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Cognitive style and competence motivation in creative problem solving

Øyvind Lund Martinsen and Adrian Furnham

*Norwegian Business School, Norway

Correspondence and requests for reprints should be sent to Øyvind Lund Martinsen, Department for Leadership and Organizational Behavior, Norwegian Business School, Nydalsveien 37, 0484 Oslo, Norway. E-mail: oyvind.martinsen@bi.no

Abstract

This study was conceived by the idea that there exist different kinds of cognitive style-based, task competencies that have implications for task motivation and cognitive performance on creative problem-solving tasks/insight. Specifically, the relationships among the Assimilator–Explorer styles (Kaufmann, 1979), experimentally manipulated task competence for each style, and performance on insight tasks was examined. A total of 264 participants with a mean age of 17.4 years completed a cognitive style test, two measures of task motivation, and three practical construction-type insight tasks. Explorers with experimentally increased competence beliefs were hypothesized to perform less well on typical insight problems than Explorers with experimentally decreased competence beliefs, while Assimilators with increased levels of competence beliefs were expected to perform better than Assimilators with decreased competence beliefs. A randomized experiment with written instructions was conducted to test these hypotheses. The results supported the main hypothesis, yet an additional three-way interaction hypothesis among styles, experimentally manipulated task competence, and task structure was not supported. Limitations are discussed.

Key Words: Cognitive style, perceived competence, motivation, creative problem solving, insight.

Cognitive Style and Competence Motivation in Creative Problem Solving

Insight describes problem-solving processes where solutions typically come suddenly (the "aha" experience) and after restructuring the understanding of the problem. The phenomenon has been studied for more than 100 years and has been associated with important processes like creativity and scientific discovery (Finke, 1995). The association with creativity is quite clear, and many use the label "creative problem solving" instead of insight. Despite its long history, motivational perspectives and individual differences beyond cognitive abilities have rarely been taken into account in this field, which has typically been studied within a cognitive psychological framework.

To address such shortcomings Martinsen, Furnham, and Hærem (2016) presented a new, integrated theory in which classic theories of information processing (Kaplan & Simon, 1990), achievement motivation (Atkinson, 1974), and cognitive style (Exploration–Assimilation; Kaufmann, 1979) were combined to predict insight. In this new integrated theory, cognitive style was assumed to indicate competence for the task and to play a prominent role for task motivation. While the combined effects of cognitive style and motive arousal have been investigated in previous studies, the anticipated motivational role of style-based competence for the task has not been investigated, which is the purpose of the present study.

A Motivational and Style-Based Framework for Insight

The organizing framework for the integrated theory is the classic achievement motivation theory. This theory makes distinctions between motive strength and competencies that determine the perceived probability of success (Weiner, 1992). Motives and competencies are combined in a common theoretical framework, and the simplified formula for total or *resultant* task motivation (Tr) is supposed to be Tr = (Ms – Mf) * Ps * (1 – Ps) (see Rand, Lens, & Decock, 1991).

Motives are seen as learned anticipations of positive (Ms: motive to approach success) or negative (Mf: motive to avoid failure) affects in achievement settings. Mf has, however, been associated with unclear findings in previous research and is not considered further in the integrated theory.

The probability of success (Ps) is determined by the perceived competence for the task and can range from 0 to 1. The incentive value of success (1 – Ps) is oppositely proportional to Ps. Based on this, *Ps * (1 – Ps)* reflects the *competence motivation* part of the total motivational prediction, which makes competence an important part of achievement motivation (Elliot & Dweck, 2005). Indeed, it has been shown that the strongest competence and resultant motivation occurs when Ps is .50 (Atkinson, 1974).

Clearly, the theory makes a distinction between cognition and affect, which is typical for motivation research (Kanfer, Frese & Johnson, 2017).

Furthermore, resultant task motivation relates to performance in an inverted U-shaped way, and it is posited that there is an optimal level of motivation depending on task complexity or novelty (Humphreys & Revelle, 1984). The implication is that complex and novel tasks like insight tasks are better solved with a low level of resultant task motivation.

