authors proposed three possible criteria in order to accept or reject the threshold hypothesis by means of the correlational approach: The most liberal criterion would be a significant positive correlation below the threshold and an insignificant correlation above it. As a more conservative

criterion, there should be a significant positive correlation below the threshold that is significantly higher than the correlation above the threshold. The most conservative test would be to claim a significant positive correlation below, an insignificant correlation above the threshold, and a significant difference between both of them. The authors investigated the threshold hypothesis at different levels of intelligence (107.5, 115, and 120 IQ points) and found a threshold effect most likely to be observed at an IQ of 115 when considering the most conservative criterion.

Taken together, investigations of the relationship between intelligence and creative potential provide a scattered view: While some studies support a threshold effect, others report low to moderate positive correlations throughout the whole spectrum of intellectual ability. One possible reason for the seemingly contradictory empirical findings could be the different conceptions and measures of creative potential employed by these studies. While some used ideational fluency as a single quantitative indicator of creative potential, other studies also included qualitative measures including ideational originality. At this, recent research indicates that ideational originality may more strongly draw on intelligence than ideational fluency (Benedek, Franz, Heene, & Neubauer, 2012).

Moreover, Karwowski and Gralewski (2013) point out that “it is not known why the threshold is established at 120 points rather than a few IQ points more or less” (p. 25). In fact, it seems that none of the sources that are usually quoted when the threshold hypothesis is concerned (e.g., Guilford, 1967) explicitly assert that the threshold should be fixed at an IQ of 120. It hence appears that, even in absence of any empirical evidence for an IQ-threshold at 120, this very specific assumption of the threshold hypothesis has hardly ever been questioned or examined thoroughly.

1.5. The present research

This study aims at the identification of a possible threshold in the intelligence–creativity–relationship by means of continuous data analysis methods. We applied segmented linear regression analysis which allows for an empirical test of whether and where there is a significant shift in a correlation pattern. “Segmented” hereby refers to the assumption that a given regression function $Y = f(X)$ has different parameters in different segments of the independent variable X . Iterative computational algorithms are used to estimate a breakpoint ψ at which parameters of f are most likely to differ.

Segmented regression analysis is common in the field of epidemiology, where dose–response–relationships are evaluated in terms of threshold models. It can for instance be observed that a stressor X has no effect on health outcome Y up to a certain breakpoint ψ . If the level of X , however, exceeds ψ , the outcome of a disease has to be expected (Haybach & Küchenhoff, 1997; Ulm, 1991). Another common application of segmented linear regression models is the analysis of time-series data (Wagner, Soumerai, Zhang, & Ross-Degnan, 2002). Here, X reflects different time points before and after an intervention and Y represents the potential outcome. It is examined if and how an empirically derived breakpoint ψ corresponds to a theoretically assumed change in outcome Y at time point X after the intervention.

In line with the threshold hypothesis, we predicted a positive linear relationship between intelligence (X) and creative potential (Y) up to a breakpoint ψ , which should be followed by an insignificant relationship between X and Y beyond this breakpoint. We further hypothesized that this breakpoint ψ exists at an above-average level of general intelligence (i.e., $\psi > 100$ IQ points). We investigated three common indicators of creative potential: Ideational fluency, ideational originality as measured by a constant number of ideas (Benedek et al., *in press*; Silvia et al., 2008), and average ideational originality. Additionally, we tested whether the threshold hypothesis also applies to creative achievement. It was predicted that the threshold hypothesis does not hold true for creative achievement (Park et al., 2007, 2008; Wai et al., 2005).

If a significant breakpoint is detected and intelligence does not predict creative potential beyond it, it would be of particular interest to further examine which other constructs can explain variance in creative potential above the threshold. Therefore, we also tested whether correlations of creativity and personality variables are affected by potential intelligence-thresholds.

2. Method

2.1. Participants

In order to obtain a heterogeneous and not solely academic sample, we recruited participants via a local newspaper as well as the university's mailing lists. Inclusion criteria were an age between 18 and 55 years, German as mother tongue, and the absence of neurological and/or mental disorders. After excluding one person due to excessive missing data, the sample consisted of 297 respondents (101 males) with an average age of 30.40 years ($SD = 10.68$). 16% of the participants had at least nine years of schooling, 60% had at least twelve years of schooling, and 24% had a university degree. Participants were paid for taking part in the study.

