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Differential effects of cognitive inhibition and intelligence on creativity

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ABSTRACT

There are different conceptions about how cognitive inhibition is related to creativity. Creativity has either been associated with effective inhibition, or with disinhibition, or with an adaptive engagement of inhibition. In this study, we examined the relationship of cognitive inhibition, assessed by means of the random motor generation task, with different measures of creativity. We also analyzed whether this relation is mediated by intelligence. We generally found a positive correlation of inhibition and creativity measures. Moreover, latent variable analyses indicate that inhibition may primarily promote the fluency of ideas, whereas intelligence specifically promotes the originality of ideas. These findings support the notion that creative thought involves executive processes and may help to better understand the differential role of inhibition and intelligence in creativity.

1. Introduction

At the heart of every conception of creativity stands the creation of new ideas. Research, therefore, targets at a better understanding of the cognitive processes involved in creative ideation. Gilhooly, Fioratou, Anthony, and Wynn (2007) performed a detailed analysis of the alternate uses task and found that the fluent production of new uses was predicted by the "executively loading task" letter fluency, while the production of familiar uses (i.e., retrieved from long-term memory rather than created during the task) was not. They assumed that people with higher executive capacity may find it easier to inhibit dominant responses and switch strategies or categories. In a similar vein, Nusbaum and Silvia (2011) showed that fluid intelligence predicts higher switching of categories during an idea generation task, which corresponds to high divergent thinking performance. A study by Benedek, Könen, and Neubauer (in press) showed that creativity is substantially predicted by the abilities of dissociation and associative combination. This suggests that the generation of creative ideas requires fluent generation and combination of mutually remote associative elements (Mednick, 1962). At this, it was hypothesized that dissociation ability may reflect an indicator of semantic inhibition facilitating the fluent access to new and remote concepts.

These findings suggest that creative ability is related to executive functioning. Some other studies have addressed this issue by using explicit tests of executive function and specifically with tests of cognitive inhibition. Golden (1975) reports that, in a study involving high school students, high performance in the color-word Stroop task (i.e., a classic measure of cognitive inhibition which requires to name the font color of words which can be incongruent to the word meaning) was positively related to divergent thinking performance and to teacher ratings of students' creativity. Similar evidence was obtained by Groborz and Nęcka (2003), who showed that creativity assessed by divergent figural production was related to higher cognitive control as indexed by the Stroop and the Navon task (i.e., a task which requires to focus either on local or global features of a stimulus and to inhibit incongruent features).

However, not all studies find support for a positive relation of creativity and cognitive inhibition. Some studies report no correlation of creativity and cognitive inhibition (Burch, Hemsley, Pavelis, & Corr, 2006; Green & Williams, 1999; Stavridou & Furnham, 1996). And more interestingly, there also exists the opposite view that "creative people are characterized by a lack of both cognitive and behavioral inhibition" (Martindale, 1999, p. 143; see also, Eysenck, 1995). This notion may stem from the general observation that creative people are usually characterized by high ideational fluency, high associative fluency (Benedek et al., in press; Mednick, Mednick, & Jung, 1964), and are associated with increased impulsivity (Burch et al., 2006; Schuldenberg, 2000). Empirical evidence for this notion comes from a study showing that high creative achievers were found to show decreased latent inhibition as compared to low creative achievers (Carson, Peterson, & Higgins, 2003).

As a third perspective, creativity has been related to differential or flexible engagement of inhibition. It was shown that creative people show slower responses in tasks requiring inhibition of interfering information, but faster responses in tasks without interference (Dorfman, Martindale, Gassimova, & Vartanian,

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2008; Kwiatkowski, Vartanian, & Martindale, 1999; Vartanian, Martindale, & Kwiatkowski, 2007). These findings have been interpreted in terms of a differential focusing of attention; that is, creative people may be able to focus or defocus attention depending on task demands. In a similar vein, Zabelina and Robinson (2010) found that divergent thinking and creative achievement were not generally related to inhibition as measured by the common Stroop effect, but rather to a more flexible trial-to-trial modulation of cognitive control.

