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Journal Name:	Frontiers in Psychology
ISSN:	1664-1078
Article type:	Original Research Article
First received on:	18 Jul 2014
Frontiers website link:	www.frontiersin.org

Gaining insight into magic tricks

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Keywords: Insight, problem solving, magic, Aha! experience, impasse.

Abstract

Magic tricks usually remain a mystery to the observer. For the sake of science, we offered participants the opportunity to discover the magician's secret method by repeatedly presenting the same trick and asking them to find out how the trick worked. In the context of insightful problem solving, the present work investigated the emotions that participants experience upon solving a magic trick. We assumed that these emotions form the typical "Aha! experience" that accompanies insightful solutions to difficult problems. We aimed to show that Aha! experiences can be triggered by magic tricks and to systematically explore the phenomenology of the Aha! experience by breaking it down into five previously postulated dimensions. 34 video clips of different magic tricks were presented up to three times to 50 participants who had to find out how the trick was accomplished, and to indicate whether they had experienced an Aha! during the solving process. Participants then performed a comprehensive quantitative and qualitative assessment of their Aha! experiences which was repeated after 14 days to control for its reliability. Participants' faces were filmed with a digital camera throughout the experiment. 41% of all suggested solutions were accompanied by an Aha! experience. The quantitative assessment remained stable across time in all five dimensions. Happiness was rated as the most important dimension. This primacy of positive emotions was also reflected in participants' qualitative self-reports which contained more emotional than cognitive aspects. Implementing magic tricks as problem solving task, we could show that strong Aha! experiences can be triggered if a trick is solved. We could at least partially capture the phenomenology of Aha! by identifying one prevailing aspect (positive emotions), a new aspect (release of tension upon gaining insight into a magic trick) and one less important aspect (impasse).

40 1. Introduction

41 Sometimes, the solution to a difficult problem pops into mind suddenly (Davidson 1995) and
42 unexpectedly (Metcalf 1986). Ever since the Gestalt psychologists (Köhler 1921; Duncker 1945;
43 Wertheimer 1959) began to investigate problem solving, the phenomenon of insight has been of great
44 interest to psychologists (Sternberg and Davidson 1995). Insight is often reported to be accompanied
45 by an affective response, the “Aha! experience” (e.g. Gick and Lockhart 1995). This is taken as the
46 discriminative criterion to set it apart from analytic and gradual problem solving (Metcalf 1986;
47 Evans 2008).

48 The present work focuses on the phenomenology of the Aha! experience. With the aim of
49 triggering strong Aha! experiences, we used magic tricks as a problem solving task, assuming that
50 gaining insight into a magic trick would lead to a strong affective response since the secret of a magic
51 trick is typically extremely hard to find out. Further, magic tricks are ideally suited to investigate
52 insight because in order to discover the magicians’ secret method, observers must overcome implicit
53 constraints by restructuring their problem representation. This is a crucial aspect common to other
54 insight problems, too (Ohlsson 1992; Knoblich, Ohlsson, and Raney 2001). We also claim that, in
55 contrast to most classical insight problems, magic tricks are less artificially construed and are more
56 “ecologically valid” stimuli in the sense that efforts to solve the tricks are naturally set in motion.

57 Bühler provided the first reports about Aha! experiences, describing a moment “in which
58 suddenly, the lights come on” (translated from Bühler 1907, p. 341). Traditionally, the Aha! has been
59 regarded as an interesting epiphenomenon of insight (e.g. Ormerod, MacGregor, and Chronicle 2002)
60 or even the defining feature of insight (Kaplan and Simon 1990; Gick and Lockhart 1995) that defies
61 closer empirical inquiry due to its subjective nature. But the recent interest in possible neural
62 correlates of insight has led to a surge in studies that presuppose the subjective Aha! experience to be
63 the clearest observable aspect of insight (Jung-Beeman et al. 2004). Consequently, problem solvers’
64 subjective reports about the occurrence of an Aha! experience are for those studies indispensable to
65 classify a solution as insightful and to distinguish it from solutions without insight (Bowden et al.
66 2005; Aziz-Zadeh, Kaplan, and Iacoboni 2009). The self-report approach has been successfully
67 adopted by others (Sandkühler and Bhattacharya 2008; Sheth, Sandkühler, and Bhattacharya 2009;
68 Subramaniam et al. 2009). For example, Kounios (2006) analysed a time interval of 2 seconds prior
69 to problem presentation and found differences in neural activity (both in the EEG and in the fMRI
70 signal) predicting whether the following problem would be solved with insight (Aha! reported) or
71 without insight (Aha! not reported). In the present work, we adopted Bowden’s approach (Bowden et
72 al. 2005) to determine the occurrence of insight and combined this approach with an a priori selection
73 of a task (magic tricks) that is likely to trigger misleading initial problem representations.

74 Despite its successful use as a solution type classification criterion and its importance for the
75 interpretation of almost all neuroscientific studies on insight problem solving, the phenomenology of
76 the Aha! experience, as far as we know, has not been investigated in more detail. One hindrance is
77 the methodological difficulty of its assessment (introspective judgements about the occurrence of
78 Aha!), another one might be conceptual problems (what defines an Aha! experience?). So far, there is
79 no general and explicit agreement on a definition of this concept. The common denominator is that
80 an Aha! occurs if a solution suddenly pops into mind. Other aspects like a feeling of surprise,
81 certainty that the solution is correct or a gestalt-like quality of the solution are stressed or disregarded
82 to various degrees across studies (Ohlsson 1992; Sandkühler and Bhattacharya 2008; Bowden et al.
83 2005). The theoretical assumption that prior impasse is a necessary precondition for Aha!

84 experiences to occur (Ohlsson 1992; Knoblich, Ohlsson, and Raney 2001; Jones 2003; Öllinger,
85 Jones, and Knoblich 2006) is taken up by some (e.g. Schooler, Ohlsson, and Brooks 1993;
86 Sandkühler and Bhattacharya 2008) and questioned by others (e.g. Bowden et al. 2005). The
87 conceptual vagueness makes it very difficult to compare findings across studies, and thus it seems
88 critical to further elucidate the phenomenology of this special experience (compare Gick's call, 1995,
89 for further research on the affective aspects of problem solving).