2.2. Assessment of intelligence

General intelligence (g) was assessed by means of four subtests of the Intelligence Structure Battery (Intelligenz-Struktur-Batterie, INSBAT; Arendasy et al., 2004). The four computer based tests were selected to reflect a broad representation of g including *figural-inductive reasoning* (figural induktives Denken; FID), *verbal short-term memory* (verbales Kurzzeitgedächtnis; VEK), *arithmetic flexibility* (arithmetische Flexibilität; NF), and *word meaning* (Wortbedeutung; WB).

The FID is a 3×3 matrices test in which eight geometric patterns which differ according to a set of rules are shown. The task is to find the correct sequel out of eight response alternatives. In the NF test, participants are to solve equations with missing arithmetic operators. In the VEK test, participants have to remember a bus route. The route is graphically displayed and the name of each bus station is visible for a short period of time. In the WB test, participants have to decide which of four alternatives closest matches the meaning of a target word.

The INSBAT is based on item response theory (IRT) and allows for tailored testing. Target reliability for each scale was set to $\alpha = .60$, which results in an average of 10 items per

test, or an average duration of 10 min per test. The INSBAT is theoretically grounded on the Cattell–Horn–Carroll model of intelligence (for an overview see McGrew, 2009) involving a g -factor as well as five secondary factors, including fluid (g_f) and crystallized (g_c) intelligence (for details see Arendasy et al., 2004). The estimate of g used in this study is based on the factor loadings of the INSBAT subtests, which means that g is most strongly predicted by g_f . The reported intelligence scores reflect standardized IQ scores.

2.3. Assessment of creative potential

Creative potential was measured by means of three alternate uses (AU) tasks and three instances (IN) tasks. In the alternate uses tasks, participants were required to find as many novel and uncommon uses as possible for a *can*, a *knife*, and a *hairdryer*. In the instances tasks, participants were instructed to figure out many novel and uncommon solutions to the problems “What can make noise?”, “What can be elastic?”, and “What could one use for quicker locomotion?” The tasks were administered on a PC and participants were required to enter their ideas via a keyboard. Each task lasted for two minutes. After completion of each task participants were asked to rank their responses with respect to creativity.

Four students (three female) rated originality of responses (similar to the consensual assessment technique proposed by Amabile (1982) given in both the AU and the IN task on a four-point scale ranging from 1 “not creative” to 4 “very creative”. Mean interrater-reliabilities were $ICC = .80$ in the alternate uses tasks and $ICC = .69$ in the instances tasks.

We computed three common scores of creative potential. Ideational fluency was defined as the number of ideas given in the task. For the assessment of ideational originality we used two different scores which avoid the typical confound with ideational fluency. First, we computed a Top 2 originality score, which reflects the creativity ratings of the two most original responses according to the participant's ranking (cf., Silvia et al., 2008). Second, we also computed an average originality score, which reflects the mean creativity ratings of all ideas.

2.4. Assessment of creative achievement

We administered a newly devised measure of creative achievement, the Inventory of Creative Activities and Achievements (ICAA; see also Jauk, Benedek, & Neubauer, *under review*). The ICAA measures everyday creative activities as well as actual creative achievements with two different scales. The ICAA achievements scale is similar to the CAQ (Carson et al., 2005), but has less extreme distributional properties (Jauk, Benedek, & Neubauer, *under review*) thus making it more suitable for breakpoint detection. Across eight domains (literature, music, arts and crafts, creative cooking, sports, visual arts, performing arts, and science and engineering) of creative accomplishment, participants are presented with statements ranging from “I have never been engaged in this domain” (zero points) to “I have already sold some of my work in this domain” (10 points). Internal consistency of the ICAA achievements scale across domains was satisfactory ($\alpha = .71$).

2.5. Assessment of personality

Personality structure was assessed by means of the Big-Five Structure Inventory (Big-Five Struktur Inventar, BFSI; Arendasy, Sommer, & Feldhammer, 2011). The BFSI measures the Big Five personality dimensions with six facets each. The test is based on IRT and could be shown to have good correlations with the German Big Five questionnaire NEO-PI-R, while internal consistency is even higher (Arendasy et al., 2011). Each of the 30 facets is assessed with ten items. The test was administered without time restriction.

2.6. Procedure

The experiment took place in a computer laboratory where groups of up to 10 participants performed all tests on a standard desktop computer. Two experimenters explained the procedure and were present during the whole session. Since this study was part of a larger screening for further investigations, participants also completed motivation scales and a speed of information processing task.