Hence, although there is increasing evidence that creativity is related to cognitive inhibition, this evidence appears to be conflicting, either associating creativity with high cognitive inhibition, with cognitive disinhibition, or an adaptive cognitive control. It should also be noted that most studies on creativity and inhibition so far have not considered the role of intelligence. Executive functions such as cognitive inhibition are commonly conceived to reflect essential cognitive processes underlying general intelligence (e.g., Arffa, 2007). Moreover, intelligence shows a moderate but consistent relationship with creativity (e.g., Kim, 2005), and there is an increasing understanding on how intelligence may facilitate creative thought (Nusbaum & Silvia, 2011; Silvia & Beaty, in press). Taken together, intelligence may qualify as a mediator of the inhibition-creativity relationship.

The first main aim of this study is to examine the correlation of cognitive inhibition and creativity and see whether it is consistent for different indicators of creativity. Since inhibition as defined above is related to cognitive flexibility and non-perseverative behavior, we hypothesize that there generally should be a positive correlation. The second main aim of this study is to examine whether the relation of creativity and inhibition is mediated by intelligence. Analyses shall be performed at latent level in order to estimate the correlations devoid of the influence of measurement error.

2. Methods

2.1. Participants

A total of 109 students enrolled in local universities participated in this study. Five people were excluded because of substantial missing data, resulting in a final sample of 104 (79 women, 25 men; mean age: 23.6 years, $SD = 4.0$). The sample had a wide range of majors with the most common being Psychology (53.8%). Participants received either a feedback on personality structure or course credits for participation.

2.2. Psychometric tests and questionnaires

2.2.1. Cognitive inhibition

Cognitive inhibition was measured by means of a random motor generation (RMG) test. We used an adapted computerized version of the Mittenecker Pointing Test (Mittenecker, 1958 Schulter, Mittenecker, & Papousek, 2010), which requires participants to generate random sequences of key responses at a specified response rate. There is substantial empirical evidence that RMG indicates the efficiency of inhibitory processes (cf., Schulter et al., 2010). Effective generation of random sequences requires the inhibition of the naturally occurring tendency to repeat previously selected sequences. Therefore, task performance is usually lower when the task is performed at higher pace or with a larger set of response alternatives (Brugger, 1997). Moreover, low RMG performance was consistently related to reduced executive functioning in neurological disorders such as schizophrenia (e.g., Morrens, Hulstijn, & Sabbe, 2006) and Parkinsons' disease (e.g., Stoffers, Berendse, Deijen, & Wolters, 2001). Finally, latent variable analyses of executive functions revealed that random sequence generation is solely related to inhibition, but not to shifting or updating (Miyake et al., 2000).

We realized four task conditions by varying the number of keys (4 vs. 9) and the response rate (2 Hz vs. 1 Hz). The response rate was guided by a regular acoustic beat presented via headphones. The performance in the RMG task was scored for context redundancy of sequence pairs (CR_1; for details, see Schulter et al., 2010). High context redundancy reflects dominant use of certain sequences of keys; low context redundancy reflects inhibition of ''prepotent associates'' and indicates executive inhibition (Miyake et al., 2000; Towse & Neil, 1998). Since the scale range of CR_1 is between 0 and 1, for further analyses, we reversed the scale by $CR^* = 1 - CR$, so that high scores reflect high inhibition. The inhibition score showed good internal consistency (Cronbach's $\alpha = .80$).

