The interrelationship between speeded and unspeeded divergent thinking and reasoning, and the role of mental speed

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ABSTRACT

The relationship between intelligence and creativity is still subject to substantial debate in the research literature. In the present study, we focused on core dimensions of both constructs, that is divergent thinking and reasoning. We hypothesized their relationship to depend both on the speededness of test tasks and on the subject’s mental speed, positing that with increasing speededness of the tasks, mental speed would have a stronger impact on task outcomes. We disentangled the effects of task speededness and mental speed experimentally, testing 261 participants (mean age 14.48 years) with 12 divergent thinking and 12 reasoning tasks, 6 of each under power conditions, 6 time-constrained. In addition, we assessed mental speed with 6 tasks. We analyzed the data through structural equation modeling. Results confirmed our expectations: test speededness contributed significantly to mental speed variance in divergent thinking task performance. Divergent thinking assessed under time constraints was fully explained by divergent thinking assessed under power conditions and by mental speed. Divergent thinking and reasoning showed no correlation when controlling for mental speed. Our findings suggest that the correlations between divergent thinking and reasoning are mainly the result of variance both constructs share with mental speed, and that timed versus untimed test-taking plays a minor role.

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1. Introduction

How much intelligence is needed to be creative? Is one construct a predictor of the other, and can intelligence and creativity be separated at all? There is no generally accepted definition for either construct. But most experts agree that the key aspects of intelligence are the capacities for information processing, problem-solving, and abstract reasoning (Snyderman & Rothman, 1987), while creativity relies on the ability to generate both novel and adaptive (useful, appropriate) solutions to problems (e.g., Amabile, 1996; Sternberg & Lubart, 1999). Creativity can therefore be understood as “a specific capacity to not only solve problems but to solve them originally and adaptively” (Feist & Barron, 2003, p. 63).

The study of the relation between intelligence and creativity has a long history and is still under vigorous debate (for an overview, see Batey & Furnham, 2006). According to Sternberg and O’Hara (1999), conceptualizations of the relationship between intelligence and creativity range from proposals of distinct psychological constructs to partially overlapping constructs such as “creative intelligence” (Lubart, 2003), and in some cases are simply different labels for the same thing. The psychometric approach frequently conceptualizes creativity as a subset of intelligence. Correspondingly, the prevalent models of intellect generally include creativity constructs as lower-order factors of general intelligence (e.g., Carroll, 1993; broad retrieval ability or idea production; Jäger, 1984: divergent thinking; Vernon, 1950: creative abilities). These models would, however, be challenged if it were shown that intelligence and creativity are unrelated or that their relation is
mainly due to another common cause (e.g., long-term memory or elementary cognitive processes like mental speed). And if it were shown that the correlation between intelligence and creativity can be traced back to shared variance with mental speed, this would lead to a fundamental discussion about the hierarchical level of intelligence, creativity, and mental speed and the nature of their common cause. The investigation of the strength and particularly the nature of the relationship between intelligence and creativity are therefore of high theoretical interest. But also in applied fields of ability assessment, insights into the intelligence-creativity relationship will be important in helping to explain (and not just describe) individual differences.

1.1. Divergent thinking as an indicator of creative potential

Divergent thinking (DT), also denoted as divergent production or fluency (Carroll, 1993), can most generally be described as the ability to generate diverse and numerous ideas (Runco, 1991). Guilford (1950) was one of the first to see DT as a major component of creativity. Together with his associates he differentiated four main aspects of DT: (a) fluency of thinking or the ability to produce a large number of ideas or solutions to a given problem in a short period of time (consisting of word, ideational, expressionial, and associational fluency); (b) flexibility of thinking or the ability to consider a variety of approaches to a solution (consisting of spontaneous and adaptive flexibility); (c) originality of thinking or the ability to produce unusual ideas different from those of most other people; and (d) elaboration of thinking or the ability to think through the details of an idea (consisting of figural and semantic elaboration) (Batey & Furnham, 2006). In the 1960s, Mednick suggested an associative basis for individual differences in divergent thinking performance (Mednick, 1962). This conception is still prominent (Kauman, 2009) and suggests that the knowledge base of less creative people is smaller and organized in steeper associative hierarchies than the one of creative people. Creative people, on the other hand, are assumed to have a qualitatively and quantitatively richer knowledge base with flat associative hierarchies. Therefore they have access to a larger pool of associations and show a higher likelihood for creative combinations (that is, a new combination of beforehand conceptually distant mental elements).