The order of tasks was the same for all participants. After completing a sociodemographic questionnaire and motivation scales, they performed the INSBAT taking about 50 min. After a short break of 15 min, they worked on the speed of information processing task, the tasks of creative potential, the creative achievement questionnaire, and finally the BFSI personality inventory (for 20 min). The total test session took about 2.5 h. The study was approved by the Ethics Committee of the University of Graz.

2.7. Data analyses

We computed creative potential (CP) scores by averaging over the scores of the six divergent thinking tasks. The internal consistency was $\alpha = .88$ for the fluency score, $\alpha = .63$ for the Top 2 originality score, and $\alpha = .75$ for the average originality score. The internal consistency would have been lowered by the exclusion of any single task.

All measures of intelligence and creative potential were normally distributed (Kolmogorov–Smirnov-tests: $Z_{IQ} = 0.73$, ns ; $Z_{CP: Fluency} = 0.90$, ns ; $Z_{CP: Top 2} = 1.21$, ns ; $Z_{CP: Average} = 0.76$, ns). As predicted by theory (Eysenck, 1995; Simonton, 1999), creative achievement displayed positive skewness and

kurtosis ($Z_{Achievement} = 2.13$, $p < .01$; skewness = 1.78, kurtosis = 4.66). Descriptive statistics and intercorrelations of all measures are shown in Table 1. The data were checked for outliers in the multivariate distribution of the IQ score with each of the creative potential and achievement measures by means of Mahalanobis distance as well as Cook's distance. For analyses involving the fluency score and the Top 2 originality score, one person was excluded due to an excess of Mahalanobis distance from the centroid of the multivariate distribution at $p < .001$. For the creative achievement score, four persons were excluded due to an excess of Mahalanobis distance. No influential data points were detected by means of Cook's distance (all $Ds < 0.1$).

Prior to applying the segmented regression analyses, the relationships between intelligence and the measures of creative potential as well as creative achievement were tested for nonlinearity. To this end, we set up hierarchical multiple regression models to examine whether a squared intelligence variable can explain incremental variance in creative potential or achievement over and above the linear term (cf. Coward & Sackett, 1990; Karwowski & Gralewski, 2013). Collinearity of the predictors was avoided by means of residual centering (Lance, 1988). The squared predictor term was found to explain a significant incremental amount of variance for fluency and Top 2 originality, respectively ($CP_{Fluency}$: $\Delta R^2 = .01$, $p < .05$; CP_{Top2} : $\Delta R^2 = .02$, $p < .01$), and it also tended to explain incremental variance for the criterion of average originality (CP_{Avg} : $\Delta R^2 = .01$, $p = .08$). In all cases, beta weights were negative indicating a decrease in slope as predictor scores increase. However, the squared intelligence term did not predict incremental variance in creative achievement ($\Delta R^2 = .00$, $p = .72$). Thus, this relationship is likely to be linear.

2.8. Segmented regression method

The segmented regression analyses were performed with the open statistic software R (version 2.15.0) using the *segmented* package (Mueggli, 2008). IQ served as the independent variable, and each of the measures of creative potential and achievement served as the dependent variable. The algorithm has to be supplied with one or more initial guess parameter(s) for the breakpoint(s). We used an initial guess parameter of $\psi_0 = 100$ IQ points.

Empirically determined breakpoints were tested for statistical significance by means of the Davies test (Davies,

Table 1

Descriptive statistics and intercorrelations of intelligence, creativity, and personality measures.

	Min	Max	<i>M</i> (<i>SD</i>)	2	3	4	5	6	7	8	9	10
IQ (1)	59.27	147.37	107.21 (14.63)	.22**	.36**	.35**	.28**	-.15**	.08	.14*	-.06	-.07
CP: Fluency (2)	4.17	27.17	12.37 (3.89)		.15**	.02	.28**	-.11	.17**	.26**	.00	.08
CP: Top 2 originality (3)	1.31	2.54	2.04 (0.21)			.75**	.26**	.01	.10	.16**	-.13*	-.15*
CP: Average originality (4)	1.45	2.16	1.82 (0.12)				.21**	.05	.08	.14*	-.16**	-.11
Creative achievement (5)	0	208	40.72 (35.15)					-.10	.22**	.37**	-.03	-.03
Neuroticism (6)	-2.30	3.20	-0.04 (0.75)						-.48**	-.24**	-.25**	-.37**
Extraversion (7)	-2.43	2.28	0.13 (0.81)							.53**	.20**	.27**
Openness (8)	-2.07	2.03	0.16 (0.78)								.31**	.28**
Agreeableness (9)	-2.27	2.83	0.00 (0.80)									.40**
Conscientiousness (10)	-2.15	2.46	-0.05 (0.89)									

Note. $N = 297$. Big five personality measures reflect person parameters according to the IRT model. CP: creative potential.