90 The aim of the present study was to provide a detailed analysis of the Aha! experience during
91 sudden moments of insight into magic tricks. We assumed a multidimensional model where the
92 interplay of different dimensions establishes the Aha! experience and assessed the relative
93 importance of the involved components quantitatively as well as qualitatively. As a basis for this
94 assessment, we identified five dimensions of the Aha! experience that have been postulated
95 previously:

96 1. Suddenness: That insightful solutions are experienced as very sudden was demonstrated by
97 Metcalfe (Metcalfe 1986; Metcalfe and Wiebe 1987) who showed that although problem solvers are
98 able to accurately judge their progress towards solution (recorded as feeling-of-warmth ratings) for
99 non-insight problems, they are unable to do so for insight problems. This finding was further
100 confirmed by Davidson (1995).

101 2. Surprise: Based on introspection and informal observation, Gick and Lockhart (1995) suggested
102 a division of the Aha! experience in two components: Surprise and suddenness. In their account, the
103 surprise aspect can vary by strength and it can be accompanied by either positive (delight) or
104 negative (chagrin) emotions. In order to disentangle surprise from these accompanying emotions, we
105 decided to assess the emotional component separately, adding "happiness" as a new dimension.

106 3. Happiness: Because Gick and Lockhart (1995) proposed the emotional response to vary
107 between the positive and negative pole, we used a scale with "unpleasant" and "pleasant" as two
108 extremes. There is also anecdotal evidence for this dimension of the Aha! experience, for example
109 Gruber (1995) who analyzed Darwin's notes from the time of his great discovery on 28th September,
110 1838 and from them, inferred "a state of elevated happiness" (1995, 425).

111 4. Impasse: Ohlsson postulated that prior impasse is a necessary precondition for Aha!
112 experiences to occur (1992). An impasse is defined as a state of mind where problem solving
113 behavior ceases (Ohlsson 1992; Öllinger, Jones, and Knoblich 2008; Sandkühler and Bhattacharya
114 2008). In an eye-movement study, Knoblich et al. (2001) demonstrated that for successful solvers of
115 insight problems, the number of long fixation times (i.e. periods with few eye movements) increases
116 throughout the problem solving process, with longest fixation times occurring in the last time interval
117 before the solution. That is, before insight occurred, there was a phase without systematic eye-
118 movement patterns. Their interpretation of such an "idling" phase was that more appropriate
119 representations can be established that yield a new insight.

120 5. Certainty: Obviousness of solution, i.e. the certainty that an insightful solution is correct, was
121 stressed as an additional aspect by Bowden and Jung-Beeman (2007). This "intuitive sense of
122 success" related to insightful solutions is also often described in the context of scientific discoveries
123 (Gick and Lockhart 1995, 215).

124 Furthermore, we wanted to test Bowden's claim (2005) of the reliability of subjective judgements.

125 The differential assessment of the five dimensions was therefore repeated after two weeks. The
126 present study addressed the following two hypotheses:

- 127 1. Multidimensionality: We assumed that the Aha! experience is a syndrome of well-defined
128 characteristics and hypothesized that all five dimensions are equally important.
- 129 2. Reliability: We tested whether participants' assessment of their Aha! experiences would be
130 stable across time and predicted a high reliability.

131

132 **2. Materials and methods**

133 **2.1. Participants**

134 50 students (mean age 24.4; 16 male) participated for 32€ in the study and were tested
135 individually after giving informed consent. Two participants were excluded because they did not
136 solve any of the presented tasks, resulting in a final sample size of 48.

137 **2.2. Testing material**

138 The testing material consisted of 37 (3 of them used for practice) video clips of magic tricks that
139 had been performed by a professional magician (TF) and recorded in a standardized setting. The
140 video clips that ranged from 6 to 80 seconds were presented on a 17" computer screen displayed by
141 the Presentation® software version 12.1. The tricks covered a wide range of different magic effects
142 (e.g. transposition, restoration, vanish) and methods (e.g. misdirection, gimmicks, optical illusions).
143 The magic tricks were presented to participants as a problem solving task. See
144 <http://www.youtube.com/watch?v=3B6ZxNR0uNw> for a sample trick clip from our study. Stimulus
145 development, a complete list of the tricks and the experimental rationale are described in further
146 detail in another paper (Danek et al. 2014).

147 **2.3. Procedure**

148 There were two separate testing sessions with exactly 14 days delay. In session 1, participants'
149 task was to watch magic tricks and to find the secret method used by the magician to produce the
150 magic effect. If a trick was solved, they had to indicate on a trial-by-trial basis whether they had
151 experienced an Aha! during the solution. Participants' faces were filmed with a digital camera
152 throughout the experiment. After completing all tricks, participants were asked to evaluate their Aha!
153 experiences. 14 days later, participants were invited again for a second evaluation of their Aha!
154 experiences, this time from memory. In addition, a recall of participants' solutions was conducted in
155 session 2. The results of this recall do not contribute to the present research question and are thus
156 reported elsewhere (Danek et al. 2013). Both sessions lasted about two hours.

157 **2.3.1. Session 1: Magic tricks**

158 Participants were seated in a distance of 80 cm in front of a computer screen. After filling in an
159 informed consent, they were orally instructed by the experimenter to watch the video clips of magic
160 tricks and think of a solution how the trick could work. If participants failed to solve the trick, the

161 video clip was repeated up to two more times while solving attempts continued.

162 As soon as they had found a potential solution, participants were required to press a button which
 163 stopped the video clip and ended the trial. A dialog with the following question appeared (all
 164 questions in German): Did you experience an Aha! moment? Participants indicated Yes or No with a
 165 mouse click. Subsequently, they were prompted to type in the solution on the keyboard and gave a
 166 certainty rating of how confident they felt about the correctness of their solution on a scale from 0 to
 167 100%. Fig. 1 shows the procedure of one trial.

