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Motivation through insight: the phenomenological correlates of insight and spatial ability tasks

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ABSTRACT

In an experiment (n = 430), grounded in an integrative fluency account of the phenomenology of the Aha-experience, we tested the assumption that problem solving through insight is distinct from other strategies of problem-solving in that the affective response invoked by Aha-experiences is more influential than other solution strategies on motivational processes. Results indicated that insight tasks, compared to non-insight tasks, had the strongest affective and motivational outcomes both during and after task solution. Moreover, for insight tasks, sudden insight was the strongest predictor of correct solutions. Interestingly, step-by-step and guessing strategies were positive and negative predictors, respectively, of correct solutions. Finally, only trial and error significantly predicted correct solutions for non-insight tasks. We argue that solution strategies are not mutually exclusive. However, some strategies are more frequently used and possibly more adapted to different types of tasks. The study supports the integrative fluency account and motivational outcomes of Aha-experiences.

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Aha-experiences; insight; problem-solving; metacognitive feelings; motivation

Introduction

The Aha-experience that accompanies sudden insight is often identified as the proverbial "eureka!" or "light bulb" moment of problem-solving, the instant when an apparently correct answer manifests itself in consciousness (Danek & Wiley, 2017; Shen et al., 2015). Though the phenomenon has been studied scientifically since the early twentieth century (Sternberg & Davidson, 1995), so far there exists no single definition of the Aha-experience (Webb et al., 2018). Cognitive psychologists have traditionally approached insight through studying tasks that are supposed to elicit insights – so-called insight problems – and sometimes comparing them with non-insight problems that are solved differently (e.g. Metcalfe & Wiebe, 1987; see Öllinger & Knoblich, 2009). In this approach, the experimenter manipulates the characteristics of the task. However, a more recent approach involves studying the phenomenal experience that accompanies sudden insight (e.g. Bowden & Grunewald, 2018; Danek, 2018). Instead of manipulating tasks, researchers classify whether a task or item has been solved by insight depending on whether the solution has been accompanied by an Aha-experience. This phenomenological approach focuses on cognitive, affective, and motivational correlates and consequences of Aha-experiences. Knowledge about such phenomenological correlates is important in order to develop tasks and interventions that tap potential positive effects of Aha-experiences. The present study applied such a view, and more specifically adopted the integrative fluency account of the phenomenology of the Aha-experience as proposed by Topolinski and Reber (2010). According to this account, the Aha-experience is the result of four defining features: (1) a sudden insight leads to change in (2) processing fluency that increases (3) positive affect and (4) subjective certainty that the insight is true. Note that insight denotes the fact of a sudden change in understanding a problem, which is related to underlying

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cognitive processes, whereas Aha-experience denotes the phenomenological correlates, which in Topolinski and Reber's account include metacognitive feelings like fluency, positive affect, and certainty (for overviews on metacognitive feelings, see Reber, 2016; Schwarz & Clore, 2007).

Several studies indicate that problem-solving through insight provides different affective responses, especially pleasure, compared to other strategies (Danek et al., 2014; Danek & Wiley, 2017; Shen et al., 2015; Webb et al., 2016). However, little is known of whether insight differs from other strategies in term of motivational outcomes. This is an important aspect of insight because it has been shown that when students had at least one Aha-experience during a semester course, they developed a more positive attitude toward their subject (Liljedahl, 2005). In this qualitative study with pre-service elementary school teachers who disliked mathematics, Liljedahl arranged discussion groups and asked students whether they had an Aha-experience during the sessions. Those students who had at least one Aha-experience reported to have developed a more positive attitude towards the subject. The question arises whether other strategies could yield similar positive motivational outcomes in an experimental study. Furthermore, there are several studies showing that insight problems can be solved in various ways other than through sudden insight (Ash et al., 2009; Chein & Weisberg, 2014; Danek et al., 2014; Fleck & Weisberg, 2004, 2013). In a recent study, Skaar and Reber (2019b) used a questionnaire and survey design to test the fluency account. The authors explored the four defining features of the Aha-experience, in addition to sense of agency (i.e. control of thought), motivation and coping. Each of the seven latent constructs was measured through eight statements, where participants rated each statement in relation to three stages, *before*, *during* and *after* the Aha-experience. According to exploratory factor analysis and structural equation modelling, the authors identified four overarching dimensions encompassing the phenomenology of Aha-experiences: (1) sudden insight, (2) metacognitive feelings (i.e. fluency, positive affect and certainty), (3) sense of agency and (4) motivation and coping. Based on the results, Skaar and Reber developed a model of the phenomenology of Aha-experiences that supported the suggested fluency account. However, as the data was based on retrospective self-reports, it may be fruitful to complement survey data with experimental paradigms to examine the integrative fluency account.

Thus, the purpose of the current experiment was first and foremost to test the assumption that problem-solving through insight yields stronger affective and motivational outcomes compared to other approaches to problem-solving. We test this assumption through four research questions where we attempt to validate the findings on affective and motivational outcomes by comparing results of the current study to previous findings (e.g. Danek et al., 2016; Fleck & Weisberg, 2013). Specifically, we explore the association of problem-solving strategies and affective and motivational responses (Research Question 1); strategies used to solve insight and non-insight tasks (Research Question 2); affect and motivation before and after the test (Research Question 3); finally, to answer Research Question 4, we applied a mediation model of the phenomenology of Aha-experiences in order to ascertain that the one-item scales of the experimental paradigm yield the same factor and causal structure as the full scales used in the model tested by Skaar and Reber (2019b).