* $p < .05$.

** $p < .01$.

1987). This test estimates the probability of a significant change in slope (H_1) under the assumption that the breakpoint parameter ψ vanishes under H_0 . The Davies test has to be supplied with a number of K equally spaced evaluation points between the 5 and 95% quantiles of the independent variable. According to common recommendations this parameter was set to $K = 7$ (Mueggel, 2008). Significance tests were performed two-tailed at $\alpha = .05$.

3. Results

3.1. Segmented regression analyses

Segmented regression analyses were computed for all three criteria of creative potential and for creative achievement.

For the criterion of ideational fluency, a breakpoint was detected at an IQ of 86.09 points. This breakpoint is statistically significant according to the Davies test for a change in the slope ($p < .05$; 95% CI = 75.57–96.61 points). The bivariate correlations (i.e., standardized β s) between intelligence and ideational fluency were $r = .56$ ($p < .01$, $n = 21$) below the breakpoint of 86.09 IQ points and $r = .09$ (ns , $n = 275$) above it. These correlations differed significantly according to Steiger's z -test ($z = 2.23$, $p < .05$). The breakpoint model is shown in Fig. 1a.

For creative potential assessed by means of the Top 2 originality score, a significant breakpoint was detected at an IQ of 104.00 points ($p < .05$; 95% CI = 93.07–114.90 points). The bivariate correlations between intelligence and creative

potential were $r = .38$ ($p < .01$, $n = 121$) below the breakpoint and $r = .14$ (ns , $n = 175$) above it and differed significantly ($z = 2.17$, $p < .05$). The scatter plot with the segmented relationship is shown in Fig. 1b.

When the average originality was considered as a criterion, the breakpoint was estimated at an IQ of 119.60 points. This breakpoint, however, failed to reach statistical significance in the Davies test ($p = .14$; 95% CI = 107.5–131.7). Nonetheless, again, a significant correlation between intelligence and creative potential was obtained for the lower IQ range ($r = .35$, $p < .01$, $n = 232$), but not for the upper IQ range ($r = -.01$, ns , $n = 65$). These correlation coefficients were significantly different ($z = 2.62$, $p < .01$). Fig. 1c shows the scatterplot containing the segmented linear relationship.

Finally, segmented regression analysis was also performed for the criterion of creative achievement (although no non-linear relationship was observed; see above). In line with the test of nonlinearity, no significant breakpoint was detected ($p = .64$). The linear model is shown in Fig. 1d.

3.2. Multiple regression analyses

Since a statistically significant threshold for creative potential (Top 2 originality score) could be detected at an IQ of 104.00 points, we performed separate multiple regression analyses for subsamples below and above this threshold. General intelligence and the personality dimensions openness to experiences, conscientiousness, and agreeableness were entered as predictors since these variables showed significant