Within the psychometric study of creativity, DT tests are well established as measures of creative potential (Barron & Harrington, 1981; Kim, 2008; Silvia et al., 2008). DT tests assess the ability to generate multiple alternative solutions and require individuals to produce several responses to a specific prompt within a certain time period (Plucker & Renzulli, 1999). The responses are usually scored quantitatively for fluency (number of responses), but sometimes also for flexibility (number of different categories covered by the responses), originality (statistical infrequency of the responses), or elaboration (amount of details given). Psychometric properties of DT tests are satisfactory. They show good concurrent validity with other creativity tests (Plucker, 1999), good criterion validity with non-test indices of creativity (e.g., real-life criteria, other-ratings; Barron & Harrington, 1981), and sufficient reliability (for an overview, see Copley, 2000). Importantly, almost all of the existing tests of DT include tasks from semantic and figural content areas only, and neglect the numerical content area, which is well established in intelligence research (Marshalek, Lohman, & Snow, 1983). In this study, we used DT tests covering all of the aforementioned content domains.

1.2. Findings on the relationship between divergent thinking and intelligence

In their comprehensive review, Batey and Furnham (2006) concluded that creativity and intelligence are modestly correlated with correlations in the area of $r = -0.2$ to $r = -0.4$. This range also holds for the correlation of divergent thinking and intelligence for samples as diverse as regular or gifted students, architects, or air force officers (see also Furnham & Nederstrom, 2010). In other words, the strength of the correlation seems to be the same across the entire ability range. Accordingly, recent research does not support the so-called threshold theory, which states that creativity and intelligence show a curvilinear relationship, that is, decreasing correlations with increasing levels of intelligence (Kim, 2005; Preckel, Holling, & Wiese, 2006; Sligh, Conners, & Roskos-Ewoldsen, 2005).

It is important to note that the nature of the relation between intelligence and creativity is not very well understood (see Section 1.3 below). Since most of the available studies do not control for possible confounds, one cannot exclude the possibility that a third variable might explain the intelligence-creativity correlation (e.g., openness to experience, which is positively related to both creativity and intelligence; Silvia, 2008). Moreover, research results are inconsistent. There are several studies documenting that divergent thinking test scores as indicators of creative potential and also creative achievements or creativity test scores are not related to psychometric intelligence (e.g., Copley, 1968; Feist & Barron, 2003; Furnham & Bachtiar, 2008; Guilford, 1950; Nelson & Crutchfield, 1971; Rossmann & Horn, 1972; Torrance, 1977; Vartanian, Martindale, & Matthews, 2009).

1.2.1. The influence of task speededness. This heterogeneity of findings on the relationship between creativity and intelligence can be traced back in part to the different time allocations used in assessing creativity and intelligence. Wallach and Kogan (1965) showed that the intelligence–creativity relationship is strongly dependent on the degree of speededness of test tasks. Speededness refers to the extent to which time available to complete test tasks is constrained. According to Nunnally and Bernstein (1994), time constrains introduce speededness into a test when less than 90% of a sample completes all items. While substantial correlations were found under unspeeded conditions, essentially no intelligence–creativity relationship was observable under unspeeded conditions. The authors stressed the importance of unspeeded assessment conditions in creating a non-evaluative, game-like environment, which they consider a necessary condition for creativity assessment (Kogan, 2008). It is important to note that with increasing speededness of the tasks, mental speed is likely to become more influential on task outcomes because faster processing of information is advantageous when time is limited. For reasoning ability, Wilhelm and Schulze (2002) demonstrated the influence of test speededness on construct validity and the contribution of mental speed. In their study, they found that the variance of speeded reasoning could be...
fully explained as a linear function of unspeeded reasoning ($\beta = .84$) and mental speed ($\beta = .28$). Thus, the relation between intelligence and creativity might be due partly to the variance both constructs share with mental speed. In support of this assumption, Preckel et al. (2006) found that the relation between intelligence and divergent thinking decreased significantly when controlling for mental speed. However, Preckel et al. (2006) assessed divergent thinking and intelligence under timed conditions and found that the influence of task speededness and mental speed were confounded. In the present study, we disentangled both effects experimentally.

1.3. Divergent thinking, intelligence, and their relation with mental speed

There is a plethora of studies investigating the relation between intelligence and mental speed (for recent reviews, see Danthiir, Roberts, Schulze, & Wilhelm, 2005; Jensen, 2006; Sheppard & Vernon, 2008). Among the many studies employing a vast array of mental speed tasks, the correlations between mental speed and intelligence range from $r = .30$ to $r = .40$ (Sheppard & Vernon, 2008). Grudnik and Kranzler (2001) conducted various meta-analyses of the relationship between intelligence and mental speed (e.g., Preckel et al., 2006). Task speededness and mental speed are confounded, since with increasing speededness of mental speed (e.g., Preckel et al., 2006). Task speededness and mental speed are confounded, since with increasing speededness of mental speed (e.g., Preckel et al., 2006). Task speededness and mental speed are confounded, since with increasing speededness of the tasks the impact of mental speed on task performance may increase (Wilhelm & Schulze, 2002). To our knowledge, for the relation between mental speed and WMC or complex cognitive abilities like reasoning are: (1) Speed-dependent working memory. It is assumed that representations in working memory decay quickly and that fast processing therefore helps to complete a task before necessary information is lost (Jensen, 1998; Salthouse, 1996). (2) Shared method variance. WMC and reasoning tests are usually administered under time constraints, which increase the impact of mental speed on task performance. (3) A common underlying cause that cannot be identified with any of the three constructs involved (e.g., neurophysiological parameters like myelination; for an overview, see Wilhelm & Oberauer, 2006).