168 ---- Fig. 1 about here ----

169 Following Bowden and Jung-Beeman's approach (2007), participants categorized their solution
 170 experiences into insight (with Aha!) and noninsight (without Aha!) solutions. We used the following
 171 instruction for these judgements (adapted from Jung-Beeman et al. 2004): "We would like to know
 172 whether you experienced a feeling of insight when you solved a magic trick. A feeling of insight is a
 173 kind of "Aha!" characterized by suddenness and obviousness. Like an enlightenment. You are
 174 relatively confident that your solution is correct without having to check it. In contrast, you
 175 experienced no Aha! if the solution occurs to you slowly and stepwise, and if you need to check it by
 176 watching the clip once more. As an example, imagine a light bulb that is switched on all at once in
 177 contrast to slowly dimming it up. We ask for your subjective rating whether it felt like an Aha!
 178 experience or not, there is no right or wrong answer. Just follow your intuition."

179 After three practice trials, the experiment started and for each participant, a randomized sequence
 180 of 34 magic tricks was presented.

181 2.3.2. Session 1: Assessment of Aha! experience

182 Adopting a similar procedure from MacGregor and Cunningham (2008) who collected a global
 183 self-rating of insight after participants had worked on several different insight problems, we decided
 184 to conduct the comprehensive assessment after all tasks were completed. This procedure of asking
 185 participants to report their overall feeling of Aha! allowed us to collect the most basic, overarching
 186 characteristics of the insight experience, independent from individual fluctuations caused by
 187 differences between single problems (e.g. a very difficult trick in contrast to a less difficult one that
 188 might lead to less strong Aha! experiences). We used a two-fold approach:

- 189 • Self-report (qualitative): Participants were given the opportunity to describe the thoughts
 190 and emotions that occurred while they gained insight into the working of a magic trick.
 191 This self-report was performed prior to the rating of importance to avoid possible transfer
 192 effects - so that participants could freely describe their actual Aha! experience without
 193 being influenced by the given dimensions.
- 194 • Rating of importance (quantitative): Five previously postulated dimensions were
 195 subjected to a rating of importance by participants (compare Sandkühler and Bhattacharya
 196 2008).

197 2.3.2.1. Session 1: Self-report

198 After completing all 34 magic tricks, participants were asked to give introspective self-reports
 199 ("Think back to the Aha! moments that you had during the experiment. Please describe these Aha!

200 experiences in your own words!”). It was stressed that the self-reports should refer to Aha! solutions
201 only, not to the other solutions which participants had classified as non-insightful. Participants used
202 the keyboard to type in their descriptions. There was no time limit for this task.

203 2.3.2.2. Session 1: Rating of importance

204 Subsequently, participants rated their Aha! experiences on each dimension separately, using a
205 visual analogue scale with the following end points: Suddenness (slow solution - fast solution),
206 surprise (not surprising - surprising), happiness (unpleasant - pleasant), impasse (no impasse -
207 impasse), certainty (uncertain - certain). For each dimension, the scale was displayed on the screen
208 (see fig. 2). As default, the cursor was set in the middle of the scale and participants moved it along
209 the scale using the mouse to select a position. The left end of the scale corresponded to a value of 0
210 and the right end to a value of 100, but participants did not see any numbers.

211 ---- Fig. 2 about here ----

212 To control for familiarity, at the end of session 1 participants received a questionnaire with a
213 screenshot from each trick and were asked to indicate whether the solution of a trick had previously
214 been known to them. These tricks were excluded on an individual level and handled as missing
215 values (5.2% of all trials).

216 2.3.3. Session 2: Re-assessment of Aha! experience

217 To control for its stability across time, the same assessment (self-report and rating of importance)
218 was conducted 14 days later. The procedure was identical to session 1. Again, participants were
219 explicitly asked to refer to the Aha! experiences they had had during the experiment (now two weeks
220 ago) and to describe them from memory.

221

222 3. Results

223 3.1. Categorization of self-reports

224 Each participant produced a free report of their subjective Aha! experiences that was repeated
225 after a 14 day delay. For six participants, the second rating was missing. The full statements are
226 provided in as supplementary material (translated from German). The reports were sorted into five
227 main categories (see below). To avoid any a priori assumptions about the nature of Aha! experiences,
228 the categories were compiled by a rater who was blind to the experimental rationale, and who based
229 the compilation only on data from session 1. The rater read all statements from session 1 and
230 collapsed them into meaningful, self-created categories. This rating scheme was subsequently used
231 by three independent raters who re-categorized all reports (both session 1 and 2). A categorization
232 was valid if at least two of the three raters assigned the same category. Critical ones were discussed
233 until an agreement was reached. Each report could be assigned to more than one category, because
234 participants often mentioned several different aspects that belonged to different categories. These
235 were the categories:

236

- 237 1. Cognitive aspects
- 238 a. Elaboration (compare Ohlsson 1992): A solution is found because a crucial detail is
239 detected.
- 240 b. Restructuring (compare Ohlsson 1992): A new way of looking at the problem,
241 separate parts suddenly fit together, everything falls into place.
- 242 2. Emotional aspects
- 243 a. Happiness: Feelings of joy, contentment, pleasure, positive arousal.
- 244 b. Tension release: Strain is released, feelings of relaxation and relief.
- 245 c. Performance-related emotions: Pride, drive, increased motivation, competitiveness,
246 satisfaction.
- 247 3. Somatic reactions: Physiological arousal or other reactions related to the body.
- 248 4. Reproduction of instruction: If participants simply repeated parts of the instruction that
249 described the “standard” Aha! experience, this category was assigned, including the following
250 aspects: Suddenness, rapidness, clarity of solution, certainty about correctness of solution,
251 light bulb metaphor and common conceptions of Aha! experiences (e.g. “struck by lightning,
252 the penny has dropped”).
- 253 5. Other: Rest category

254 3.2. Magic tricks

255 Table 1 provides an overview of the problem solving data obtained in session 1. See Danek et al.
256 (2014) for a detailed analysis of solution rates, solution accuracy, certainty and influence of
257 demographic variables.