Methods

Participants

We recruited participants from two public Norwegian high schools ($N = 245$), in addition to undergraduate students in psychology ($N = 211$) from a research pool. We compensated participation of the school sample at class level to fund field trips. The undergraduate students participated in the study in exchange for course credits. In total, 456 subjects participated in the study. Participants could request that their data be excluded from analysis, and we removed 26 cases, all undergraduate students, prior to analyses per request. Thus, the final sample encompassed 430 subjects between 17–27 years (mean age = 21.4, median age = 20.0, $SD = 3.24$, 109 male and 252 female). Please note that due to missing data, the actual sample sizes vary between conducted analyses. The study obtained ethical approval from the Norwegian Social Science Data Services and the Internal Research Ethics Committee at University of Oslo.

Design and procedure

The study applied a 2×2 mixed factorial design applying an online questionnaire (Qualtrics, 2014).

The within-subjects condition included four matchstick arithmetic tasks (from here, *Matchsticks*), which is an insight task (Knoblich et al., 1999), and four Piaget's and Inhelder's (1956) water level tasks (from here, *Bottleneck*), which is a non-insight spatial ability task. The between-subjects condition involved a weighted random order of each block of the two task-types, where the four tasks within the Matchstick or Bottleneck blocks were presented in a fixed order. In other words, the experimental factor was the order in which participants would solve the two task-types (i.e. Matchstick tasks first, Bottleneck second and vice versa).

We constructed the tasks using HTML5, CSS and JavaScript (jQuery), designed to work in any modern desktop web browser (see Online Resource 1 for complete survey). Prior to solving the tasks and after a brief introduction to the study asking for informed consent, participants completed the Big Five Inventory (John et al., 1991, 2010) and self-efficacy through nine items (Chen et al., 2001). As a pretest and posttest, participants rated four items measuring positive affect, motivation and coping. However, the present paper will not discuss the Big Five Inventory and self-efficacy scales, as they were part of another research question.

During the experiment and for each of the tasks, participants could try different solutions and for each attempt would rate the subjective certainty that the current solution was correct. After rating the level of certainty, the participant could then try again or move on to the next set of questions. Regardless of number of attempts, the participants would not receive feedback on the correct solutions until the participant had attempted to solve all four tasks of each task-type block (i.e. Matchstick or Bottleneck). After each of the eight tasks, participants rated items measuring positive affect, sense of agency, motivation and coping, problem-solving strategies and the difficulty of the task, as detailed below under Measures, subsection Phenomenology. The questionnaire ended with demographics questions, including gender, age, and most recent grades in mathematics and Norwegian.

Measures

The study applied three main set measures, in addition to the proportion of solved tasks: (1) problem-solving strategies, (2) phenomenology dimensions, and (3) pre and post-tests. For each of the two task types, we created mean scores across the pertinent tasks, for example, mean score of ratings of step-by-step problem-solving strategy for each of the four Bottleneck tasks.

Problem-solving strategies

We applied four measures of problem-solving strategies: (1) step-by-step ("I solved the task step-by-step"), (2) trial and error ("I tried and failed until I found the answer"), (3) sudden insight ("I suddenly knew the answer") and (4) guessing ("I guessed the answer"). Each statement was measured on a 7-point Likert-type scale that ranged from 1 = completely disagree, 2 = strongly disagree, 3 = slightly disagree, 4 = neither or, 5 = slightly agree, 6 = strongly agree, and 7 = completely agree.

Phenomenology

Similar to Skaar and Reber (2019b), we measured in total seven phenomenology dimensions of the Aha-experience. During the process of solving each of the tasks, participants were asked to rate their *subjective certainty* that their solution were correct ("how sure are you of your solution?"), Which was measured on a 5-point Likert-type scale that ranged from 1 = very uncertain, 2 = somewhat uncertain, 3 = neither or 4 = somewhat certain, 5 = very certain. After each of the tasks, participants rated five statements measuring: (1) processing fluency ("Thinking flowed smoothly"), (2) positive affect ("I was pleased"), (3), sense of agency ("I experienced control over my thoughts"), (4) motivation ("I wanted to give up") and (5) coping ("I did not know what to do"). These five statements were measured on the same 7-point Likert-scale as the problem-solving strategies. In addition, we measured suddenness (i.e. sudden insight), but as part of the problem-solving strategies (see previous section).

The study by Skaar and Reber (2019b) applied eight statements for each of the seven dimensions; however, we used only a single statement selected on basis of the highest intercorrelation with the statements form the respective dimensions acquired from the data by Skaar and Reber (2019b). Like in the previous study, we averaged and created a composite score of the items measuring fluency, positive affect and certainty (based on the final attempt on each of the tasks) into a scale labelled *metacognitive feelings*. Furthermore, we reversed the negatively worded items measuring

motivation and coping, followed by the creation of an averaged, composite score.

Pre and post-test

The study applied four measures to assess positive affect, motivation and coping *prior* to solving, and *after* receiving the correct solutions for the tasks: (1) I am motivated, (2) I am nervous, (3) I am happy and (4) I have faith in myself. Each statement was measured on the same 7-point Likert scale as the problem-solving strategy and phenomenology statements. However, "I am nervous" shared close to zero intercorrelation with the other items and was therefore removed from the composite scores labelled "Pre-test" and "Post-test" that contained the average of the scores on motivation, happiness, and coping (faith in oneself).

Matchstick tasks

The theoretical framework for the insight part of the study is grounded in Öllinger's extended representational change theory (Öllinger et al., 2014). The theory assumes that both supposed insight and non-insight tasks may be solved with or without insight. However, when insight does occur it is through representational change. Three of four tasks (1, 3 and 4, see Figure 1) were derived from Knoblich et al. (1999). The tasks were randomly chosen from simple (Task 1) to intermediate (Task 3 and 4) task difficulty.