There are no theories or empirical studies of comparable sophistication that have sought to explain the relation between DT and mental speed. Research is still rather descriptive and limited to correlational analyses (e.g., Carroll, 1993). Particularly in the case of DT assessed under time constraints, it is commonly assumed that mental speed increases performance because participants have to access their knowledge stores quickly to build associations, and, in some of the DT tasks, to combine given pieces of information in new and different ways (Batey & Furnham, 2006). Mental speed or the speed of information processing can be assumed to be a central prerequisite for the production of many inventive and divergent ideas. Faster information processing should help a person to produce many different ideas under time constraints (Vock, Preckel, & Holling, in press).

Few studies to date have focused on the relation between mental speed on the one hand and DT on the other. Rindermann and Neubauer (2004) examined 14- to 17-year-old high school students and found a latent partial correlation of $r = .50$ between (verbal) DT and processing speed (positive polarity: higher values represent fast response) when controlling for intelligence. Vartanian, Martindale, and Kwiatkowski (2007) investigated the correlations of (verbal) DT with reaction time tasks in a sample of university students. They found faster reaction times for more divergent thinkers (correlations were $r = -.27$, Hick paradigm, and $r = -.42$, concept verification test). In a recent study with 31 female participants (mean age 19.8 years), Vartanian et al. (2009) investigated the relation between DT and reaction time in relatedness judgments. Here, participants had to judge whether the two stimuli (word–word or word–picture) were related or unrelated by pressing one of two keys on a computer keyboard. Reaction time in relatedness judgments correlated significantly with DT ($r = -.44$). To sum up, the results overwhelmingly show that higher DT is associated with higher mental speed.

1.4. Research aims

In our study, we focused on DT as a measure of creative potential and reasoning ability which is "traditionally considered to be at or near the core of what is ordinarily meant by intelligence.” (Carroll, 1993, p. 196). We investigated the relation between DT and reasoning (R), taking into account two possible moderators. These are, first, the degree of speededness of the tasks (e.g., Wallach & Kogan, 1965) and second, mental speed (e.g., Preckel et al., 2006). Task speededness and mental speed are confounded, since with increasing speededness of the tasks the impact of mental speed on task performance may increase (Wilhelm & Schulze, 2002). To our knowledge,
no study to date on the relation between DT and R has disentangled the two effects experimentally. We carried out the present investigation to fill this research gap.

Our research aim was twofold. First, we were interested in the impact of mental speed on DT assessed under timed conditions. Unlike most other studies, the present study used a DT measure covering all content domains (verbal, figural, numerical). In other words, our first research aim was to investigate the construct validity of DT. We expected to find a larger impact of mental speed on DT assessed under time constraints than on DT assessed under power conditions, that is, a higher interdependence among domains under time constraints.

Second, we wanted to investigate the relation between DT and R independently of both timed test-taking and mental speed. Prior research documented weak to no relationships between intelligence and creativity assessed under power conditions (Hattie, 1980; Wallach & Kogan, 1965) and a decrease in the relation of DT and R when controlling for mental speed (Preckel et al., 2006). Thus, we expected no relation between DT and R under power conditions and when controlling for mental speed.

2. Method

2.1. Participants and procedure

The sample comprised 261 German ninth grade students (149 female, 111 male; one participant gave no information on sex) with a mean age of 14.84 years (SD = .58). To cover the entire ability range and to avoid range restrictions or restricted variability, participants were recruited from all tracks of the German three-tier secondary school system.1 For the present study, four classes per track were investigated (12 classes total). Sixty-four participants attended the lower track, 98 the middle track, and 99 participants the top track.

Participants were tested in their classrooms. Each testing session was conducted by two trained experimenters and took about 180 min (including breaks). Participants responded to the tests anonymously. They received no rewards but obtained feedback on their results in the form of a self-referenced description of the tasks).

Every participant worked on the same two sets of tasks A and B, each comprising six R tasks, six DT tasks, and three mental speed (MS) tasks (alternating order of R and DT tasks, MS tasks at the end; see Appendix A1). We manipulated the order of A and B. In addition, we presented A and B under either timed or untimed conditions (this only applied to the R and DT tasks within the sets, since the MS tasks were always speeded). Thus, there were four experimental conditions.