2.2.2. Creativity measures

In order to obtain a comprehensive measure of the multi-faceted construct of creativity, a set of different well-established tests and questionnaires was employed. We used five tests of divergent thinking from the Berlin-Intelligence-Structure test (BIS; Jäger, Süß, & Beauducel, 1997), including three verbal tests AM (''Anwendungs-Möglichkeiten''; find many alternative uses for a cushion), EF (''Eigenschaften-Fähigkeiten''; find characteristics that a good salesman should not have), IT (''Insight-Test''; find many explanations why many people think that person X is likeable), and two figural tests OJ (''Objekt-Gestaltung''; compose many objects out of given figural elements), ZF (''Zeichen-Fortsetzen''; draw many different objects by completing a figural element). These five tasks were selected because for them the test manual provides category lists allowing for the scoring of ideational flexibility. The working time per task ranged from 120 to 150 s resulting in a total working time of about 12 min. After completing all tasks, participants were instructed to select their three most creative ideas in each task by marking the responses with corresponding numbers (''1'', ''2'', or ''3''). All tasks were scored for the three most relevant indicators of divergent thinking ability (Runco, 2010) including ideational fluency (i.e., number of ideas), ideational flexibility (i.e., number of categorically different ideas), and ideational originality (i.e., originality and creativity of ideas). For the scoring of ideational originality, the selected three ideas per task were compiled to idea lists, and then rated for creativity/originality by five independent raters (inter-rater reliability ranging from ICC = .47 [AM task] to .84 [ZF task]). This method allows one to obtain a score of ideational originality that is not directly dependent on ideational fluency (Silvia et al., 2008). The originality scores of the five tasks showed only moderate internal consistency (Cronbach's $\alpha = .54$). We also tried alternative scorings using the two most creative ideas (cf., Silvia et al., 2008), or the single most creative idea, which, however, resulted in even lower reliabilities (Cronbach's $\alpha = .47$ or .30, respectively). Additionally, a compound score of divergent thinking was computed as the average of the three z-standardized measures of divergent thinking (i.e., ideational fluency, flexibility, and originality).

We measured self-reported ideational behavior by means of a German version of the Runco Ideational Behavior Scale (RIBS; Runco, Plucker, & Lim, 2000), and creative personality by means of a German version of the Creative Personality Scale (CPS; Gough, 1979). We also devised an inventory of creative accomplishments which lists 48 creative accomplishments (e.g., ''I wrote a poem'') from eight different domains (cf., Hocevar, 1979). Participants indicated how often they had done each activity within the last 10 years (never, 1–2 times, 3–5 times, 6–10 times, more than 10 times). We computed domain scores and the scale showed good internal consistency over domains (Cronbach's $\alpha = .81$). Finally, we administered two items of a dissociation task, which requires participants to generate as many unrelated concepts as possible within 1 min. Dissociative ability was shown to be highly predictive of creativity (Benedek et al., in press).

2.2.3. Intelligence

Psychometric intelligence was assessed by means of the short form of the test of processing capacity from the Berlin-Intelligence-Structure test (BIS; Jäger et al., 1997) involving two tasks from the verbal (WA, TM), figural (CH, AN), and numerical domain (ZF, SC). Processing capacity reflects the ability of "formal logical thinking and judgement" (Carroll, 1993, p. 64) and can be interpreted as reasoning ability. The working time per task ranged from 60 to 220 s resulting in a total working time of about 14 min. Preliminary analyses of internal consistency revealed that one subtest (TM; "Tatsache-Meinungen" [fact-opinion]) shows a low corrected subtest-total correlation of only .26, which substantially affects internal consistency of the total score. Therefore, we removed this subtest, so that the total intelligence score resulted in an acceptable Cronbach's α of .70.

2.2.4. Personality

We also assessed personality structure by means of the Big-Five personality test NEO-FFI (Borkenau & Ostendorf, 1993). This was done as part of a standard procedure, and in order to provide feedback to the participants; the test, however, was not further analyzed here.

2.3. Procedure

Participants were tested in groups of 2–5 people in a computer room at the Department of Psychology. Participants first were requested to indicate some relevant socio-demographic variables. They then worked on the RMG task, followed by the dissociation task, the divergent thinking tasks, the CPS, the RIBS, the list of creative accomplishments and some further self-developed questions related to creative behavior. Finally, the intelligence tests were administered followed by the NEO-FFI. The total test session took about 90 min. All participants gave written informed consent prior to participation. The procedure was approved by the local Ethics Committee.

3. Results

3.1. Correlation of inhibition, intelligence and creativity

Descriptive statistics, internal consistency and inter-correlations of all measures are presented in Table 1. Inhibition shows positive correlations with most indicators of creativity. Correlations are highest with ideational flexibility and ideational fluency but there are also significant correlations with self-report measures of creativity and with dissociative ability by trend. Intelligence is positively related to inhibition, to the compound score of divergent thinking and to ideational originality. As expected, ideational fluency and ideational flexibility show an extremely high correlation ($r = .86$), which is probably due to the scoring methods which, in both cases, focus on the number of ideas. However, these two quantitative measures show only a moderate correlation with ideational originality. Interestingly, the quantitative scores (i.e., ideational fluency and flexibility) and the qualitative score (i.e., ideational originality) also showed a disjunct correlation pattern with respect to other creativity measures. While the quantitative scores are correlated with inhibition, dissociation and the creative personality scale, originality is correlated with intelligence, self-reported ideational behavior, and creative accomplishments.