Probability of success has traditionally been operationalized as cognitive abilities: the higher the ability, the higher the probability of success (Gjesme, 1973). However, *ability beliefs* seem also to play a role for Ps (Durik, Vida, & Eccles, 2006), and the same is the case for the need for cognition and other variables (Dickhäuser & Reinard, 2006; Schunk & Pajares, 2005). In this respect we add to this and include competencies for different task types along novelty–familiarity or simplicity–complexity dimensions as indicators of Ps. Constructs like cognitive styles are relevant here because these variables typically describe competencies for different types of tasks beyond abilities (Martinsen, Kaufmann, & Furnham, 2011).

In this respect, the Assimilator–Explorer (A–E) cognitive style (Kaufmann, 1979; Martinsen & Kaufmann, 2000) seems to be of particular importance. Assimilators are seen as more rule bound in problem-solving behaviour and interpreting new events in terms of existing knowledge. Explorers have a disposition towards novelty seeking, as manifest by searching for new types of solutions and new ways of solving problems without any external pressure to do so. Consequently, Explorers should have higher competence (and then Ps) on insight tasks than Assimilators.

The A–E styles have been operationalized as a continuum where higher scores describe Explorers and lower scores describe Assimilators. These have been placed in the Wholist–Analyst category of style constructs (Riding & Raynor, 1998). Like several other style constructs in this category, the A–E styles correlate with all the factors in the five-factor model of personality (Martinsen & Diseth, 2011), but not extensively so, and do not correlate with general intelligence (Martinsen & Kaufmann, 2000). Moreover, Martinsen and Furnham (2016) found that there were significant but not strong correlations between the A–E styles and scores on a creative activities' checklist and with fluency (Explorers had higher creativity and fluency scores).

Previous studies have found support for the integrated theory of insight. In an experimental study with more than 400 participants, Martinsen et al. (2016) assessed the style dimension in question and experimentally manipulated the arousal of the achievement motive and also the level of task complexity. The integrated theory including optimal motivation for the task was fully supported through two predicted three-way interactions, where Explorers performed less well on insight tasks when achievement motive arousal was strong. The same was the case for Assimilators but then on more structured versions of the same tasks. In another and smaller study (Martinsen &

Furnham, 2015), where both the style dimension in question and the achievement motive were assessed, the theory was also supported through a predicted two-way interaction. The tasks were in favour of the Assimilator competence, and they did less well when motive arousal was stronger.

Because competence based, motivational effects of these styles were based on assumptions in the studies above, the present study aims at further investigating the specific implications as regards Ps and competence motivation for the A–E styles. This is investigated in a study where style-based competence for insight tasks (Ps for Assimilators and Explorers) is experimentally manipulated and implications for task motivation and performance are observed.

The Present Study

Martinsen et al. (2016), reasoned that Ps under neutral conditions for Assimilators on insight tasks would be .10. Competence motivation would then be .10 X .90 = .09 according to the formula above. Ps for Explorers would be .30, and competence motivation would be .30 X .70 = .21. This was based on research showing that insight tasks are difficult tasks with low solution frequencies and previous findings where Explorers performed somewhat better on such tasks than did Assimilators (Martinsen, 1994).

To experimentally influence Ps for Assimilators and Explorers, we used written instructions. We based this procedure on Bong and Skaalvik (2003), who maintained that verbal persuasion is one of the mechanisms that may shape competence beliefs. In our two experimental instructions we informed participants that a) the following problem-solving tasks would fit the Explorer style, or b) the following problem-solving tasks would fit the Assimilator style (for full instructions see the Methods section). We expected Explorers to feel more competent for the task in the Explorer experimental condition (and Assimilators less so) and Assimilators to feel more competent for the task in the Assimilator experimental condition (and Explorers less so), leading to two interaction hypotheses on two aspects of task motivation (Deci & Ryan, 1985): perceived competence and interest.

H1: There is a significant interaction between the A–E styles and the experimental treatments on a measure of perceived competence where the slope for the A–E styles should be positive in the Explorer condition and negative in the Assimilator condition.

H2: There is a significant interaction between the A–E styles and the two experimental treatments on a measure of interest for the tasks where the slope should be positive in the Explorer condition and negative in the Assimilator condition.