Timed administration referred to the original administration time as given in the instructions of the BIS-HB, which is known to be of rather speeded character (Vock et al., in press). Untimed administration was defined as 2.5 times the original administration time (Tindal & Fuchs, 1999; Wilhelm & Schulze, 2002). We planned to provide additional time for students to complete all tasks, but this turned out to be unnecessary. We randomly assigned one class from each track to one of the four experimental conditions (1: A-speeded, B-unspeeded, n = 62; 2: A-unspeeded, B-speeded, n = 58; 3: B-speeded, A-unspeeded, n = 74; 4: B-unspeeded, A-speeded, n = 67).

2.2. Study measures

All tasks used in the present study were taken from the Berlin Structure of Intelligence Test for Youth: Assessment of Talent and Giftedness (BIS-HB; Jäger et al., 2006), which is the most recent paper-and-pencil test based on the Berlin Model of Intelligence Structure (BIS) by Jäger (1984). The BIS is a faceted model of intelligence. The operation facet includes processing capacity (reasoning ability or the “capacity for processing power/formal logical thinking and judgment ability”; Carroll, 1993, p. 64), processing speed (mental speed; Neubauer & Bucki, 1996), creativity (divergent thinking; Preckel et al., 2006), and short-term memory. The content facet includes verbal, figural, and numerical ability. On a higher hierarchical level, the abilities from the operation facet and from the content facet are integrated into general intelligence. The BIS-HB is designed for students of average and high ability between 12.5 and 16.5 years of age. It assesses the abilities specified in the BIS using 45 types of tasks. Construct validity of the BIS-HB has been documented by confirmatory factor analyses (multiple group comparisons for the different age and ability groups; range of CFIs = .97–.99); criterion validity has been documented by correlations with other intelligence tests (e.g., BIS-HB reasoning with the German version of the culture fair test [Weiße, 1998]: r = .74, N = 1080; BIS-HB creativity with a verbal creativity test [VKT; Schoppe, 1975]: r = .52, N = 146), school grades (BIS-HB IQ with grade point average: r = .50, N = 1320; BIS-HB reasoning with grade point average in Math and sciences: r = .47, N = 1313), and – for the creativity scale – by correlations with self-estimated creativity (r = .28, N = 192).

For the present study, twelve R tasks, twelve DT tasks, and six MS tasks were used (see Appendix A2 for a detailed description of the tasks).

2.2.1. Scoring of the DT tasks

DT tasks from the BIS-HB were scored for fluency (number of solutions). Five tasks were also scored for flexibility (variability of solutions). Correlations between fluency and flexibility scores for the five tasks ranged between r = .76 (EF, specific traits) and r = .92 (OJ, object design); the remaining correlations were: r = .77 for AM, possible uses; r = .82 for IT, insight test; r = .87 for ZF, symbol completion). The correlation between the DT scale scored for fluency and flexibility and DT scored for fluency only was nearly perfect, with r = .97 for timed test-taking and r = .96 for untimed test-taking (all N = 261). The finding that the different scoring dimensions of DT tasks (e.g., fluency, flexibility, originality, uniqueness, elaboration) lack discriminant validity and strongly depend on fluency has already been reported by Hocevar (1979a, 1979b). Therefore, for further analyses, we used only the DT scale scored for fluency.

1 In the German school system, after elementary school, students are put on one of three tracks (lower, middle, and top track) according to their level of achievement.
2.2.2. Psychometric properties. Internal consistency was found to be satisfactory (R: 12 tasks, α = .78; DT: 12 tasks, α = .71; MS: 6 tasks, α = .78). The scoring of the DT tasks of the BIS-HB showed good objectivity. The unadjusted intraclass correlation coefficient between the ratings of two independent raters showed satisfactory values for all DT tasks (M = .96, SD = .05, range = .87–.99).

2.3. Scoring procedure and data analyses

2.3.1. Scoring procedure

We used the scoring procedure introduced by Wilhelm and Schulze (2002). First, we recorded the number of correctly solved items for each of the subtests. Second, we standardized these scores across all participants and conditions. Third, we computed means of these standardized scores for both R and DT scales under timed and untimed conditions, and for the MS scale. Thus, every participant obtained five scores (each with an overall group mean of zero): two scores for the R scales (speeded vs. unspeeded), two scores for the DT scales (speeded vs. unspeeded), and one score for the MS scale. These scores were used in subsequent analyses of means and correlations. Additionally, we formed subtest parcels for speeded and unspeeded test-taking, ignoring test form and sequence of test, as input variables for structural equation modeling. For each scale (R-speeded, R-unspeeded, DT-speeded, DT-unspeeded, MS), we formed two parcels. Each parcel consisted of three subtests from the respective domain (R, DT, MS) that were heterogeneous with respect to content (verbal, numerical, figurial) to suppress unwanted content variance (Jäger, 1982; Wittmann, 1988).