3.2. Structural equation models

As inhibition, divergent thinking, and intelligence showed significant inter-correlations (see Table 1), in a next step, we tested whether the significant relationship of inhibition and divergent thinking is actually mediated by intelligence. This mediation hypothesis was tested by means of latent variable modeling with *Mplus* 5.2, using maximum likelihood (ML) estimation.

In this mediation model, divergent thinking was regressed on inhibition and intelligence, and intelligence was regressed on inhibition (see Fig. 1A). The latent variable inhibition was defined by four context redundancy scores (reversed scale), the latent variable intelligence was defined by five intelligence tests, and the latent variable divergent thinking was defined by ideational fluency, flexibility and originality. Additionally, an error correlation of two inhibition scores, representing the shared experimental condition of four keys, was specified. However, we did not obtain an acceptable fit for this model ($\chi^2[41] = 131.20$, $p < .001$ [$\chi^2/df = 3.20$], CFI = .80, RMSEA = .15 [90% CI = .12–.17], and SRMR = .08). The poor fit of this model may be due to the heterogeneous definition of divergent thinking (i.e., ideational originality showed only moderate correlations with ideational fluency and flexibility).

Therefore, a similar but more differentiated model was estimated in a next step, defining two correlated latent variables of ideational fluency and originality in place of the compound measure of divergent thinking (see Fig. 1B). In order to constrain model complexity, ideational flexibility, which was extremely highly correlated with fluency at manifest level, was not included in the model, but analyzed separately. This model showed an improved

Table 1
Descriptive statistics, internal consistency, and inter-correlations.

	M	*SD*	α	2	3	4	5	6	7	8	9	10
1 Inhibition	0.81	0.06	.80	.29**	.36**	.38**	.40**	.11	.20*	.24*	.00	.18^{+}
2 Intelligence	4.55	1.25	.70		.21*	.05	.15	.31**	.10	.08	.04	−.07
3 DT	0.00	0.81	.68			.90**	.88**	.67**	.19^{+}	.25**	.14	.43**
4 I-Flu	9.80	2.14	.75				.86**	.34**	.10	.22*	.06	.56**
5 I-Flx	6.50	1.26	.70					.39**	.11	.25**	.03	.42**
6 I-Org	2.09	0.21	.55						.25*	.15	.25*	.08
7 RIBS	64.89	13.85	.90							.42**	.41**	.04
8 CPS	7.38	3.12	.65								.24	.14
9 CAcc	55.22	25.74	.81									.07
10 Dissoc	12.96	3.53	.79									

Note: DT, divergent thinking; I-Flu, ideational fluency; I-Flx, ideational flexibility; I-Org, ideational originality; RIBS, Runco ideational behavior scale; CPS, creative personality scale; CAcc, creative accomplishments; Dissoc, dissociative ability.
$^{+}$ $p < .10$.
* $p < .05$.
** $p < .01$.

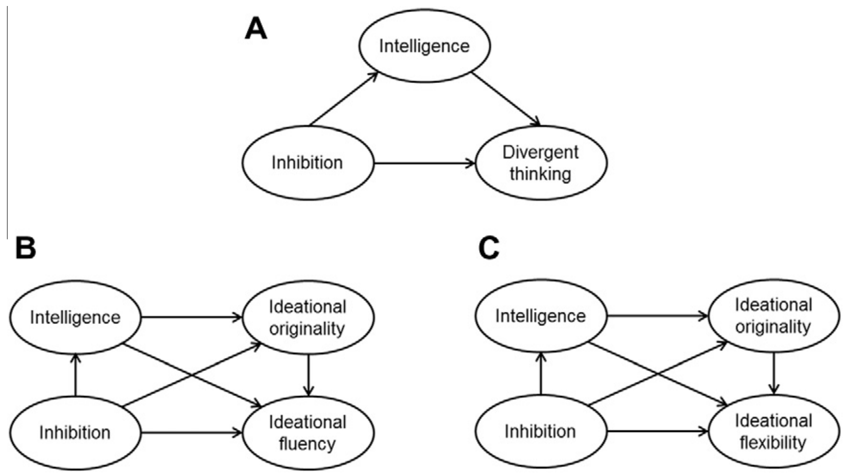

Fig. 1. The main latent variable models tested in this study.