As dependent tasks, we chose to use insight problems of the practical construction type, which tend to rank high on complexity and novelty. These task characteristics are in favour of the Explorer type of style competence (Martinsen, 1994) and should lead to higher Ps than is the case for Assimilators. Based on the theory elaborated above, where total task motivation and the principle of optimal motivation for the task were important, we expected Explorers with strengthened competence beliefs to perform *less well* than Explorers *without* experimentally elevated competence beliefs. On the other hand, Assimilators with experimentally elevated levels of competence beliefs should perform *better* than Assimilators with *lower* competence beliefs.

This expected pattern of results led to the hypothesis of different types of *curvilinear* effects in our two experimental conditions. In the Assimilator condition, the slope for the A–E scores should be U-shaped because Assimilators should perform well when their competence motivation is experimentally elevated, and Explorers should perform well because their competence motivation is reduced (closer to a low level of motivation that would be optimal for tasks). In the Explorer experimental condition, the slope should have an inverted U-shape because performance should increase gradually with increasing scores on the A–E styles, but only up to a certain point, where the experimentally elevated competence motivation becomes too strong for those identifying themselves as Explorers to perform well. Therefore, our third hypothesis was:

H3: There is a significant curvilinear, interactive effect between the A–E styles and the experimental manipulations on task performance, where the slope for the A–E styles on performance should have a U-shape in the Assimilator condition and an inverted U-shape in the Explorer condition.

Moreover, although the dependent insight tasks were considered to be in favour of the Explorer style, we included search constraints (problem-solving hints) randomly distributed within the two experimental groups to create a condition that would give Assimilators an advantage because they are better at structured tasks (hints provided). We expected this to create a three-way interaction among experimental instructions, A–E styles, and availability of search constraints.

H4: There is a significant three-way curvilinear, interactive effect between the A–E styles, availability of search constraints, and the experimental manipulations of competence on task performance. The slope for the A–E styles in the no-hints condition for performance should have a U-shape in the Assimilator condition and an inverted U-shape in the Explorer condition. In the hints condition, this pattern should change such that it should have a U-shape in the Explorer condition and an inverted U-shape in the Assimilator condition.

Due to gender differences on insight problems in previous studies (Kaufmann & Martinsen, 2006), we included gender as a control variable.

Method

Participants

There were 264 participants, of whom 106 were male and 158 were female. The mean age was 17.4 years, and they were all students in senior high school in a Norwegian city.

Measures

A–E inventory. The revised A–E inventory (Kaufmann & Martinsen, 1992) was used. The scale is continuous, with Explorers receiving high scores and Assimilators low scores. Each item has a 5-point response scale, and the present version of the inventory had 30 items. The inventory showed promising validity in previous validation studies (Martinsen & Diseth, 2011; Martinsen & Kaufmann, 2000). The alpha coefficient for the A–E inventory was .91 in the present study.

Perceived competence and interest for the tasks. Four items were used to obtain a post-treatment measure of perceived competence. Items were constructed to reflect expectancies of competent performance, such as "I anticipate performing well on the tasks." The Cronbach's alpha for this measure was .79. Moreover, the emotion interest often accompanies competence beliefs (Deci & Ryan, 1985), and four items were used to obtain a post-treatment assessment of the participants' level of anticipated interest. Items were constructed to reflect anticipated interest, such as "I anticipate that I'll like working on these tasks." The Cronbach's alpha for this measure was .84.

Insight problems. Three classic insight problems were employed where two tasks—the Hatrack and Two string problems (see Maier, 1970)—were chosen based on their taxonomic classifications as insight and construction problems (Greeno, 1978; Weisberg, 1995), and a third problem—the ring problem (see Raaheim, 1961)—was chosen based on its similarity with the other two. They were administered in paper-and-pencil format with a simple drawing of the situation for each of the problems. Each insight problem was regarded as an individual item and scored 0, 1, or 2; 1 point was given for a predefined "good try". The average polychoric correlation calculated in EQS (Bentler & Wu, 2007) between the three tasks was .24, and they were used as a composite score based on their taxonomic classification (Greeno, 1978; Weisberg, 1995). Solution hints were given to approximately half the participants within each motivation condition to serve as external search constraints, thus improving the structure of the dependent insight problems. We used the same solution hints as in Martinsen et al. (2016).