Task 1 required only relaxation of value constraints to find the correct solution (VI = III + III), what Knoblich et al. (1999) refers to as Type A. Task 3 and 4 required both relaxation of value and operator constraints to find the correct solutions (VIII – VI = II and II = VI – III, respectively), what Knoblich et al. (1999) refers to as Type B. Task 2 was intended as a task more difficult than Task 1 but simpler than task 3 and 4, what Knoblich et al. (1999) refers to as Type D. Unlike the other tasks, Task 2 had two possible solutions, however, the first solution (XI = VIII + III) was difficult to achieve and the second (VI = VIIII – III) is in fact wrong as VIIII is written IX in Roman numerals. We intended to compute the mean score of task solutions from the four Matchstick tasks. However, none of the participants solved Task 2 and consequently we removed all items associated with this task, including phenomenology and problem-solving strategies.

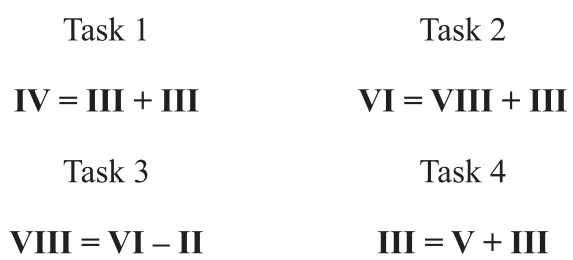

Figure 1. Four unsolved Matchstick tasks. Participants moved one matchstick to solve the arithmetic problem (cf., Knoblich et al., 1999).

Bottleneck tasks

Intended as a counterpart to the Matchstick tasks, the Bottleneck task does not require representational change, but rather an understanding, or more likely practical application, of the principle of invariance (see Tran & Formann, 2008). The four Bottleneck tasks all involved the same principle. We rotated each bottle according to a specified degree (45°, 60°, 90° or 120°) with all bottles said to contain liquid equaling 60% of capacity (see Figure 2). The tasks involved marking the horizontal waterline according to the classic water-level task of Piaget and Inhelder (1956). Accepted answers were set within a predetermined ±25 pixels (i.e. 0.66 cm) error margin of the mathematical correct answer (see dotted lines in Appendix 5 for boundaries of accepted answers).

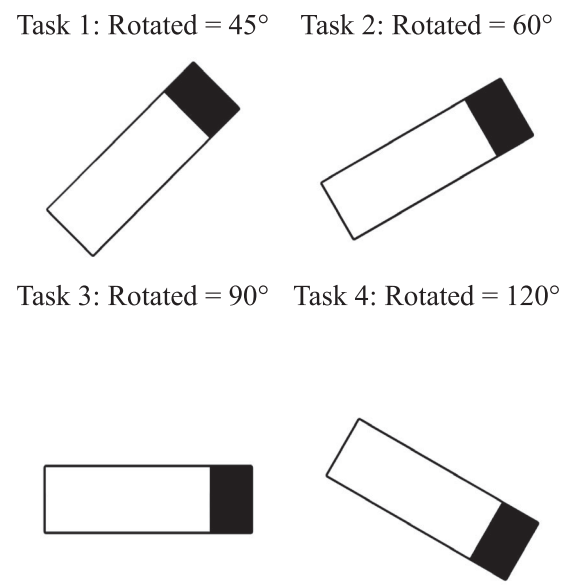

Figure 2. Four unsolved Bottleneck tasks said to contain 60% liquid. Participants solved the task by drawing a horizontal line within given tolerance level (cf. Appendix 5).

Data-analytic strategy

Data were analysed using *R* (R Core Team, 2019) by using the *psych* package (Revelle, 2019) for analysing descriptive and correlational data. Regression analysis for Research Questions 2 was conducted using the built-in *stats* package in *R*. In addition, the *lavaan* package (Rosseel, 2012) was used to conduct the mediation analysis for Research Question 3 and 4.

Results

Table 1 provides a descriptive overview of all variables for the two task types used in the study. Furthermore, Appendix 1 depicts time spent on each of the tasks.

Research question 1: problem-solving strategies and affective and motivational response

Correlational analyses revealed that the problem-solving strategies shared some similarities with the phenomenology dimensions across the Matchstick and Bottleneck tasks (see Table 2). Clearly, in both tasks the correlations are in the same direction and, in particular, the step-by-step strategy seems to share fairly consistent correlations with the four dimensions for both task types. However, there are some notable differences. First and foremost, insight showed higher correlations with sense of agency, metacognitive feelings, and motivational outcomes in the Matchstick task than in the Bottleneck task. The trial and error strategy had stronger correlations for Bottleneck compared to Matchstick tasks, and step-by-step correlated more strongly with metacognitive feelings for the Bottleneck task. Finally, the guessing strategy seems to be more detrimental for Matchstick compared to Bottleneck tasks, though the differences between the two task types are not significant for motivation and coping. It should be noted that the guessing strategy was more frequently endorsed as part of solving the Bottleneck tasks (cf., Appendix 2).

Research question 2: problem-solving strategies for insight and non-insight tasks

The differences in problem-solving strategies between Matchstick and Bottleneck tasks presented in the preceding section could also be seen when examining intercorrelations between strategies and their relationship with solving the respective task types. The correlational analyses indicated that participants used several strategies to solve

Table 1. Descriptive overview of measures for matchstick and bottleneck tasks.

	Matchstick					Bottleneck				
	M	*SD*	*α*		*n*	*M*	*SD*	*α*		*n*
Sense of Agency	4.82	1.66	.76	.72, .80	378	4.00	1.71	.89	.87, .91	380
Metacognitive feelings	4.39	1.35	.88	.86, .89	378	3.38	1.21	.90	.89, .91	380
Motivation and Coping	4.93	1.59	.85	.83, .87	378	4.16	1.60	.90	.89, .92	380
Step-by-step	4.04	1.57	.72	.67, .76	378	3.48	1.51	.86	.83, .88	380
Trial and error	3.72	1.52	.64	.58, .70	378	3.92	1.58	.86	.83, .88	380
Insight	4.53	1.75	.72	.67, .76	378	2.94	1.38	.82	.79, .84	380
Guessing	2.87	1.69	.79	.75, .82	378	4.01	1.70	.86	.84, .88	380
Task Solutions	0.52	0.41	.78	.74, .81	430	0.56	0.39	.78	.75, .82	430

Note: *M*: Mean; *SD*: Standard Deviation; *α*: tau-equivalent reliability. Subscripts indicate lower and upper bounds for the 95% confidence interval.