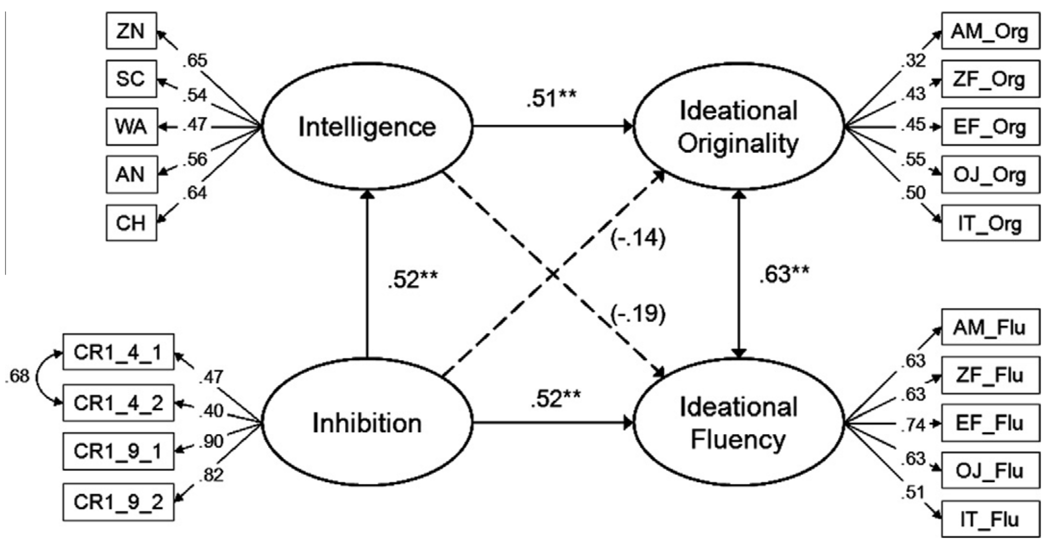

Fig. 2. Latent variable model (completely standardized solution) of the direct and indirect effects of inhibition and intelligence on ideational fluency and originality. Note that the scale of dyadic context redundancy (CR1) scores was reversed so that high scores reflect high inhibition.

and acceptable fit (χ^2[145] = 196.59, $p < .01$ [$\chi^2/df = 1.36$], CFI = .90, RMSEA = .06 [90% *CI* = .04–.08], and SRMR = .08) with substantial significant positive loadings of all regression paths except for the paths from inhibition to ideational originality and from intelligence to ideational fluency (see Fig. 2). A further model, in which the non-significant paths were removed, showed equal model fit (χ^2[147] = 199.20, $p < .001$ [$\chi^2/df = 1.36$], CFI = .90, RMSEA = .06 [90% *CI* = .04–.08], and SRMR = .08), suggesting that the non-significant regression paths of the previous model are actually dispensable. The assumption that intelligence mediates the relation of inhibition and originality was further tested using a bootstrap procedure (cf., Preacher & Hayes, 2008) with 1000 parametric bootstrap samples to obtain 95% confidence intervals for the indirect path. This analysis supported a significant mediation effect of intelligence (estimate = .23 [95% *CI* = .04–.42]).

Finally, we also estimated the model using the latent variable ideational flexibility instead of ideational fluency (see Fig. 1C). This model showed again an acceptable model fit (χ^2[145] = 188.10, $p < .01$ [$\chi^2/df = 1.30$], CFI = .90, RMSEA = .05 [90% *CI* = .03–.07], and SRMR = .08), with only minor changes to the values of the significant path coefficients (ideational flexibility on inhibition: .55; ideational originality on intelligence: .51; intelligence on inhibition: .52; ideational flexibility with originality: .53).