Experimental competence manipulations. Competence beliefs for participants were varied experimentally using two contrasting written instructions given immediately after completing the A–E inventory. The following two variations of instructions were presented in random order.

The Assimilator instruction was:

You are about to solve a rather common type of task that you have probably been exposed to before. These tasks are well suited to people who like to work according to a plan and who prefer situations that are clear and straightforward. The tasks are not necessarily simple, but the probability of success is higher if you are normally precise, like rules, and prefer to follow a clear approach.

The Explorer instruction was:

You are about to solve a rather common type of task that you have probably been exposed to before. These tasks are well suited to people who like to experiment and try out alternative solutions and who prefer situations that are open-ended or unstructured. The tasks are not necessarily simple, but the probability of success is higher if you are normally explorative and like to experiment and try out new ways to solve problems.

These instructions aimed at increasing the assumed competence associated with the A–E styles in two different ways as described in the introduction.

Procedure

All materials were presented in experimental booklets. There were different versions of this booklet, including the two experimental instructions and the problem-solving tasks, the hints or no-hints conditions. The different booklets were randomly distributed among participants.

Participants first completed the A–E inventory and were then exposed to one of the two written experimental instructions. Subsequent to this, participants completed the measures of perceived competence and interest. After this, they were presented with each of the three insight tasks and were allowed six minutes for each problem. The problem-solving hints were given to half the participants within each experimental competence condition. Subjects volunteered, participated anonymously, and were debriefed when the experiment was completed.

Results

Included variables were inspected and found to be within the normal distribution. Correlations between the included variables are displayed in Table 1.

Table 1 here

To test our first hypothesis about an interaction between conditions and the A–E styles on perceived competence, we used hierarchical regression analyses and centred the A–E styles as recommended by Aiken and West (1991). This interaction was clearly significant in the predicted direction. R^2_{incr} for A–E X Instructions was .093, F_{incr} was 28.47 (df = 1, 255), and p_{incr} was .000. The full model (A–E, Experimental instructions, A–E X Experimental instructions) explained 17% of the variance in perceived competence scores (R^2 *adjusted* was .16, F = 17.42, MS = 100.53, (df = 3, 255), p = .000). The simple slopes for the experimental instructions were significant at both one standard deviation above (Explorers; *simple slope* = .929, SE = .377, t

(255) = 2.46, p = .01) and below the mean (Assimilators; *simple slope* = –2.343, *SE* = .364, t (255) = 6.427, p = .000) on the A–E styles. When gender was used as a covariate, the interaction was still significant.

To test our second hypothesis about an interaction between conditions and the A–E styles on interest, hierarchical regression analysis was used again. In these analyses, R^2_{incr} for A–E X Instructions on interest was .039, F_{incr} was 10.92 (df = 1, 256), and p_{incr} was .001. The full model (A–E, Experimental instructions, A-E X Experimental instructions) explained 8.3% of the variance in the interest scores (R^2 *adjusted* was .073, F = 7.77, MS = 64.69, (df = 3, 256), p = .000). The simple slope for the experimental instructions at one standard deviation above the mean on the A–E styles was significant (*simple slope* = 1.98, *SE* = .451, t (256) = 4.39, p = .000), while the simple slope for the experimental instructions was significant at two standard deviations below the mean (*simple slope* = –.1.66, *SE* = .767, t (256) = 2.167, p = .03). Thus, the pattern of interaction was the same as the interaction above. When gender was used as a covariate, the interaction was still significant.

The analyses above supported the assertion that the experimental instructions had the intended effect of increasing perceived competence and interest for the task differentially for Explorers and Assimilators.

To test our third hypothesis about a curvilinear interaction between the A–E styles and experimental instructions on task performance, we again used hierarchical regression analysis. This time we included a quadratic term for the centred A–E style scores and created product variables as described by Aiken and West (1991). The dependent variable was the composite problem-solving variable. This analysis revealed a significant, curvilinear interaction where the slopes for the A–E styles had different U-shapes in the Assimilator and Explorer experimental competence conditions. In the Explorer competence condition, the slope was an inverted U-shape, and in the Assimilator condition the slope was U-shaped. With controls for gender and the hints/no hints variable (which correlated significantly with the dependent tasks in Table 1), the curvilinear interaction was significant at p = .052. The results can be seen in Table 2, and the slopes for the A–E styles can be seen in Figure 1.