258 Table 1. Solution rates collapsed into different categories. 34 tricks x 48 participants yielded a
259 total of 1632 trials. 51% of them were either not solved or discarded due to familiarity of the trick
260 (see first two rows) and 49% of all trials were solved (see four last rows). False solutions refer to
261 implausible or even physically impossible solution suggestions.

262

Outcome	Frequency ($\Sigma = 1632$)	Percentage of all trials ($n = 1632$)	Percentage of solved trials ($n = 800$)
Not solved	747	45.8%	--

Discarded trials	85	5.2%	--	
True insight solution (with Aha!)	254	15.6%	31.7%	} 41.1% insight
False insight solution (with Aha!)	75	4.6%	9.4%	
True non-insight solution (without Aha!)	263	16.1%	32.9%	} 58.9% non- insight
False non-insight solution (without Aha!)	208	12.7%	26.0%	

263

264 For 41% of all solved magic tricks, participants indicated that they had experienced an Aha!
 265 during the solving process. Of course, the subsequent Aha! assessment referred only to those events.
 266 Participants had been instructed to think back to their insight experiences, and to rate only those
 267 (compare methods).

268

269 3.3. Assessment of Aha! experience

270 3.3.1. Reliability of Aha! ratings across time (ratings of importance)

271 There was a delay of 14 days between the first and the second rating time point. We addressed the
 272 reliability of those ratings by statistically comparing the two time points. For six participants, the
 273 second rating was missing.

274

---- Figure 3 about here ----

275 Fig. 3 shows that the 2nd rating of importance (conducted in session 2) did not differ substantially
 276 from the 1st rating (session 1). This observation was confirmed by a repeated measures ANOVA with
 277 the factors Session (two levels: session 1 and session 2) and Dimension (five levels: suddenness,
 278 surprise, happiness, impasse and certainty) that revealed no significant main effect for the factor
 279 Session ($F(1, 41) = 1.1, p = .3$). Thus, participants' ratings of their Aha! solution experiences
 280 remained stable across time.

281 There was a significant main effect for the factor Dimension, $F(4, 164) = 16.43, p < .01$, indicating
 282 that there were differences between dimensions. We will focus on the two dimensions that
 283 significantly differed from all others, the one with the highest (happiness) and the lowest (impasse)
 284 rating, respectively. Pair-wise post hoc comparisons revealed that happiness (mean 88.5%) was rated
 285 significantly higher than all other dimensions (all $p < .05$). This means, happiness was the most
 286 important aspect of the Aha! experience. The feeling of being stuck in an impasse was in comparison
 287 less often reported: Impasse ratings were in general lower (mean 60.9%), and differed significantly
 288 from all other dimensions (all $p < .05$).

289

290 **3.3.2. Analysis of self-reports**

291 Table 2 shows how often the aspects had been described and provides one prototypical example
 292 each.

293 Table 2. Categorization of participants' self-reports with prototypical examples (translated from
 294 German). Their corresponding frequencies are listed separately for the two time points, as well as
 295 summed up (last column).

#	Category	Example	Frequency in session 1	Frequency in session 2	Total frequency
1a	Cognitive (Elaboration)	I detected a small detail and suddenly, the things that I had observed previously make sense.	8	1	9
1b	Cognitive (Restructuring)	What in the beginning didn't fit together suddenly makes sense.	6	2	8
2a	Emotional (Happiness)	I am happy and get into a good mood.	20	23	43
2b	Emotional (Tension release)	I feel relieved and relaxed.	8	11	19
2c	Emotional (Performance-related emotions)	- I was much more motivated to continue working on the task. - Like a competition between me and the magician, and in Aha! moments, I felt like the winner. - I feel so much more intelligent.	12	12	24
3	Somatic reactions	Like a shot through my body.	3	3	6
4	Reproduction of instruction	I suddenly feel an enlightenment.	29	22	51
5	Other		6	4	10
			Σ 92	Σ 78	Σ 170

296

297 For the 1st assessment (from session 1), comparing the cognitive and the emotional categories
 298 (1a+1b vs. 2a+2b+2c) with a cross tab, we found that 24 participants mentioned emotional aspects
 299 (but no cognitive ones) whereas only 5 participants mentioned cognitive aspects (but no emotional
 300 ones). This difference was significant (McNemar test, $p < .01$).

301 After two weeks, this difference was even more pronounced: In session 2, 30 participants
 302 mentioned emotional, but no cognitive aspects (in contrast to only two participants with the reverse
 303 pattern), and the McNemar test was significant with $p < .01$.

304 Regarding the emotional categories, clearly the most relevant aspect was happiness (mentioned 43
 305 times). Performance-related emotions (24 times) and the feeling of tension release (19 times) were
 306 mentioned less often.

307 Apart from reproductions of the instruction, which dealt mainly with the solution strategy used
308 (Aha! vs. more analytic solving styles), only few cognitive aspects were mentioned.

309 Somatic reactions were only mentioned by three participants at each time point. Two statements
310 were from the same participants, i.e. in session 2, two participants described the same physiological
311 reactions as they had during the first session. In the first case, this was “a slight pull in my chest and
312 tummy”, and the second participant expressed the feeling “like a shot through my body”.

313 Category 4 was used as a manipulation check. Obviously, participants remembered the instruction
314 well or used the same characteristics, with 51 total instances of naming one of these aspects.

315

316 **3.4. Behavioral aspects**

317 The video recordings of participants’ behavior during the solution process may serve to illustrate
318 the emotional response following Aha! experiences. Here we present two paradigmatic cases (figures
319 4 and 5). The depicted participants gave written consent for the publication of this material.