4. Discussion

This study examined the role of cognitive inhibition and intelligence in creativity. It was found that cognitive inhibition, assessed by means of the random motor generation task, shows a positive correlation with various measures of creativity including quantitative indicators of divergent thinking (i.e., ideational fluency and flexibility) and different self-report measures. This provides further direct evidence that creativity is related to executive functions (e.g., Gilhooly et al., 2007). Cognitive control in terms of the ability to inhibit salient but irrelevant responses appears to substantially facilitate the fluent generation of new ideas. Effective inhibition may be needed to suppress the increasing proactive interference of previous responses in order not to get stuck with initial ideas. It may thus support the active dissociation from prepotent concepts and promote the steady access to unrelated concepts and ideas, allowing for high ideational fluency (cf., Benedek et al., in press).

The results, however, appear to conflict with the view of creativity as a "disinhibition syndrome" (Eysenck, 1995; Martindale, 1999). If disinhibition is understood as the ability to fluently generate many different responses or original ideas, then it has to be concluded that this functional type of disinhibition is related to high cognitive inhibition. This may be different from a dysfunctional type of disinhibition, which may rather result in more perseverative behavior and in the inability to break away from common or previous ideas (Ridley, 1994).

Intelligence was found to be related to inhibition and divergent thinking (specifically to ideational originality), but not to self-report measures of creativity. A latent variable model was used to test whether intelligence acts as a mediator in the relationship of cognitive inhibition and divergent thinking. It revealed that cognitive inhibition specifically drives the fluency and flexibility of idea generation (i.e., the quantitative aspect of ideation), while intelligence has a positive effect on the originality of ideas (i.e., the qualitative aspect of ideation). This fits nicely to recent evidence showing that intelligence is particularly relevant to creativity, when creativity is defined by originality rather than mere fluency (Nusbaum & Silvia, 2011; Silvia, in press). Moreover, the findings could be seen in line with the Geneplore model (Finke, Ward, & Smith, 1992), with inhibition being more related to the "generation" stage and intelligence contributing to the "exploration" stage.

For the scoring of ideational originality we employed a method that avoids a trivial correlation of fluency and originality (Silvia et al., 2008). Nevertheless, these two measures still show a substantial positive correlation at the latent level. Our model here did not assume a unidirectional relation, as both directions are generally conceivable and thus might be operant. On the one hand, a fluent generation of ideas may for simple statistical reasons be beneficial for coming up with original ideas. Or, as the Nobel laureate Linus Pauling put it, "The best way to get good ideas, is to get lots of ideas and throw the bad ones away" (as cited in McPherson Shilling & Fuller, 1997, p. 112). On the other hand, the ability to generate not only common but also original ideas should result in higher total number of available ideas. Besides the different contributions of inhibition and intelligence on fluency and originality of ideas, these divergent thinking measures also showed a discriminable correlation pattern with respect to other measures of creativity. Ideational fluency was significantly related to dissociative ability and the creative personality scale, whereas ideational originality was significantly related to the self-reported ideational behavior and to creative accomplishments. Taken together this suggests that these two divergent thinking measures show discriminant validity, which corroborates the usefulness of obtaining two non-confounded indicators of quantitative and qualitative aspects of ideational ability.

As a limitation of this study, it should be noted that only one specific inhibition task (i.e., a random sequence generation task) was used. This task is valid with respect to other measures of inhibition (Miyake et al., 2000), but the findings might not generalize to all conceptualizations of cognitive inhibition. This may be especially true, when referring to a wider definition of cognitive inhibition which also includes the suppression of interfering stimuli and distractors (e.g., Friedman & Miyake, 2004). The variety of conceptualizations of inhibition may also be one reason for the number of apparently inconsistent findings in the literature. Future studies, therefore, should address the question whether different inhibition-related functions differentially contribute to creative thought. As another limitation, the internal consistency of the originality scores was found to be rather low. Employing a scoring of originality which is not confounded with fluency is useful in order to obtain a measure with discriminant validity, but it may also result in lower reliability. As a consequence, it should be noted that manifest first-order correlations with originality probably are underestimated, and that the estimated latent parameters related to originality have to be interpreted with some caution.

This study adds to the growing evidence on the relation between inhibition and creativity. It supports the emerging notion that creativity draws on executive processes, and it provides a model of how inhibition and intelligence are involved in the creative idea generation. Inhibition primarily facilitates the fluent generation of ideation, while intelligence has positive effects on the quality of ideas.

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