2.3.2. Data analyses

First, we ran a manipulation check. We used ANOVAs to test if untimed test-taking led to higher scores and if these higher scores could be attributed to more liberal time allocations and not to differences in test order (speeded or unspeeded first). Second, we tested for the equality of variance-covariance matrices of latent factors in the four conditions (as a precondition for pooling values, regardless of condition). Third, we calculated intercorrelations among all scales. Finally, we used structural equation modeling to explain speeded DT by MS and unspeeded DT and to investigate the latent correlation between R and DT when controlling for MS under timed and untimed conditions.

3. Results

3.1. Manipulation check

As expected, all mean differences between speeded and unspeeded measures were significant, with higher scores for the unspeeded measure (see Table 1).

Two two-way repeated-measure ANOVAs were conducted (dependent variables: R, DT) using PASW Statistics (version 18.0.0) to test if these differences were due to the more liberal time allocations and not to differences in test order (within-subjects factor: speeded vs. unspeeded score; between-subjects factor: timed vs. untimed test-taking first). For R, only the within-subjects factor was significant [F(1,1259) = 302.10, p < .01, η² = .54; interaction term and between-subjects factor both ps > .01], indicating that higher scores could be attributed solely to the more liberal time allocations. For DT, however, the interaction and between-subjects factor also gained significance [within-subjects factor F(1,1259) = 1519.22, p < .01, η² = .85; between-subjects factor F(1,1259) = 7.07, p < .01, η² = .03, interaction F(1,1259) = 78.91, p < .01, η² = .23]. The significant interaction revealed that for unspeeded DT, the group that worked on the speeded tasks first profited significantly more than the group that worked on the unspeeded tasks first. There were no such group differences for speeded DT.

With respect to the structural equation models for testing the construct validity of speeded DT and the relation between DT and R, the question of comparable variance-covariance matrices between conditions is more important than mean differences between conditions. To preclude that the different conditions led to differences in the covariance structure between latent scores (DT-speeded, DT-unspeeded, R-speeded, R-unspeeded, S), we tested the variance-covariance matrices of conditions 1–4 for equality by multiple-group comparison using AMOS 18.0.0 (Arbuckle, 1983–2009). Although the χ² value gained significance (χ² = 137.79, df = 100, p = .007), the ratio of the χ² value and its degrees of freedom of 1.37, as well as other indicators of model fit (CFI = .97, TLI = .95, RMSEA = .038 [90% CI = .021 ; .053]), showed that the null hypothesis of equal variance-covariance matrices for summed scores in conditions 1 through 4 could be maintained. The values from the DT scales and from the R scales of the four conditions could therefore be pooled to compute correlations and covariances, regardless of test form and test sequence.

3.2. Intercorrelations and results of structural equation modeling

Zero-order as well as latent correlations are given in Table 2. With respect to zero-order correlations, speeded and unspeeded R correlated equally strongly as speeded and unspeeded DT (r = .66). Independently of speededness, DT and R showed correlations of medium size (range: .37–.44, rmean = .41). Both constructs showed similar relations with MS (around .55). When controlling for measurement error, correlations increased (range: .48–.60, rmean = .54), with speeded DT showing stronger relations to speeded and unspeeded R than unspeeded DT (.60/.58 vs. .48). Moreover, unspeeded DT showed a weaker relation to MS than speeded DT (.61 vs. .74). Speeded DT, again, was equally strongly related to MS as speeded and unspeeded R (between .71 and .74). This indicates that part of the relation between speeded DT and speeded and unspeeded R might be caused by variance both constructs share with MS.

With respect to the question of construct validity, speeded DT could be explained by unspeeded DT and MS (see Fig. 1). When setting the explained variance of speeded DT to 1 (disturbance term set to zero), model fit was excellent (χ² = 10.62, df = 7, p = .16; CFI = 1.00; RMSEA = .045 [90% CI = .000 ; .095]). Thus, variability of speeded DT was fully explained—to a larger extent by unspeeded DT (β = .75) and to a smaller extent by MS (β = .35).

Finally, we investigated the partial correlation between DT and R, controlling for MS. Model fit was acceptable to excellent for both models (see Fig. 2). For timed test-taking, both constructs correlated at .20 (model fit: χ² = 17.29, df = 6,
In the present study, we investigated the correlation between divergent thinking and reasoning ability. Our main research aim was twofold. First, we wanted to assess the construct validity of divergent thinking. Second, we wanted to improve our understanding of the nature of the relationship between divergent thinking and reasoning by controlling for the effects of the degree of speededness of the tasks and for the effects of mental speed. One strength of our study is that we disentangled possible confounds of task speededness and mental speed experimentally. To our knowledge, this has not been done before in research on the relationship between divergent thinking and reasoning. We expected the impact of mental speed on divergent thinking task performance to increase with speededness of the tasks. We also expected divergent thinking and reasoning to be independent of each other when assessed under power conditions and when controlling for the influence of mental speed. Our results confirm these expectations.