Table 2 here

Figure 1 here

Simple slope analyses, where the Assimilator competence condition was coded 0 and the Explorer competence condition was coded 1, revealed that the slopes for the A–E scores in the Assimilator competence condition were negative, but not significant, at three, two, and one standard deviations below the mean, and at one standard deviation above the mean, but positive at two and three standard deviations above the mean, but not significantly so. In the Explorer competence condition, the corresponding simple slopes were significantly different from zero and were positive from three standard deviations below the mean to one standard deviation above the mean, while the slopes were negative at two and three standard deviations above the mean (3 SDs below: *simple slope* = .077, *SE* = .036, *t* (256) = 2.166, *p* = .031; 2 SDs below: *simple slope* = .051, *SE* = .025, *t* (256) = 2.065, *p* = .04; 1 SD below: *simple slope* = .118, *SE* = .053, *t* (256) = 2.25, *p* = .027; 1 SD above: *simple slope* = .17, *SE* = .076, *t* (256) = 2.255, *p* = .025; 2 SDs above: *simple slope* = –.054, *SE* = .024, *t* (256) = 2.298, *p* = .022; 3 SDs above: *simple slope* = –.081, *SE* = .035, *t* (256) = 2.33, *p* = .021).

When using multiple regression with a quadratic term for the A–E scores, the quadratic term was clearly significant in the Explorer condition. In this analysis, R^2_{incr} for A–E X A–E on problem-solving performance was .04, F_{incr} was 6.0 (df = 1, 131) and p_{incr} was .02. The full model (A–E, A–E X A–E) explained 4.5% of the variance in the dependent variable (R^2 *adjusted* was .03, F = 3.08, MS = 7.17, (df = 2, 131), p = .05).

Aiken and West's (1991) procedure for the Johnson-Neyman (1936) technique to test slope differences at specific points was also followed to test the difference between the two conditions at both poles of the A–E styles. In these analyses, the slopes differed significantly at two standard deviations above the mean (b = –2.358, t = 3.565, p = .000) and at three standard deviations above the mean (b = –4.567, t = 3.12, p = .002) on the A–E scores, but not on the corresponding values on the Assimilator side. Yet, as shown in Figure 1, the distribution of scores for A–E style scores in the Assimilator competence condition seemed more restricted than the A–E style scores in the Explorer condition. To further investigate this, we conducted Levene's test of equality of variance on the A–E style scores in the two conditions, which was significant (Assimilator competence condition SD = 14.7; Explorer competence condition SD = 17.8; F = 5.27, p = .02).

Taken together, the interaction analysis supported our third hypothesis. More specific analyses, however, showed that the more important part of the interaction was that Explorers performed less well when perceived competence for the task was in the higher range. For Assimilators, there was a tendency to perform better when perceived competence was manipulated to be higher.

Finally, we tested our fourth hypothesis. However, the analysis of a curvilinear three-way interaction among the A–E styles, competence manipulations, and the presence of search constraints (hints–no hints) on problem-solving performance showed no significance.

Discussion

The results showed that our two experimental competence instructions worked in the hypothesized way by varying competence expectations and task interest for Assimilators and Explorers. Furthermore, the results showed that increased competence beliefs reduced performance for Explorers compared to the condition where Explorers had lower competence beliefs and interest. On the other hand, elevated competence beliefs increased performance for Assimilators compared to the other condition where Assimilators had reduced competence, although the latter effect was smaller. Consequently, these findings, although based on quite different aspects of the achievement motivation theory than was used in previous studies, are in line with previous findings (Martinsen & Furnham, 2015; Martinsen et al., 2016).

The curvilinear interaction can most adequately be attributed to a theoretically meaningful inverted U-effect between task motivation and performance under the Explorer competence condition. Although it was not significant by itself, the U-effect in the Assimilator competence condition could also be attributed to theory, as Assimilators with elevated competence beliefs should perform better on tasks where they normally do not expect to perform well. The reason why these results did not fully support our expectations in the Assimilator condition may have been the restriction of style variance in this condition. We would have expected the stronger effect of our experimental manipulation for those with very high (Explorer) or very low scores (Assimilator), in line with the third hypothesis. This effect may simply have been reduced because there were, for some unknown reason, fewer participants with extreme style scores in this experimental group.