Table 2. Phenomenology by problem-solving strategies. Correlation.

	Sense of Agency		Metacognitive Feelings		Motivation and Coping	
Matchstick (n = 378)						
Step-by-step	.49***	.41, .56	.46***	.38, .54	.36***	.27, .45
Trial and error	.17***	0.07, .27	.17***	0.07, .27	0.03	−0.07, .13
Insight	.58 ***	.51, .64	.65 ***	.59, .70	.49 ***	.40, .56
Guessing	−.48***	−.56, −.40	−.53***	−.60, −.46	−.55***	−.62, −.48
Bottleneck (n = 380)						
Step-by-step	.58***	.51, .64	.61 ***	.54, .67	.30***	.20, .39
Trial and error	.54***	.46, .61	.52***	.45, .59	.18***	0.08, .28
Insight	.36***	.27, .45	.47***	.39, .55	.17**	0.07, .26
Guessing	−0.02	−.12, 0.08	−0.09	−.19, 0.01	−.40***	−.48, −.31

Note: Subscripts indicate lower and upper bounds for the 95% confidence interval. Shaded correlations are significantly more positive than the corresponding correlation in the other task (cf., Appendix 3).
*$p \leq 0.05$, **$p \leq 0.01$, ***$p \leq 0.001$.

the two task types, but some strategies appeared to be more successful for Matchstick compared to Bottleneck (see Table 3) tasks. Insight, but also step-by-step, were in the Matchstick tasks more strongly correlated with successful task solution than in the Bottleneck tasks. Note that the intercorrelations among insight, step-by-step, and trial and error were positive and significant. Guessing seemed more disadvantageous for solving the Matchstick tasks; the only consistent positive correlation with another strategy across the two task types occurred for trial and error.

When statistically controlling for the shared variance between strategies (see Table 4), the regression analysis indicated that insight was the strongest predictor for solving Matchstick tasks, albeit, both step-by-step (positive) and guessing (negative) explained a significant amount of variance in solving the four insight tasks. Conversely, only trial and error was a significant predictor for solving Bottleneck tasks. Importantly, whereas the regression model explained 42 percent of the variance in solving Matchstick tasks, the strategies only explained six percent of the variance for Bottleneck tasks. Thus, the results implicate that the four strategies were more important for solving Matchstick compared to Bottleneck tasks.

Research question 3: pre- and post-test measures, controlled for order

Participants started by either solving Bottleneck tasks (coded as 0, $n = 201$) or Matchstick tasks (coded as 1, $n = 225$), with pre-test ($M = 4.70$, $SD = 1.17$, $\alpha = .74$, 95% CI [.70, .78], $n = 452$) and post-test ($M = 3.89$, $SD = 1.52$, $\alpha = .84$, 95% CI [.81, .86], $n = 399$) ratings. Remember that these ratings comprised the average of items on motivation, happiness, and coping. Initial correlation tests indicated that participants that scored higher on the Pre-test also reported higher ratings on the Post-test ($r = .44$, 95% CI [.35, .52], $p \leq 0.001$, $n = 375$).

As seen from Table 5, Pre-test scores shared a weak, yet positive relationship with both task solutions and motivation and coping from solving Matchstick and Bottleneck tasks. Moreover, the positive correlation was even stronger for the Post-test scores. The results indicate that positive affect and motivation prior to solving tasks was beneficiary for both affective outcome and task solutions during the experiment and that task solving and motivation during the experiment had a positive influence on positive affect, motivation and coping after concluding the experiment.

Table 3. Task solutions and problem-solving strategies for the two sasks. Intercorrelation.

	Task Solutions		Step-by-step		Trial and error		Insight	
Matchstick (N = 349)								
Step-by-step	.30***	.21, .39						
Trial and error	0.08	−0.02, .18	.33***	.24, .42				
Insight	.53***	.45, .60	.33***	.24, .42	.30***	.20, .39		
Guessing	−.51***	-.58, -.43	.16**	−.26, −0.06	.24***	.14, .33	−.31***	−.40, −.22
Bottleneck (n = 352)								
Step-by-step	.17**	0.07, .26						
Trial and error	.25***	.15, .34	.66***	.60, .71				
Insight	0.09	−0.01, .19	.50***	.42, .57	.42***	.33, .50		
Guessing	−0.01	−.11, 0.09	0.02	−0.08, .12	.26***	.16, .35	0.05	−0.05, .15

Note: $n = 352$. Subscripts indicate lower and upper bounds for the 95% confidence interval. Shaded correlations are significantly more positive than the corresponding correlation in the other task (cf., Appendix 4).
*$p \leq 0.05$, **$p \leq 0.01$, ***$p \leq 0.001$.

Table 4. Task solutions by problem-solving strategies. Regression.

	Matchstick ($n = 378$)[a]			Bottleneck ($n = 380$)[b]		
	B	*SE*	*β*	*B*	*SE*	*β*
Intercept	0.34***	0.07		0.47***	0.06	
Step-by-step	0.03*	0.01	0.11	0	0.02	−0.01
Trial and error	0.01	0.01	0.03	0.06***	0.02	0.28
Insight	0.08***	0.01	0.36	−0.01	0.01	−0.02
Guessing	−0.09***	0.01	−0.39	−0.02	0.01	−0.08

Note: [a]$R^2 = .43$, $F = 69.41$***.
[b]$R^2 = 0.07$, $F = 6.93$***.
*$p \leq 0.05$, **$p \leq 0.01$, ***$p \leq 0.001$.