320

321 ---- Figure 4 about here ----

322

323 ---- Figure 5 about here ----

324

325 Comparing the right upper panel of figure 4 with the right upper panel of figure 5, there are
326 striking differences in the behavioral response of the same participant. In both cases, the participant
327 is shown 1 s after she discovered the secret method of a magic trick, but in figure 4, she later
328 classified her solution as insightful (with Aha! experience), whereas in figure 5, she classified it as
329 non-insight solution. The participant reacts differently, with a positive affective response to the
330 insight solution (figure 4) that is completely missing for the non-insight solution (figure 5). The other
331 participant (lower panel) exhibits the same pattern.

332

333 **4. Discussion**

334 The new task domain of magic tricks proved to be well suited to trigger Aha! experiences with
335 41% of all solutions classified as such. This finding provides evidence for our conception of magic
336 tricks as an insight task. The comprehensive assessment of solution experiences revealed
337 participants’ strong emotional involvement upon gaining insight into the working of a magic trick.
338 To our knowledge, this emotional component of insight has not been specifically documented yet for
339 any other problem solving task. We therefore advocate magic tricks as useful tools to investigate
340 insight problem solving.

341 With regard to phenomenology, the present results support our conception of the Aha! experience

342 as multi-dimensional. However, the hypothesis that all five dimensions of the Aha! experience would
343 be rated as equally important was not confirmed. Instead, we found “happiness” as prevailing aspect.
344 This primacy of positive emotions is also reflected in participants’ self-reports although two different
345 methods were used (qualitative self-reports and quantitative ratings on a visual analogue scale with
346 fixed dimensions).

347 The dimension “impasse” appears to be less important than previously thought (Ohlsson 1992),
348 casting doubt on the theoretical assumption that being in a state of impasse is a prerequisite for
349 experiencing insight later. This finding is in accordance with results from a study on the Candle
350 Problem (Duncker 1945) by Fleck et al. (Fleck and Weisberg 2004) who found only few instances of
351 impasse in verbal protocols obtained during the solution process. However, this finding might
352 perhaps also be attributed to characteristics of our new stimulus domain. We argue that watching a
353 magic trick directly puts the observer in a state of impasse – namely in the first moment of
354 astonishment and wonder about the magic effect. At first, the observer is left completely baffled,
355 without any solution prospect. But later, after the problem solving process has been initiated,
356 participants don’t necessarily experience an impasse.

357 The importance ratings remained stable across time in all five dimensions (see fig. 2). To evaluate
358 such a fleeting moment by pinpointing its dimensions on a scale is arguably quite a difficult task. It
359 seems impressive that participants were able to recall their Aha! experience so vividly after 14 days
360 that they rated it identically. This finding provides empirical support for Bowden’s claim (2005) for
361 the usefulness and reliability of self-reports in insight research.

362 A weakness of the visual analogue scale used here is the lack of negatively poled questions,
363 reflected in the answers’ general trend towards the positive pole. The temporal stability of the
364 importance ratings might thus partly be explained by reduced variability caused by this positive bias.
365 An alternative explanation for the ratings’ stability must also be considered: It is conceivable that
366 participants did not actually remember their Aha! experiences, but instead reported what they
367 remembered reporting in session 1. However, this seems unlikely for two reasons: First, participants
368 had not been informed about what would happen in the second experimental session - they were
369 completely unaware that the rating would have to be repeated. Second, to make it difficult to
370 remember the previous rating, we had deliberately implemented a visual analogue scale without any
371 numbers. There was only a line on which the cursor had to be positioned. In this way, participants
372 could never know the value to which the selected position corresponded and could therefore not
373 retain any numbers, only a visual image of the scale. It seems unlikely that participants were able to
374 retain this visual impression for two weeks for five different dimensions.

375 The free self-reports helped to obtain further information about problem solvers’ actual
376 experience. A qualitative analysis of this data revealed positive emotions as the prevailing aspect of
377 Aha! experiences. Here is an example from one participant: “A moment of bliss. I am happy and get
378 into a good mood.” (see supplementary material). This is in accordance with results from the
379 importance ratings in which happiness received the highest value. Comparing participants’ behavior
380 (recorded on video tape) directly after insight and non-insight solutions further validates the strong
381 emotional impact of Aha! experiences. The affective response to solutions found through insight is
382 reflected in smiling, laughter and other positive facial expressions whereas the responses to non-
383 insightful solutions are less strong or completely missing. A quote from one of our participants may
384 serve to illustrate this: “Explosively, the bad feeling of frustration and confusion turns into a feeling
385 of happiness and I feel a swell of pride.” We thus demonstrated the occurrence of strong positive
386 emotions during sudden moments of insight.

387 We found two new aspects in participants' self-reports. The comparably high frequency of
388 performance-related aspects (e.g. "I feel really clever now" or "The magician can't fool me anymore
389 because by now, I could do the trick by myself") was not expected, and might be attributed to the
390 special task situation with our participants being confronted with the magician as a kind of rival, thus
391 engaging in a competition with him. Therefore, they might be only task specific and we would not
392 expect similar reactions to classic insight puzzles without any opponent.

393 Tension release was the other new aspect of the Aha! experience (e.g. "I feel relieved and relaxed
394 now" or "feeling of relief after a phase of strain caused by failure"). It seems plausible to assume that
395 tension arises if there exists no obvious solution for a problem. During unsuccessful problem solving
396 attempts, the tension builds up further. If at last, unexpectedly, a solution is found, the tension will
397 rapidly decline. Apparently, this is an important aspect still missing from current definitions of the
398 Aha! experience.

399 These empirical findings relate to theoretical assumptions about the phenomenology of the Aha!
400 experience. Ohlsson (1984) summarized the Gestalt psychologists' main ideas in a set of principles.
401 Some of them overlap with the self-report data: In the category "performance-related emotions",
402 participants repeatedly describe heightened motivation ("I am much more motivated to continue
403 working on the task"). This closely resembles proposition N (Ohlsson 1984, 70) in which an
404 "energizing effect on problem solving behavior" is described. Other aspects also match: "Recentering
405 as a displacement of attention from one part of the situation to another [...] reveals what the central
406 part of the situation really is" (Ohlsson 1984, 70). This corresponds to the "elaboration" category and
407 matches the idea of selective encoding (Davidson 1995), i.e. that a problem solver suddenly detects
408 certain features which were not obvious before (and not encoded) as relevant for a solution. For
409 example, one of our participants noted that "Through a small detail, the entire action sequence
410 becomes clear".