Before discussing our findings, we would like to point to some limitations of our study. First of all, we used divergent thinking as an indicator of creative potential. Divergent thinking cannot be equated with creativity or creative achievements, but should rather be seen as one cognitive component thereof (e.g., creative thinking skills; Batley & Furnham, 2006). In addition, despite of their good reliability or concurrent and criterion-related validity, DT tests have been criticized for their lack of content validity (Barron & Harrington, 1981). Nevertheless, the majority of psychometric studies on creativity use tests of DT in the tradition of the Guilford tests. Thus, our results relate to the majority of studies and extend the literature in this field of research. A further limitation of our study is the restricted age range of our sample (13 to 16 years). In an earlier study on the relationship between measures of speed of information processing and psychometric intelligence (Neubauer, Spinath, Riemann, Borkenau, & Angleitner, 2000) the correlation between aggregated mental speed and intelligence in a heterogeneous sample with regard to age reduced this correlation to \( r = .36 \). Replications of our findings with other age groups are required.

### 4. Discussion

In the present study, we investigated the correlation between divergent thinking and reasoning ability. Our main research aim was twofold. First, we wanted to assess the construct validity of divergent thinking. Second, we wanted to improve our understanding of the nature of the relationship between divergent thinking and reasoning by controlling for the effects of the degree of speededness of the tasks and for the effects of mental speed. One strength of our study is that we disentangled possible confounds of task speededness and mental speed experimentally. To our knowledge, this has not been done before in research on the relationship between divergent thinking and reasoning. We expected the impact of mental speed on divergent thinking task performance to increase with speededness of the tasks. We also expected divergent thinking and reasoning to be independent of each other when assessed under power conditions and when controlling for the influence of mental speed. Our results confirm these expectations.

### 4.1. Construct validity of divergent thinking

We found that the total variance in divergent thinking assessed under speeded conditions could be explained by divergent thinking assessed under power conditions and mental speed. Since we used common and established divergent thinking tasks that even covered all content domains, we are confident that our findings can be generalized to other divergent thinking tests that are applied with time constraints. That is, these tests are combined measures of divergent thinking and mental speed. However, the question arises if test speededness contributes significantly to mental speed variance in divergent thinking task performance, or if

### Table 1

Means and standard deviations of speeded and unspeeded reasoning, of speeded and unspeeded divergent thinking, and of mental speed under the four experimental conditions.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Reasoning</th>
<th>Divergent thinking</th>
<th>Mental speed</th>
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<tbody>
<tr>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
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<tr>
<td></td>
<td>Speeded</td>
<td>Unspeeded</td>
<td>Speeded</td>
</tr>
<tr>
<td>1</td>
<td>62</td>
<td>(-.42 (.54))</td>
<td>(.19 (.67))</td>
</tr>
<tr>
<td>2</td>
<td>58</td>
<td>(-.17 (.52))</td>
<td>(.42 (.71))</td>
</tr>
<tr>
<td>3</td>
<td>74</td>
<td>(-.26 (.51))</td>
<td>(.24 (.65))</td>
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<tr>
<td>4</td>
<td>67</td>
<td>(-.24 (.50))</td>
<td>(.27 (.62))</td>
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Notes: R: Reasoning. DT: Divergent thinking. All correlations are significant with \( p < .01 \). Latent correlations are depicted in the upper triangle of the correlation matrix (model fit: \( \chi^2 = 42.06, df = 25, p = .02; \text{CFI} = .99 \)).

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<td>Unspeeded</td>
<td>Speeded</td>
</tr>
<tr>
<td>1</td>
<td>62</td>
<td>(-.42 (.54))</td>
<td>(.19 (.67))</td>
</tr>
<tr>
<td>2</td>
<td>58</td>
<td>(-.17 (.52))</td>
<td>(.42 (.71))</td>
</tr>
<tr>
<td>3</td>
<td>74</td>
<td>(-.26 (.51))</td>
<td>(.24 (.65))</td>
</tr>
<tr>
<td>4</td>
<td>67</td>
<td>(-.24 (.50))</td>
<td>(.27 (.62))</td>
</tr>
</tbody>
</table>

Notes: R: Reasoning. DT: Divergent thinking. All correlations are significant with \( p < .01 \). Latent correlations are depicted in the upper triangle of the correlation matrix (model fit: \( \chi^2 = 42.06, df = 25, p = .02; \text{CFI} = .99 \)).
4.2. Relationship between divergent thinking and reasoning

Our results confirm the conclusion of Batey and Furnham (2006) that creativity and intelligence are moderately correlated. In the present study, we used divergent thinking as indicator of creative potential and reasoning ability as a core dimension of the intelligence construct. We found divergent thinking and reasoning ability to be moderately related, both under timed conditions as well as under power conditions of test-taking. However, when controlling for mental speed, there was no longer any significant correlation — neither for timed nor for power conditions. No study has yet disentangled the effects of timed test-taking and mental speed on divergent thinking. Some researchers found no correlations between creativity and intelligence under power conditions (e.g., Wallach & Kogan, 1965). It is therefore unclear whether the correlations found under timed conditions are due to an increased impact of mental speed or other possible effects of timed test-taking (e.g., a higher importance of personality factors like stress resistance or motivational goal orientations on test performance). Our findings suggest that the correlations between divergent thinking and reasoning are due mainly to variance both constructs share with mental speed, and that timed versus untimed test-taking plays only a minor role.