Table 5. Motivation and coping and task solutions by pre-test, post-test and task order. Correlation.

	Pre-test		Post-test		Task order	
Matchstick	0.16**	0.06, 0.26	0.39***	0.30, 0.47	0.04	−0.07, 0.14
Motivation and Coping						
Task Solutions	0.08	−0.02, 0.18	0.29***	0.20, 0.38	0.11*	0.01, 0.21
Bottleneck	0.15**	0.05, 0.25	0.28***	0.18, 0.37	−0.06	−0.16, 0.04
Motivation and Coping						
Task Solutions	0.10*	0.00, 0.20	0.11*	0.00, 0.21	0.07	−0.03, 0.17

Note: $n = 375$.
Subscripts indicate lower and upper bounds for the 95% confidence interval.
*$p \leq 0.05$, **$p \leq 0.01$, ***$p \leq 0.001$.

The order of tasks was not significantly correlated with the Pre-test scores ($r = 0.02$, 95% CI [-0.07, .12], $p = .65$, $n = 426$). On the other hand, the order of tasks was negatively correlated with Post-test scores ($r = -.14$, 95% CI [-.24, -0.04s], $p \leq 0.01$, $n = 375$). In other words, participants who began the experiment with Matchstick tasks reported lower ratings of post-test scores compared to those who began with Bottleneck tasks. In conclusion, the order of tasks had weak to no impact on motivation and coping and task solution during the experiment itself.

To explore these results further, we conducted two mediation models where we assessed the effects of Pre-test scores and the order of tasks on Post-test scores when controlled for motivation and coping (see Figure 3) and rates of solved tasks (see Figure 4), respectively. The two models were fairly similar, with significant direct effects of Pre-test scores (positive) and order of tasks (negative) on Post-test scores. Moreover, rates of task solutions and motivation and coping from Matchstick tasks were significantly related to higher ratings on the Post-test, whereas Bottleneck tasks did not exhibit similar significant results. However, there were also some notable differences. Although Pre-test scores were a significant and positive predictor of motivation and coping from both tasks, Pre-test scores did not significantly predict rates of solutions. The two models also exhibited two different significant indirect effects. In the first model, Pre-test scores predicted higher scores on motivation and coping, which predicted higher Post-test scores ($\beta = 0.04$, 95% CI [0.01, 0.07], $p \leq 0.05$). In the second, participants that began the experiment with Matchstick task solved more

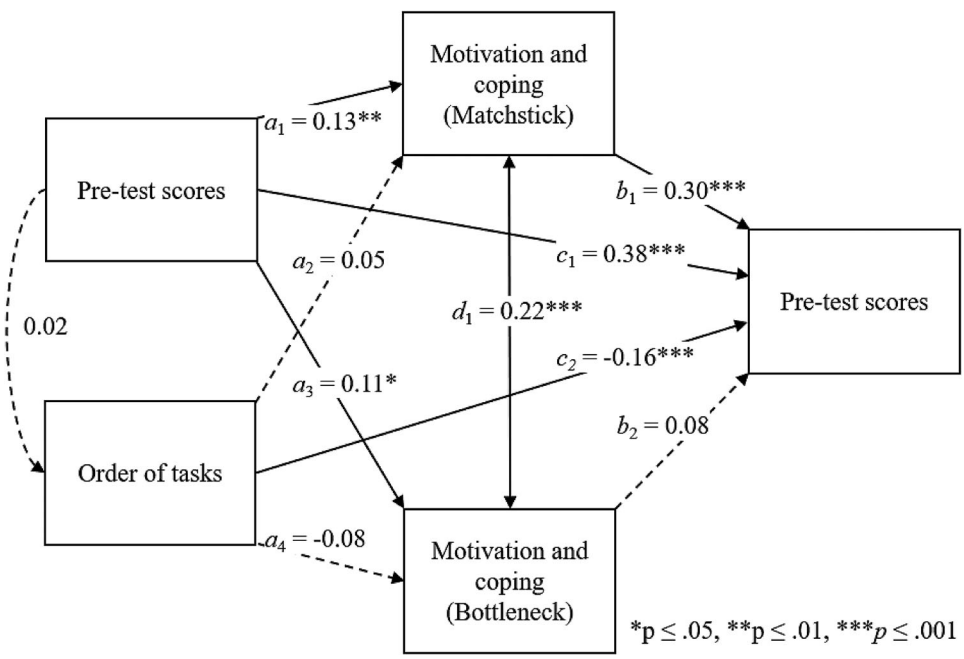

Figure 3. Mediation model of Post-test scores by order of tasks, Pre-test scores and motivation and coping. Standardised coefficients, $n = 375$. Subscripts indicate lower and upper bounds for the 95% confidence interval. Motivation and coping was a composite measure of motivation and coping.