411 We conclude that there is a wealth of information to be gained through subjective self-reports.
412 Most participants took several minutes to diligently describe their thoughts, using vivid and
413 expressive language as documented in the supplementary material. Using the self-report approach to
414 access participants' subjective Aha! experiences, we could at least partially capture the
415 phenomenology of Aha! by identifying one prevailing aspect (positive emotions), a new aspect
416 (release of tension) and one less important aspect (impasse). We recommend the use of such direct,
417 qualitative self-reports as a promising tool to learn more about the phenomenological aspects of
418 insight problem solving.

419 Of course, there are obvious limitations to the introspective method: It is highly subjective, and
420 general conclusions can only be drawn with caution. Durso even suggested that because participants
421 were shown to be not able to correctly judge their progress toward a solution (Metcalf 1986),
422 "...self-reports following insight are equally unreliable." (Durso, Rea, and Dayton 1994, 94). Yet we
423 argue that for the elusive phenomenon of insight, subjective Aha! reports might provide information
424 that would not be accessible through more rigorous experimental methods. Other researchers have
425 successfully used verbal protocols to elucidate the processes during insight problem solving (Kaplan
426 and Simon 1990; Fleck and Weisberg 2004; Dominowski and Buyer 2000; see also Fox, Ericsson,
427 and Best 2011, for a recent meta-analysis on verbalization procedures in general) and others even
428 argue that the rejection of introspective methods hinders the advancement of the field (Jäkel and
429 Schreiber 2013). We suggest that the traditional approach of using pre-defined "insight problems"
430 and assuming the occurrence of insight in the case of a solved problem, without taking into account
431 participants' individual problem solving experiences, should always be complemented by subjective

432 measures (e.g. Aha! self-reports or thinking-out-loud protocols) directly obtained from participants.

433 Critical appraisal of magic tricks as problem solving tasks: We claimed that magic tricks represent
434 a more authentic task domain than previous insight tasks because participants start working on the
435 problem quite naturally, eager to find out the magician's secret. During the testing, participants were
436 highly motivated to solve the presented tricks, even after many trials. In addition, magic tricks are
437 less artificially construed than classical insight problems in which participants must solve verbal
438 riddles, logical brainteasers, mathematical problems or connect dots according to arbitrary rules.
439 They are authentic because they take place in familiar situations with ordinary objects like coins or
440 cigarettes. The present work indicates that such authentic stimuli can be as valuable as strictly
441 controlled paper-and-pencil tasks. A systematic comparison of magic tricks with traditional types of
442 stimuli (e.g. with regard to motivational aspects) is needed to further substantiate this claim.

443 Inducing positive mood could be another important advantage of using magic tricks in insight
444 research. It has been shown previously that positive affect facilitates insight (e.g. Bolte, Goschke, &
445 Kuhl, 2003; Isen, Daubman, & Nowicki, 1987; Subramaniam et al., 2009; Sakaki & Niki, 2011). Isen
446 and colleagues (1987) induced positive mood by presenting a comedy film (Gag reel) to participants
447 shortly before they began working on Duncker's Candle Problem (1935). A control group who had
448 watched a neutral film (a math film, Area under a curve) produced significantly less solutions than
449 the positive mood group. In an fMRI study, Subramaniam et al. (2009) found that participants who
450 were high in positive mood solved a greater number of CRA problems with insight than participants
451 who were lower in positive mood. It seems plausible that in the present study, participants' emotional
452 state was positively influenced by watching the magic tricks, similar to watching a comedy film. The
453 self-reports showed the high emotional impact of solving a magic trick. Although we did not directly
454 assess mood, it was obvious that participants liked to watch the tricks and were highly motivated to
455 do the task. Perhaps the drop-out rate of zero (for the second visit to the lab) can also be accounted to
456 that. In pilot studies, participants scored very high on the question "How much did you like the
457 trick?" with a mean of 2.94 (on a rating scale from 1 = not at all to 4 = very much). We speculate that
458 the positive mood induced by watching magic tricks also facilitated insight in the present study. In
459 future experiments using magic tricks, we recommend to systematically control for mood.

460 In sum, this study demonstrates that the Aha! experience should not only be regarded as an
461 interesting epiphenomenon or trial-sorting criterion, but that the phenomenon itself can be
462 investigated systematically and fruitfully. Implementing magic tricks as problem solving task, we
463 could show that strong Aha! experiences can be triggered if a trick is solved. We could at least
464 partially capture the phenomenology of Aha! by identifying one prevailing aspect (positive
465 emotions), a new aspect (release of tension upon gaining insight into a magic trick) and one less
466 important aspect (impasse). We hope to have contributed to a deeper understanding of the nature of
467 this complex phenomenon by introducing magic tricks as a useful research tool for insight problem
468 solving.

469

470 **5. Acknowledgement**

471 We thank Matus Simkovic for help with programming the experiment.

472

473 6. References

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547
548
549
550
551

552 7. Figure legends

553 Figure 1 Procedure of one trial. Different phases and timing are displayed. Note that individual tricks
554 vary in length.

555 Figure 2 Visual analogue scale for the dimension Surprise.

556 Figure 3 Comparison of the averaged 1st (circle) and 2nd (triangle) importance rating for each
557 dimension. For each time point, the mean rating across participants is depicted. Horizontal bars
558 denote standard errors of the mean.

559 Figure 4 An insight solution. Stills from the video recordings that were run during the entire
560 experiment. The behavioral response of two participants directly before (left panel) and after (1 s
561 later, right panel) an insight solution is shown.