4.3. General discussion

Psychometric research always relies on the properties of the measurement instrument. Our findings, and also those reported by Wilhelm and Schulze (2002) on the domain of reasoning, show that timed test-taking increases the influence of mental speed on the measurement outcome, thereby changing the construct validity of the measurement instrument. It is important to take into account, that divergent thinking assessed under time constraints is not the same construct as divergent thinking assessed under power conditions but a mixture of the latter and mental speed. For practical purposes of divergent thinking assessment our study implies that divergent thinking should be assessed under power conditions if pure measures of this construct are required. Adding time constraints would add mental speed variance to the measure.

In prominent structure of intellect models (Carroll, 1993; Jäger, 1984), reasoning, divergent thinking (or broad retrieval ability, idea production), and mental speed are located at the same hierarchical level. This is a consequence of the use of factor analytic methods, resulting in models that merely describe the factor structure of intelligence (Vock et al., in press). In order to explain cognitive individual differences, it will be crucial to develop new analytical approaches to intelligence that aim at studying the foundations of higher cognitive processes like divergent thinking and reasoning. In our study, mental speed turned out to be a common source of...
variance for both constructs. As stated in the introductory section, the nature of the relationship between mental speed and divergent thinking is elusive and could be discussed on the basis of the various explanations for the WMC/reasoning–mental speed correlation. An interesting finding on this issue is the one reported by Vartanian et al. (2009), as noted in the introduction of this paper. They found significant correlations between divergent thinking and reaction time in relatedness judgements. It is interesting to speculate on this correlation with respect to the theoretical considerations of Wilhelm and Oberauer (2006) on the WMC-speed relationship presented before. According to their understanding, the main function of working memory is to set up and update temporary bindings between elements in the service of maintenance and flexible manipulation of relational representations. The higher the WMC, the faster the response on relatedness judgments, because high WMC is assumed to help maintain temporary bindings between stimulus and response categories. Thus, WMC as understood by Wilhelm and Oberauer (2006) might be the common cause of divergent thinking, mental speed, and reasoning. However, these thoughts are rather speculative and reach far beyond the scope of the present paper. Nevertheless, we believe that this line of thinking is promising and hope to initiate further research in this vein.

Fig. 2. Structural models relating the residual variance of (1) speeded reasoning and speeded divergent thinking as well as (2) unspeeded reasoning and unspeeded divergent thinking when controlling for mental speed. Given are maximum likelihood parameter estimates: Standardized regression weights, correlations between (1) speeded or (2) unspeeded reasoning and divergent thinking, as well as amount of explained variance (sum of products of path/regression coefficients and correlations) for the manifest variables. Error variances for the manifest variables can be computed by subtracting the respective amount of explained variance from 1. ** p < .01. *** p < .001.
Appendix A

Table A1
Allocation of tasks to sets of tasks (A or B) and timing of tasks under the four conditions.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Task order and time allocations to sets of tasks (A or B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A speeded, B unspeeded</td>
</tr>
<tr>
<td></td>
<td>ZN_s, LO_s, AN_s, EF_s, WA_s, DR_s, TM_s, ZF_s, SC_s, MA_s, CH_s, TN_s, XG, BD, TG (about 45 min)</td>
</tr>
<tr>
<td></td>
<td>pause 1 (15 min)</td>
</tr>
<tr>
<td></td>
<td>BG_us, OJ_us, SV_us, IT_us, RD_us, ZG_us (about 46 min)</td>
</tr>
<tr>
<td></td>
<td>pause 2 (15 min)</td>
</tr>
<tr>
<td>2</td>
<td>A unspeeded, B speeded</td>
</tr>
<tr>
<td></td>
<td>ZN_us, LO_us, AN_us, EF_us, WA_us, DR_us (about 46 min)</td>
</tr>
<tr>
<td></td>
<td>pause 1 (15 min)</td>
</tr>
<tr>
<td>3</td>
<td>B speeded, A unspeeded</td>
</tr>
<tr>
<td></td>
<td>BG_s, OJ_s, SV_s, IT_s, RD_s, ZG_s, FA_s, ZK_s, WS_s, AM_s, BR_s, ZR_s, ZT, ZS, KW (about 45 min)</td>
</tr>
<tr>
<td></td>
<td>pause 2 (15 min)</td>
</tr>
<tr>
<td>4</td>
<td>B unspeeded, A speeded</td>
</tr>
<tr>
<td></td>
<td>BG_us, OJ_us, SV_us, IT_us, RD_us, ZG_us (about 46 min)</td>
</tr>
<tr>
<td></td>
<td>pause 1 (15 min)</td>
</tr>
</tbody>
</table>

Notes. Reasoning tasks are printed in bold face. Mental speed tasks are underlined. _s_: speeded. _us_: unspeeded.