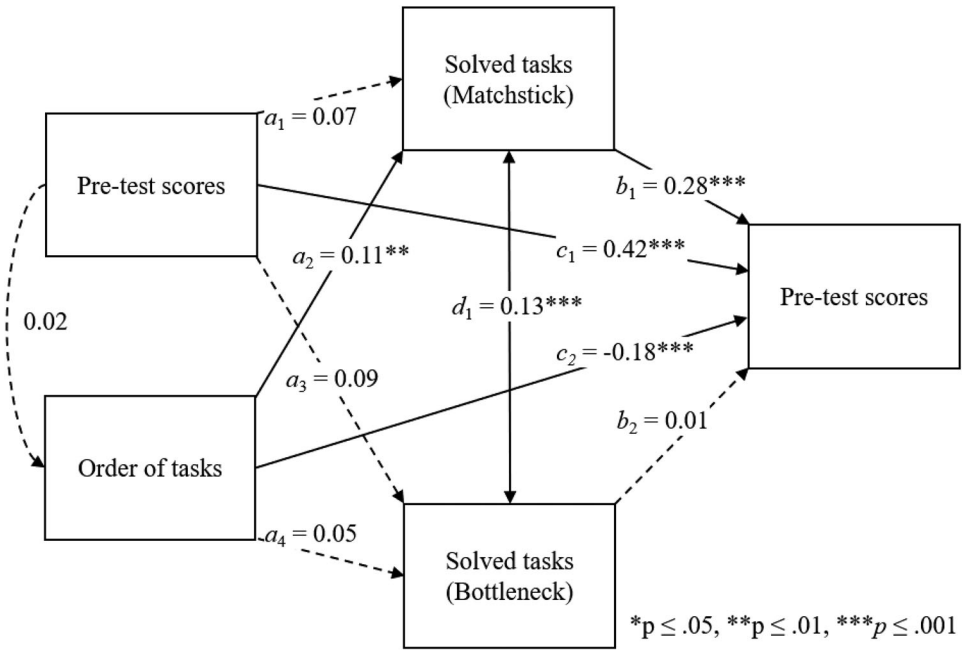

Figure 4. Mediation model of Post-test scores by order of tasks, Pre-test scores and solved tasks. Standardised coefficients, $n = 375$. Subscripts indicate lower and upper bounds for the 95% confidence interval. Motivation and coping was a composite measure of motivation and coping.

Matchstick tasks, which predicted higher Post-test scores ($\beta = 0.03$, 95% CI [0.00, 0.06], $p \leq 0.05$).

Research question 4: a model of the phenomenology of Aha-experiences

As depicted in Figure 5, participants that reported higher scores on sudden insight reported higher scores of metacognitive feelings (e.g. fluency, positive affect and certainty). Higher scores on metacognitive feelings, in turn, mediated the positive effect of insight on sense of agency. Finally, the combined contribution of metacognitive feelings and sense of agency fully mediated the effect of sudden insight on motivation and coping.

Compared to a model using only sense of agency as mediator, where sudden insight had significant effects on both sense of agency and motivation/coping (cf., Figure 6), the complete model of the phenomenology of the Aha-experience indicates that metacognitive feelings, induced by insight rather than the insight itself, has the strongest influence on both sense of agency and motivation and coping.

Discussion

In this study, using an experimental paradigm, we explored four research questions. *First*, the relationship between the problem-solving strategies (i.e. step-by-step, trial and error, insight and guessing) and the phenomenology dimensions (i.e. sense of agency, metacognitive feelings and motivation and coping) from what is often considered insight (i.e. Matchstick) and non-insight (i.e. Bottleneck) tasks. *Second,* the relationship between strategies employed and solving such tasks. *Third*, examining whether experienced motivation and coping from the tasks and task order predict post-test scores on positive affect and motivation. *Fourth,* testing a mediation model of the phenomenology of Aha-experiences.

We found several similarities in the relationships between problem-solving strategies and phenomenology across the two different task types. Importantly, the strategy that contributed most to successful solution of tasks of a certain type was most strongly correlated with the phenomenology dimensions. This finding means that insight was more strongly correlated with sense of agency, metacognitive feelings, and motivation and coping in Matchstick than in Bottleneck, whereas trial and error showed stronger correlations with sense of agency and metacognitive feelings in Bottleneck than in Matchstick.

Correct solutions in insight and non-insight tasks were predicted by different variables. Multiple regression indicated that insight and step-by-step

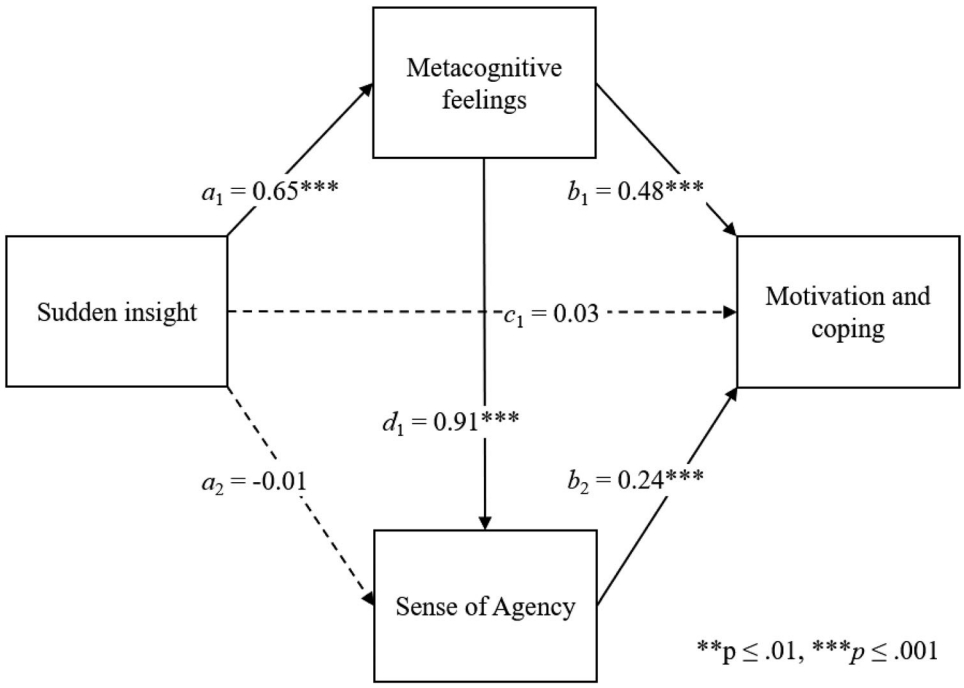

Figure 5. Mediation model of the phenomenology of the Aha-experience. Standardised coefficients, $n = 378$. Subscripts indicate lower and upper bounds for the 95% confidence interval. Metacognitive feelings was a composite measure of fluency, positive affect, and certainty. Motivation and coping was a composite measure of motivation and coping. Matchstick tasks.