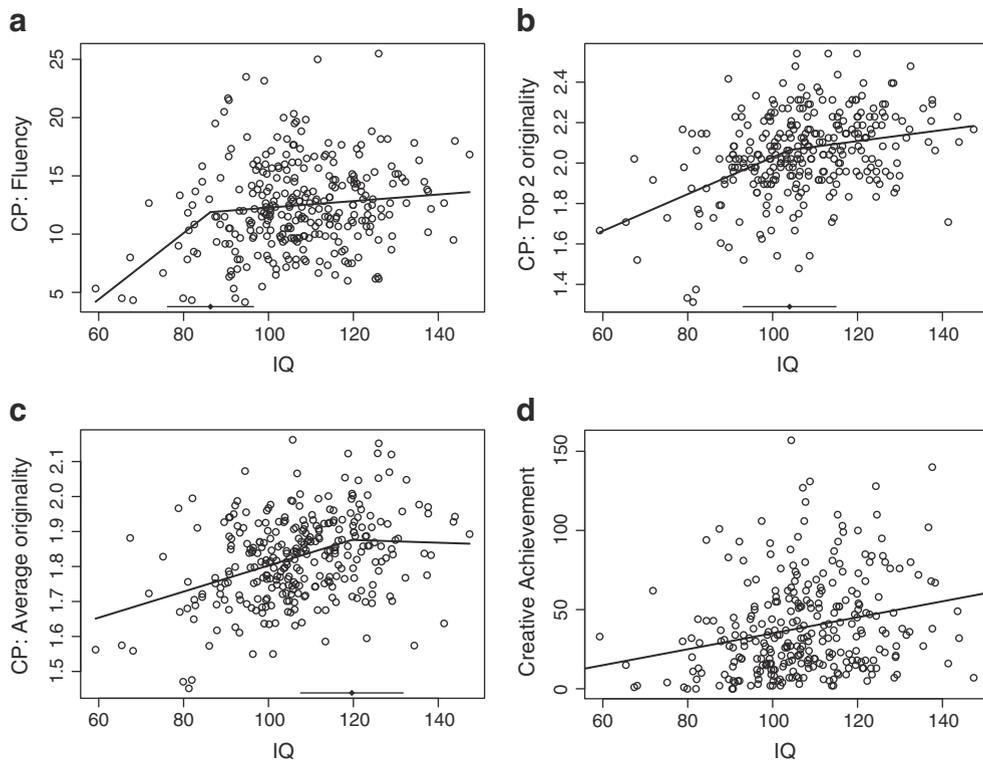


Fig. 1. Breakpoint models for the fluency score (a), the Top 2 originality score (b), and the average originality score (c). Linear model for creative achievement (d). Horizontal lines indicate 95% CI of the breakpoint. CP: creative potential.

zero-order correlations with the criterion (neuroticism and extraversion could not explain a significant increment in variance: $\Delta R^2_{IQ < 104} = .03$, *ns*; $\Delta R^2_{IQ > 104} = .03$, *ns*). The enter-method was used in regression analyses. All variables showed normal distribution by means of the K–S-test; there was no indication of multi-collinearity (Tolerance > 0.6; VIF < 1.5) and the residuals showed no visible heteroscedasticity.

Results for the two independent regression models are shown in Table 2. Both models were statistically significant (IQ < 104: $F[4, 116] = 7.15$, $p < .01$, $R^2_{adj} = .17$; IQ > 104: $F[4, 170] = 4.34$, $p < .01$, $R^2_{adj} = .07$). Below the IQ-threshold, creative potential is significantly predicted by IQ and conscientiousness, but not by openness. In contrast, above the IQ-threshold intelligence and conscientiousness are significant predictors only by trend, whereas now openness is the strongest predictor of creative potential. Despite weak significant zero-order correlations in the total sample, agreeableness does not significantly predict creative potential in both regression analyses of IQ subsamples, which is most likely due to the reduced sample size.

Separate regression analyses were not performed for creative potential as defined by average originality or ideational fluency since the subsamples above 119.60 and below 86.09 IQ points, respectively, were too small to allow for a powerful analysis. As there was no threshold for creative achievement we also did not compute separate regression analyses for this measure.

4. Discussion

While it is largely acknowledged that the constructs of intelligence and creativity are related, the exact nature of their interplay is still under debate (Kaufman & Plucker, 2011). The prominent threshold hypothesis proposes that a certain minimum level of intelligence is a necessary condition for creativity. However, extensive tests of this hypothesis showed inconsistent results and the suggested threshold of 120 IQ points represents, at best, an educated guess. We investigated the threshold hypothesis by means of segmented regression analysis aiming for an empirical determination of the potential threshold between intelligence and creativity. To our knowledge this is the first report of an application of this method in the context of the threshold hypothesis of creativity.

4.1. The threshold effect

In line with the threshold hypothesis, we found evidence for a segmented linear relationship between intelligence and

creative potential. Intelligence significantly predicted creative potential in a lower IQ range but not in the upper IQ range. Hence, the correlation between intelligence and creative potential appears to be moderated by the level of intelligence. Moreover, the actual level of the threshold was found to depend on the applied measure of creative potential. For the quantitative criterion of ideational fluency we obtained a rather low IQ threshold of 86.09 points. In contrast, IQ thresholds for qualitative measures of creative potential were higher: When ideational originality was defined by the two most creative ideas in divergent thinking tasks (cf., Silvia et al., 2008), the relationship between intelligence and creative potential showed a threshold at 104.00 IQ points. When the average originality of all ideas was considered, the estimate of 119.60 points did actually perfectly match the often mentioned threshold of 120 IQ points. The Davies test for differences in slope was not significant but correlations still differed significantly. The data hence still meet the most conservative criterion as proposed by Karwowski and Gralewski (2013): A significant positive relationship below the threshold, no significant correlation above it, and a significant difference between both.