562 Figure 5 A non-insight solution. Stills from the video recordings that were run during the entire

563 experiment. The behavioral response of two participants directly before (left panel) and after (1 s
564 later, right panel) a non-insight solution is shown.

565

566 **8. Supplementary Material**

567 **Self-reports**

568

569 1. A moment of bliss. I am happy and get into a good mood. An increasing certainty. Everything
570 becomes perfectly clear, a tingling in my head.

571

572 2. I'm excited and I feel no doubt about this sudden solution.

573

574 3. A sudden discovery, unexpected, a feeling of "that's how the solution must be", no hesitation

575

576 4. A feeling of definite knowledge or alternatively, a first sensation of knowledge that is not
577 necessarily confirmed in the next step, but initially, feels certain and irrefutable. A sense of triumph
578 because one has seen through the trick. "Gotcha!"-feeling. Yes, of course, there is no other way! As
579 long as any doubts about the correctness remain, it is no Aha! effect.

580

581 5. I perceive a certain movement of the hand, from which I can infer how the trick could possibly
582 work. Thus, it can only be detected at a certain time point of the trick. Classic Aha! experience, a
583 feeling of seeing through the trick all at once.

584

585 6. For me, I experienced an Aha! either when I could see the solution in my mind or when I had the
586 feeling of knowing the solution. This feeling is similar to being motivated to do something, knowing
587 that it is exactly the right thing. With Aha! experiences, I am much more motivated to continue
588 working on the task or problem.

589

590 7. I did not experience any Aha!

591

592 8. Sometimes it was a very strong feeling, as if I had solved an extremely difficult case that mattered
593 greatly. Other times, it was more like "ok, now I got you and I know how you did it". In the first case,
594 the excitement was much greater, in the second case, it was more relieving.

595

596 9. It can perhaps be described as a flash, suddenly I knew the answer, even if shortly before, I didn't
597 have a clue. It's a wonderful, positive feeling and for me, it felt a bit like relief.

598

599 10. It's like a small tension that gets released suddenly and a positive and liberating feeling emerges.

600

601 11. Suddenly, without prior warning, the only plausible solution pops out in my mind. Feeling of joy.

602

603 12. In a split second, I'm struck by a flash of genius.

604

605 13. When suddenly the brain knows how it happened.

606

607 14. Very good. I believe that the magician can't fool me anymore because by now, I could do the
608 trick by myself. With an Aha! experience, I feel very sure about the solution.

609

610 15. Suddenly, everything becomes perfectly clear, the missing link is found. It is awesome to
611 suddenly see through the trick, because I feel very clever. It just clicks and it is a very positive
612 feeling. Like a reward for thinking so hard. I feel lively and happy to have figured it out. A feeling of
613 bliss.

614

615 16. When the different parts fall into place and my considerations make sense. A slight pull in the
616 chest.

617

618 17. It's like a shot through my body. Being awakened from previous ignorance, I feel really happy.

619

620 18. Explosively, the bad feeling of frustration and confusion turns into a feeling of happiness and I
621 feel a swell of pride.

622

623 19. I detected a small detail and suddenly, the things that I had observed previously make sense. It
624 feels like the penny has dropped, and I feel a bit proud to be so certain now, although I had no clue
625 just a few seconds before.

626

627 20. I feel that suddenly, I know the solution, thrilled, excited, pleased to have understood something.

628

629 21. It seems as if in this moment, all confusion in my brain becomes resolved and I should have
630 known it earlier, simply because it is so logical. The Aha! experience can really be described as the
631 feeling of switching on a light bulb. And I feel somehow affirmed and positively relaxed.

632

633 22. I had no Aha! experiences.

634

635 23. Abruptly, it becomes clear what's hidden behind all this. When I search for a solution, and
636 suddenly the tension gets released, because I figured it out. A release of tension occurs in my head.

637

638 24. „It dawned on me“ is a saying which can very well be connected with this effect; you have
639 thought about a certain matter for a while and suddenly, there is a detail you had not noted earlier
640 which now is leading you in a different direction. It's also a moment of relief and relaxation – time
641 seems to have come to a standstill for a short while. Maybe it's some sort of very short flow
642 experience.

643

644 25. In contrast to the other moments I didn't have to check the realisation; the solution seemed to be
645 unambiguous, mostly like remembering something. Usually I'm quite certain about it.

646

647 26. Suddenly one knows or believes to know how it works without checking it in detail.

648

649 27. The moment comes quite suddenly, as if the idea jumps directly into your mind and doesn't
650 develop step by step by reflection. I am happy about the surprising knowledge.

651

652 28. A sudden image appears before my inner eye, triggering off an impulse for action. The further
653 course of the magic trick becomes uninteresting, the focus is on the image which seems to be the
654 solution or actually is the solution.

655

656 29. You can't understand why you didn't see that before although it is so simple. It didn't come about
657 by logical reflections but rather simply because it has to be as it is.

658

- 659 30. Like a sudden relief after a time of tension, a feeling of happiness. What in the beginning didn't
660 fit together suddenly makes sense. Thoughts can keep flowing where before they were in front of a
661 barrier.
- 662
- 663 31. The sudden understanding of the solution. The solution becomes visible before my inner eye in a
664 flash.
- 665
- 666 32. During an Aha! experience you suddenly realize a detail; somehow you are happy to have seen
667 through the magic trick.
- 668
- 669 33. Satisfaction at having found the correct solution.
- 670
- 671 34. With an Aha! experience I suddenly feel an enlightenment; it is as if quite suddenly the light was
672 switched on or a switch turned.
- 673
- 674 35. Very quick feeling, easy and liberating.
- 675
- 676 36. I think the magician always did something to distract me from his tricks. So, after the second
677 viewing, I concentrated on what had changed or had disappeared. As soon as I did so, I had this Aha!
678 experience and I was happy.
- 679
- 680 37. Very happy and surprising.
- 681
- 682 38. An Aha! experience feels good. Here, once in a while, suspicious hand movements of the
683 magician were interpreted as important for a sudden understanding of the trick; other Aha!
684 experiences felt like a sudden memory of a similar trick. Aha! experiences felt like ideas, similar to
685 agreeable memories suddenly having come back.
- 686
- 687 39. Beautiful, surprised by oneself.
- 688
- 689 40. Can't remember exactly, but it feels a bit like a sudden intuition and like „Oh, that's it! Why
690 didn't I find out earlier?“

691

692 41. The Aha! experience is marked by a feeling of joy and personal satisfaction triggered off by
693 finding the solution.