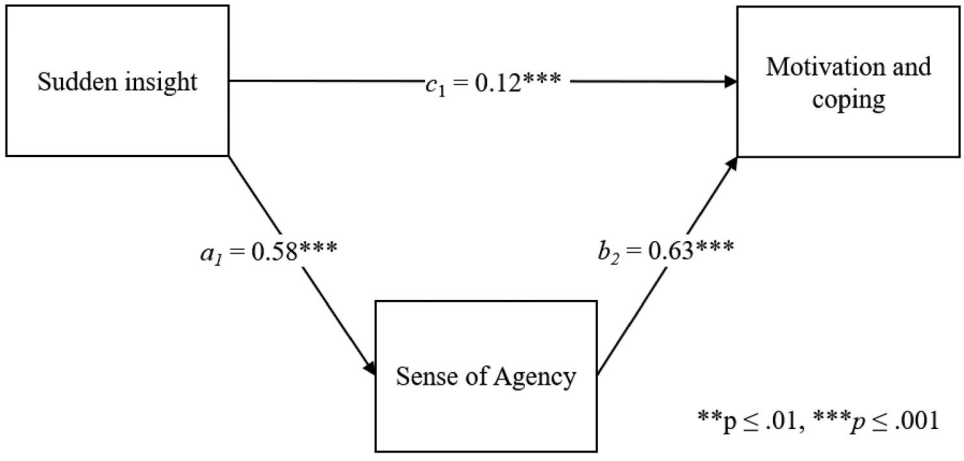

Figure 6. Mediation model the phenomenology of the Aha-experience sans metacognitive feelings. Standardised coefficients, $n = 378$s. Subscripts indicate lower and upper bounds for the 95% confidence interval. Motivation and coping was a composite measure of motivation and coping.

strategies were significant, positive predictors of solving Matchstick tasks, whereas guessing was a significant negative predictor. On the other hand, only the trial and error strategy was a significant, positive predictor of finding the solution of Bottleneck tasks. Interestingly, guessing shared a moderate positive correlation with trial and error for both task types, which might help explain why it did not share a negative relationship with solving Bottleneck tasks. Thus, though some problem-solving strategies are more frequently used, and possibly more adapted to different types of task, the strategies themselves are not mutually exclusive.

Results from pre- and post-test supplement the results from the prior questions. Though Pre-test scores was the strongest, positive predictor of

Post-test scores, motivation and coping from solving Matchstick tasks partly mediated the effect of pretest on posttest; solution was an additional predictor but not mediator of post-test ratings. Bottleneck tasks, on the other hand, had no significant impact on Post-test scores. The experimental condition of the study, the order of tasks, had a significant negative influence on Post-test scores. The latter result may be interpreted in two ways, as it is not possible from the present design to detect the direction in which the order of tasks exert influence on Post-test scores. The first interpretation is that by starting with the Matchstick block, the following Bottleneck tasks was experienced as less interesting or more vague/difficult ("anticlimactic", as some participants wrote in the optional commentary). Conversely, by ending with Matchstick tasks, participants felt the opposite. Interestingly, though not significant and weakly correlated, results from Table 5 indicate that the task order had a paradoxical effect on participants' experience of solving Bottleneck tasks. Though participants were more likely to find correct solutions, they were less motivated by solving them when they started the experiment by solving Matchstick tasks.

Finally, we found that by using single items with the same factor structure as the multi-item scales of Skaar and Reber (2019b), that the mediation model conforms with the survey-based structural equation model by Skaar (2019a, p. 51). This finding has two implications, one theoretical and the other methodological. In theory, it seems that Aha-experiences have a characteristic phenomenology that is the same across samples and robust to changes in measurement. Methodologically, this robustness means that the single item measurement of Aha-experiences in this and future studies provide reliable information about metacognitive feelings.

Naturally, the Matchstick and Bottleneck tasks are quite different in nature and were intended to invite different approaches to solve the tasks. According to Piaget and Inhelder (1956, p. 384), children by the age of nine normally have grasped the concept of horizontality, regardless of rotation of the bottle. However, research has shown that even some adults may have difficulty learning and applying the concept (Tran & Formann, 2008). Furthermore, the Bottleneck task presented in this study was more difficult than just ascertaining that the water-level was horizontal. To calculate the correct water-level, participants would have to grasp complex trigonometry, and it is therefore likely that for most participants it would be difficult to be certain that their provided solution was correct. Consequently, and as seen from Table 1, guessing and trial and error were the two highest rated problem-solving strategies. Conversely, though the Matchstick tasks had non-obvious answers, the arithmetic behind the task was elementary and participants who solved the tasks could be quite confident that their solutions were correct. As such, the high ratings of insight and step-by-step strategies are not all that surprising. However, results from this study imply that many participants used multiple problem-solving strategies. Although the phenomenology dimensions appeared to share the strongest relationship with the dominant strategies, the overall results were not drastically different. Thus, it is questionable to what extent tasks could inherently be described as either insight or non-insight based. These results are in line with previous research (Danek et al., 2016; Fleck & Weisberg, 2013) and conform with our predictions, given the integrative fluency account of the phenomenology of the Aha-experience (Topolinski & Reber, 2010) and prior research (Skaar & Reber, 2019b).