How could the observed discrepancy between the IQ thresholds of 86, 104 and 120 IQ points be explained? Considering first the thresholds of the qualitative measures of creative potential, the most straightforward interpretation would be that it simply needs higher intelligence to produce a series of original ideas than just two of them. The observation that the IQ threshold when predicting ideational fluency is around 85 IQ points further supports this notion: While one has to have at least above-average intelligence to produce *original* ideas, producing a higher *quantity* of ideas (disregarding their quality) seems easier to manage. Given a necessary minimum of intelligence of about 1 standard deviation below the population mean or higher, no significant correlation between ideational fluency and cognitive ability can be observed anymore. This result is well in line with the finding that intelligence is more predictive of ideational originality than of fluency (Benedek et al., 2012). The unusually strong correlation of $r = .56$ below this threshold also indicates that the low correlation of $r = .22$ in the total sample may merely be caused by the high covariance in the low ability range.

The differences in thresholds for different measures of creative potential might also help to explain discrepant findings of studies using only ideational fluency as a single indicator of creative potential and thereby disregarding the quality of ideas. When considering only fluency, the absence of a threshold at 120 is well in line with our data. As Batey and Furnham (2006) conclude: “Eminent samples are a highly select population who must possess certain abilities over and above fluent DT to achieve success. This discrepancy may be partly resolved by looking to quality rather than quantity of responses to traditional DT tests” (p. 367). Indeed, the threshold hypothesis does not predict that one needs intelligence in order to produce many ideas of unknown quality, but that one needs a certain intellectual capacity in order to produce creative ideas.

But what are the mechanisms by which intelligence fosters creative potential? Past research suggests that these mechanisms include the adoption of smart strategies, high

Table 2

Multiple regression analyses predicting creative potential by IQ and personality factors for subsamples below and above an IQ of 104.

Predictor	IQ < 104		IQ > 104	
	β	<i>p</i>	β	<i>p</i>
IQ	.37	.00	.14	.06
Openness	.12	.23	.25	.00
Agreeableness	-.07	.45	-.12	.13
Conscientiousness	-.21	.04	-.13	.10

Note. $n_{IQ < 104} = 121$, $n_{IQ > 104} = 175$.

cognitive control and broad knowledge. Creative idea generation is a complex task which involves many different strategies for reframing a problem (Gilhooly, Fioratou, Anthony, & Wynn, 2007). It was shown that it can depend on intelligence whether such strategies really result in higher creative performance (Nusbaum & Silvia, 2011). Moreover, there is increasing evidence that the relationship of creative potential and intelligence is mediated by executive processes such as cognitive inhibition and switching (Benedek et al., 2012; Nusbaum & Silvia, 2011). Effective executive processes may support effective retrieval from semantic knowledge and thus help to inhibit predominant responses and to access remote and unrelated semantic concepts which can be combined to form creative ideas (Benedek, Könen, & Neubauer, 2012; Benedek & Neubauer, 2013). Finally, many creative problems strongly draw on verbal abilities and general knowledge. Crystallized intelligence was found to show higher correlations with specific measures of creative potential than other components of intelligence (Cho et al., 2010). It hence can be assumed to play an important role for the elaboration of ideas and for challenging verbal creative processes such as the creation of metaphors (Silvia & Beaty, 2012).

We found evidence for an IQ threshold with respect to creative potential, but not for creative achievement. Our results thus suggest that intelligence fosters creative achievement across the whole range of intellectual ability. This is in line with previous studies reporting that IQ is predictive of creative achievement even within high ability groups (Park et al., 2007, 2008; Wai et al., 2005). Moreover, intelligence and creative potential were found to be concurrently predictive of creative achievement (Plucker, 1999). It hence can be concluded that the threshold hypothesis only holds true for indicators of creative potential but not for creative achievement. Finally, this result pattern provides evidence for the sensitivity but also the specificity of the employed analysis strategy.