The lack of support for hypothesis four was unexpected but may have been caused by the experimental competence manipulations interfering with effects of the search constraints (hints) in an unpredictable way. However, the significant, curvilinear interaction between the A–E styles and the experimental competence manipulations indicated that the moderated style-performance relationships were similar to the one previously found when search constraints were not available and when the types of tasks were in correspondence with the Explorer type of competence (Martinsen et al., 2016).

Based on these findings and interpretations, the results are important since we have shown that increased competence beliefs led to decreased performance for those with exploratory strategy dispositions, while lowered efficacy expectations for participants with the same dispositions led to better performance. This is a controversial and counter-intuitive finding compared, for example, with the theory of self-efficacy (Bandura, 1997) and other theories where it is posited that high competence motivation is always conducive to performance. Still, a number of human processes and characteristics relates to outcome-variables in a curvilinear way, including self-efficacy (Grant & Schwartz, 2011).

As regards the mechanisms involved, an interesting idea for future research is whether optimal states of motivation relates to what has been described as task shielding and task switching in insight, where high focus or goal orientation is related to task shielding, while positive affect and flexibility is associated with task switching (Kounios & Beeman, 2014). Anyhow, the present findings strengthen the idea that if schools or employers seek to increase people's motivation for complex tasks the individuals can actually have negative performance consequences when they already have competence for the task.

Taken together, the present integrated theory of insight may have the potential to expand upon information-processing theories of insight, theories of motivation and creative problem solving, expectancy-value theories of motivation, and cognitive style theories.

Limitations

An unexpected finding was the lack of correlations between perceived competence and performance and also between interest and performance. This indicates that motivational influences beyond these variables were in effect to explain problem-solving performance. In this respect, scores on the A–E inventory were taken to reflect the composite effect of stylistically based task competence (inherent in these two styles) and manipulated levels of task competence. While these effects may need to be further decomposed in future studies, our findings may also indicate that isolated measures of perceived competence and interest might not be sufficient to fully capture a total level of task motivation and performance effects in complex problem solving.

Another potential limitation is the age of the participants, as they were from a homogeneous age group. Future research should investigate if the current findings will generalize to other age groups.

Declaration of Conflicting Interests

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Table 1

Means, standard deviations, and correlations between study variables. Gender was coded Males = 1 and Females = 0. Type of Instruction was coded Assimilator competence = 1 and Explorer competence = 2. Hints/No Hints was coded Hints = 1 and No Hints = 0. N = 249–263.

	M	SD	1	2	3	4	5	6
1. Gender	-	-						
2. Type of instruction	-	.	–.074					
3. Hints/no Hints	-	-	.037	.023				
4. Perceived competence	10.89	2.62	.094	–.144*	–.030			
5. Interest	11.68	3.0	–.041	.122	–.048	.550**		
6. Assimilator-Explorer styles	90.67	16.33	.242**	–.046	–.065	.246**	.165**	
7. Problem-solving performance	2.22	1.66	.115	–.154*	.197**	.013	.055	.082

Note: * $p < 0.05$;** $p < 0.01$.

Table 2

Hierarchical regression analysis of the experimental treatments and the A–E styles. Scores on the A–E inventory were centred. Dependent variable was composite insight scores. Type of Instruction was coded Assimilator competence =1 and Explorer competence = 2. N = 262.

	Step 1	Step 2	Step 3	Step 4
Type of instruction	-.15*	-.15*	-.14*	-.04
Assimilator-Explorer styles	.08	.49*	.51*	.45*
Instruction X styles		-.44*	-.45*	-.40
Styles X Styles			-.08	.40
Instruction X Styles X Styles				-.52*
ΔRsq		.016*	.007	.016*
Rsq	.029*	.045**	.052**	.069**
F/df	3.91/2,260	4.11/3,259	3.56/4,258	3.79/5,257

Note: * $p < .05$; ** $p < .01$.

Figure 1. Plot of the quadratic slopes for the A–E styles in the two experimental conditions. In both plots, the centred A–E scores are seen on the horizontal axis while performance on the composite problem-solving variable is shown on the vertical axis.