Limitations and future directions

There is a possibility that presenting the Matchstick and Bottleneck tasks as two individual fixed blocks may have influenced the results by establishing and reinforcing cognitive fixation on the problem types (Lu et al., 2017). Another clear limitation of our study is that we use only two tasks; the study would benefit from using a variety of tasks. Furthermore, by omitting the Matchstick task that remained unsolved by all participants, we might have skewed the results. Albeit the two task types are difficult to compare, correlations within the task types nevertheless act as an indicator of the relationship between solving the tasks and the phenomenology associated with the two task types and our study provides initial experimental evidence of motivational outcomes of Aha-experiences. However, to confirm these results in more ecological environments it would be necessary to develop varied tasks, for instance, math tasks found in educational settings at school. It is noteworthy that participants used their own computers and preferred web browsers. Though we designed the tasks to work with any desktop browser, slight differences in computational power and rendering of the web pages might have affected the user-

experience. Although the procedure might have been ecologically valid, future research would benefit from replicating these findings in a more controlled, laboratory setting. Finally, as we used only one item per scale, we have lost some the width of each of the phenomenology dimensions we measured. However, as the result of the mediation model replicated previous findings, the measures provide concurrent criterion validity.

As soon as valid ways to measure Aha-experiences in field settings have been be found, the path is open to develop tasks and interventions to increase positive feelings and motivation (for eliciting feelings strategically to optimise outcomes, see Reber, 2016). The pioneering research by Liljedahl (2005) suggests that group discussion may be one way to elicit Aha-experiences and hence increase motivation. Our one-item measure is easy-to-use in educational settings, even online. Note that the present study does not only enable to measure metacognitive feelings and motivation after Aha-experiences but also as a consequence of systematic strategies, like step-by-step solutions or trial and error. Educational psychology is often preoccupied with effects of tasks and intervention on learning. However, it is important to overcome this focus on learning and to explore affect and metacognitive feelings in order to optimise motivational outcomes (see Reber et al., 2009).

Conclusion

In the current study, we found support for a model demonstrating that the combined effect of metacognitive feelings and sense of agency fully mediated the effect of sudden insight on motivation and coping from solving Matchstick tasks. Our data extend the findings reported by Skaar and Reber (2019b). Moreover, we found that the phenomenology of so-called insight and non-insight tasks relates to the strategies predominantly used to solve the respective tasks. This supports the general distinction of these tasks. However, while some strategies are more frequently used, participants seemed to use multiple approaches in solving the tasks and consequently they are not mutually exclusive (cf., Fleck & Weisberg, 2013). In conclusion, we found evidence for the assumption that solving tasks through insight has a more positive affective and motivational outcome compared to other strategies.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Appendix 1

Time Spent on Each of the Tasks. In Seconds

Task	*M*	*SD*	Min	Max	Skew	Kurtosis	*n*
Matchstick 1	90.02	88.55	3.48	613.56	2.42	8.00	413
Matchstick 2	142.22	284.87	1.74	5305.54	14.66	259.95	411
Matchstick 3	143.85	341.01	2.34	6478.21	15.85	289.68	407
Matchstick 4	93.75	153.97	1.67	2605.77	11.06	173.08	404
Bottleneck 1	109.38	108.04	4.29	1446.32	5.48	56.57	418
Bottleneck 2	60.32	65.25	2.63	749.83	4.73	37.37	410
Bottleneck 3	47.52	41.42	2.69	294.60	2.13	6.28	406
Bottleneck 4	55.33	310.26	2.72	6244.24	19.55	386.98	406

Note. M = Mean, SD = Standard Deviation.

Appendix 2

Differences in ratings between Matchstick and Bottleneck tasks. T-test.

	t	*Df*	*P*	*d*	
Sense of Agency	−6.75	755.48	0.00	−0.49	−0.49, −0.48
Metacognitive Feelings	−10.87	746.95	0.00	−0.79	−0.79, −0.78
Motivation and Coping	−6.61	756.00	0.00	−0.48	−0.48, −0.47
Step-by-step	−4.97	754.66	0.00	−0.36	−0.36, −0.36
Trial and error	1.79	755.11	0.07	0.13	0.12, 0.13
Insight	−13.88	715.95	0.00	−1.01	−1.01, −1.00
Guessing	9.21	756.00	0.00	0.67	0.66, 0.67
Task Solutions	1.33	854.54	0.18	0.09	0.09, 0.09

Note: *t* = *t*-test statistics, df = degrees of freedom, *p* = *p*-value, *d* = Cohen's *d*. Subscripts indicate lower and upper bounds for the 95% confidence interval.

Appendix 3

Phenomenology by problem-solving strategies. Difference in unpaired correlations.

	Sense of Agency		Metacognitive Feelings		Motivation and Coping	
	z	*P*	*z*	*p*	*Z*	*p*
Step-by-step	−1.65	0.099	−2.91	0.004	1.00	0.317
Trial and error	−5.91	0.000	−5.58	0.000	−2.13	0.033
Insight	3.88	0.000	3.53	0.000	4.97	0.000
Guessing	−6.89	0.000	−6.91	0.000	−2.80	0.005

Note: *z* = z-score, *p* = *p*-value.

Appendix 4

Intercorrelations of task solutions and problem-solving strategies for the two tasks. Difference in unpaired correlations.

	Task Solutions		Step-by-step		Trial and error		Insight	
	z	*p*	*z*	*p*	*z*	*P*	*z*	*p*
Step-by-step	1.97	0.049						
Trial and error	−2.35	0.019	−6.09	0.000				
Insight	6.84	0.000	−2.81	0.005	−1.92	0.055		
Guessing	−7.61	0.000	−2.59	0.009	−0.28	0.776	−5.05	0.000

Note. *z* = z-score, *p* = *p*-value.

Appendix 5

Four solved Bottleneck tasks. Dotted red lines are boundaries of accepted answers.