Table A2
Description of tasks in the study.

<table>
<thead>
<tr>
<th></th>
<th>Figural</th>
<th>Verbal</th>
<th>Numerical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reasoning</td>
<td>AN: analogies (one of five figures has to be chosen to complete a figural analogy of the form A:B::C?)</td>
<td>WA: word analogies (one of five alternatives has to be chosen to complete a verbal analogy of the type A:B::C?)</td>
<td>ZN: number series (sequences of numbers following certain rules have to be completed)</td>
</tr>
<tr>
<td></td>
<td>CH: Charkov (a sequence of line drawings, which are composed according to certain rules, has to be completed by drawing the two following figures subsequently)</td>
<td>TM: facts vs. opinion (subjects are to find out whether given assertions are expressions of facts or opinions)</td>
<td>DR: numerical reasoning (ordinary arithmetic problems have to be solved)</td>
</tr>
<tr>
<td></td>
<td>FA: choosing the geometrical figure (one of five geometrical figures is cut into several pieces; subjects have to indicate which one could be made out of the pieces)</td>
<td>SV: comparing conclusions (statements are given; for the following conclusions, subjects are to evaluate whether the conclusions are logically valid or not)</td>
<td>SC: estimations (subjects are to solve complex mathematical problems that can either be estimated or solved through simple mathematical operations)</td>
</tr>
<tr>
<td></td>
<td>BG: Bongard (two groups with 6 graphical patterns each are given; the 6 patterns of the one group have a common feature that differentiates them from the 6 patterns of the other group; three further patterns have to be assigned to the two groups)</td>
<td>WS: Vocabulary (one out of four words in a line has a different meaning than the other words; this one has to be crossed out)</td>
<td></td>
</tr>
<tr>
<td>Divergent thinking (underlined tasks were scored for fluency and flexibility; the other tasks were scored for fluency only)</td>
<td>ZF: symbol completion (given are unfinished drawings; these have to be completed into as many and as diverse real objects as possible)</td>
<td>AM: possible uses of object (as many and as diverse uses as possible have to be found for given objects)</td>
<td>DR: divergent computation (as many different combinations of numbers have to be found that equal up to a certain sum following a specified order of mathematical operations)</td>
</tr>
<tr>
<td></td>
<td>ZK: combining (given are 4 geometrical figures; these should be combined into as many abstract figures as possible)</td>
<td>MA: Masselon (from three given words, as many diverse sentences as possible have to be formed)</td>
<td>TN: inventing telephone numbers (as many x-digit telephone numbers that follow logical rules and can therefore be easily remembered have to be invented; rules should be as diverse as possible)</td>
</tr>
</tbody>
</table>

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Table A2 (continued)

<table>
<thead>
<tr>
<th>Divergent thinking (underlined tasks were scored for fluency and flexibility; the other tasks were scored for fluency only)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LO: layout (as many logotypes as possible have to be created)</td>
</tr>
<tr>
<td>OF: object design (as many and as diverse real objects as possible have to be proposed from given geometrical figures; objects have to be labeled)</td>
</tr>
<tr>
<td>IT: insight test (for a given social situation, as many and as diverse explanations as possible have to be found)</td>
</tr>
<tr>
<td>EF: specific traits (as many and as diverse traits as possible have to be found that a representative of a certain profession should not have)</td>
</tr>
<tr>
<td>ZG: equations with numbers (as many mathematical equations as possible have to be invented; numbers and mathematical operations are specified)</td>
</tr>
<tr>
<td>ZR: puzzle with numbers (as many patterns of numbers as possible have to be invented that follow logical rules; patterns have to be inscribed into given geometrical schemes)</td>
</tr>
<tr>
<td>Mental speed</td>
</tr>
<tr>
<td>ZS: number symbol test (pairs of numbers and figures are given; figures have to be assigned to given numbers)</td>
</tr>
<tr>
<td>BD: crossing out letters (a certain letter has to be crossed out in sequences of letters)</td>
</tr>
<tr>
<td>KW: classification of words (in columns of words, all words naming plants have to be crossed out)</td>
</tr>
<tr>
<td>TG: part–whole (in word lists, two words forming a part–whole relation (e.g., house, roof) sometimes follow each other; in cases where the whole stands directly above the part, the whole has to be marked)</td>
</tr>
<tr>
<td>References</td>
</tr>
</tbody>
</table>