4.2. Personality predictors of creative potential

When performing separate multiple regression analyses in samples of lower and higher intelligence, we found that openness to experiences predicts creative potential in the subsample above the threshold whereas conscientiousness is negatively related to creative potential in the lower IQ range.

While it is well documented that there exists a positive association between openness and creative potential (Batey & Furnham, 2006; Feist, 2010; King et al., 1996), the present result points to an interaction between intelligence and openness: High creative potential is not possible with a low level IQ; but once the intelligence threshold is met, openness may explain to some extent whether the required cognitive disposition is actually turned into high creative potential. Past research showed that openness influences crystallized intelligence via the path of fluid intelligence (Ziegler, Danay, Heene, Asendorpf, & Bühner, 2012) and thus can be viewed as an “investment trait” (Chamorro-Premuzic & Furnham, 2005). Moreover, King et al. (1996) found that a combination of high creative potential and high openness is predictive for creative achievement. Although further research is needed to clarify the relationship between these constructs, it could be hypothesized that high intelligence

and high openness predict creative potential, which, in turn, predicts creative achievement.

In the below-average IQ sample, low conscientiousness predicted creative potential in addition to general intelligence. Batey, Chamorro-Premuzic, and Furnham (2010) also found conscientiousness to be negatively related to self-reported ideational behavior. Analyses of the facets of conscientiousness showed that deliberation predicted ideational behavior negatively while competence was associated positively. The authors interpret their findings in the way that ideational behavior may be characterized by an inability to restrain impulses. Moreover, the relationship between conscientiousness and creativity may depend upon the investigated sample: While artists are of lower conscientiousness than non-artists, scientists are generally more conscientious. More creative scientists, however, show higher levels of facets that reflect low conscientiousness than less creative scientists (i.e., direct expression of needs and psychopathic deviance; Feist, 1998).

Taken together, our results point to different constellations of traits that are relevant to creative potential in lower and higher IQ samples: While divergent thinking ability may be supported by a lack of conscientiousness, i.e. “impulsive creativity”, in lower intelligent persons, higher creative potential in more intelligent individuals may stem from higher openness to experiences. Higher openness may foster the acquisition of a broader general knowledge and thus support creativity (Cho et al., 2010).

4.3. Limitations and conclusions

An important point for studies investigating the threshold hypothesis is the IQ range of the tested sample. It is usually considered adequate to compare lower vs. higher IQ samples for a powerful detection of an IQ threshold in creative potential (cf., Preckel et al., 2006). In the case of creative achievement, even highly selective groups of very intelligent individuals have been extensively studied (cf., Park et al., 2007, 2008; Wai et al., 2005). The present study used a naturalistic sample showing a continuous normal distribution of intelligence. This sample still included about twice as many participants with an IQ above 120 points (60 persons, or 20%) than would be expected when drawing a random sample of 300 persons. While an even more selective sample may be suitable to discriminate among the very brightest, this study made the attempt to perform an unbiased detection of potential thresholds within the typical range of intelligence (cf., Karwowski & Gralewski, 2013). Moreover, since the tests used in this study were able to detect significant thresholds, statistical power could be considered sufficient. Further studies are still needed to test the robustness of the obtained threshold estimates.

Recent research points to the relevance of crystallized intelligence with regards to the threshold hypothesis (Cho et al., 2010; Sligh et al., 2005). Since the intelligence test battery administered in the present study was assembled in order to obtain a broad and reliable measure of *g* it is not suited to decompose the effects of fluid and crystallized intelligence. Future research could employ segmented regression analyses to examine the threshold hypothesis in more detail with respect to lower order factors of intelligence.

Summarizing, intelligence is highly relevant for creativity, but the kind of relationship depends on the level of intelligence

as well as on the actual indicator of creativity. In line with early assumptions, intelligence may increase creative potential up to a certain degree where it loses impact and other factors come into play. At this, it possibly applies that the more complex the measure of creativity that is considered, the higher the threshold up to which intelligence may exert its influence. For the most advanced indicator of creativity, namely creative achievement, intelligence remains relevant even at the highest ability range.

Acknowledgments

This research was supported by a grant from the Austrian Science Fund (FWF): P23914. The authors wish to express their gratitude to Michaela Lenzhofer and Martin Wammerl as well as Maïke Sitter for their help in organizing and conducting the test sessions. Moreover, we are grateful to the students of the University of Graz who rated the originality of responses. The helpful comments of the journal editor and the anonymous reviewers are gratefully acknowledged.

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