694

695 42. Through a small detail, e.g. the cut-off upper part of the spoon, the entire action sequence
696 becomes clear, respectively foreseeable and further details can be detected, e.g. that the magician
697 once again puts the spoon in his hand and quickly takes it out again.

698

699 43. Rather nice...you observe what you can see and try to explain how it works and then a decisive
700 detail strikes you – suddenly you have an idea how it could work. As if you had found the last
701 missing part of the puzzle in order to reconstruct the rest of the picture.

702

703 44. It feels like an enlightenment, a sudden inspiration how the problem can be solved. Suddenly all
704 pieces of information fit together which before had not fitted together.

705

706 45. It feels good because suddenly I know something. It feels alright and, in a way, makes me happy.

707

708 46. Aha! experiences could be compared to a quick jump in my head. I didn't have to think rationally
709 about how the trick worked, but it simply came to me.

710

711 47. I feel as if a light had been switched on in my head and I'm thinking of my Latin teacher who
712 kept speaking about this. We had lots of Aha! experiences with him.

713

714 48. A click in my head, as if someone had turned a switch but, nevertheless, very relaxing and I feel
715 so much more intelligent.

716

717

718 **Self-reports (14 days later)**

719

720 1.-5. missing

721

722 6. Aha! experience – a short inspiration how to get out of this hopeless situation. This feeling gives

723 me wings that make me continue working on the problem which I had not been able to solve before.
724 And, naturally, I immediately feel inclined to solve further problems, as it seems you now can do
725 anything, no matter which task you have been set.

726

727 7. No Aha! experiences.

728

729 8. I had two different kinds of Aha! experiences. With one, I felt like suddenly having an idea how
730 the trick had been done – sort of thunder-struck! With the other Aha! experience, I felt as if I had
731 reflected for a moment, I was rather relieved to have seen through the trick, whereas with the first
732 kind I felt as if I had tricked the magician himself by understanding his trick.

733

734 9. I found the solution rather fast, I didn't have to think about it at all and I had no clues from which
735 to start thinking. There was a feeling of relief connected with the Aha! experience, it was a very
736 positive feeling.

737

738 10. Some sort of tension is released, it is a relaxing, positive sensation and it also gives you some
739 kind of feeling of success.

740

741 11. I was excited, felt good and satisfied, it felt as if the solution had suddenly appeared in my head.

742

743 12. The Aha! experience came suddenly and unexpectedly.

744

745 13. It suddenly appears in my head how the trick works and it somehow feels great to find this out,
746 well, the feelings are: gladness, joy to have found out and curiosity, as you can't always be sure if it
747 really works like that.

748

749 14. Very good, I think I know exactly what has just happened. I have exactly understood the trick or
750 the situation, I am quite sure to be right.

751

752 15. It simply goes snap und you've got it! Before it happens you keep thinking about it and don't
753 quite get round it, but when the Aha! experience occurs, then you suddenly understand everything –
754 it's like an insight into the whole situation.

755

756 16. Like a slight pull in my chest and tummy.

757

758 17. Excitement and a feeling like a warm swirl going through my body. I feel relieved and relaxed,
759 joyful.

760

761 18. A sudden change from a feeling of insecurity and fear of failure to a feeling of joy and pride.
762 Especially in this moment of change, I'm experiencing an incredible energy

763 flowing through my body.

764

765 19. I am glad and proud to have found a solution, relieved, for a short while I forget what is
766 happening around me.

767

768 20. I feel surprised that I have understood something, I am content, maybe even proud of myself, I
769 feel pretty good and agreeable. It certainly is a positive feeling, making me more enthusiastic and full
770 of energy.

771

772 21. An Aha! experience feels good, as if I actually saw a light switched on, suddenly everything
773 appears to be quite clear.

774

775 22. I had none.

776

777 23. Like a flash of genius, as if suddenly everything became clear, you keep brooding and then it
778 suddenly appears, tension disappears, you feel released, a bit euphoric.

779

780 24. As if a light was switched on, something that before I hadn't properly paid attention to now
781 turned out to be the cause of a whole series of effects.

782

783 25. Sudden remembrance, dissatisfaction about not having discovered it earlier.

784

785 26. Suddenly I know the answer, it is as if a light lightened up the darkness.

786

- 787 27. It is as if the idea appeared suddenly out of nowhere and came into my mind. I'm glad about the
788 surprising knowledge and I'm very content.
- 789
- 790 28. Suddenly an image appears in my mind's eye, everything else around me becomes uninteresting
791 and the concentration is focused only on that image which could be, respectively is, the solution of a
792 problem.
- 793
- 794 29. Strange that I haven't seen the solution earlier, it turned out to be much easier than I would have
795 expected. At some point, the understanding is simply there.
- 796
- 797 30. It was a feeling of relief combined with a feeling of happiness after a phase of strain caused by
798 failure.
- 799
- 800 31. A sudden moment, a feeling of understanding as if it began to dawn on me.
- 801
- 802 32. It felt good to have found the solution. It was like a competition between me and the magician,
803 and in an Aha! moments, I felt like the winner.
- 804
- 805 33. When I discovered the solution, I suddenly was content about myself.
- 806
- 807 34. It is like a sudden flash of insight, as if someone had switched on a lamp bringing light into the
808 darkness. This moment comes as a surprise and without warning.
- 809
- 810 35. A slight feeling as if something fell off. For a short moment, you get a feeling of a clear sight.
- 811
- 812 36. With some tricks, the understanding came suddenly, very easy and I felt glad.
- 813
- 814 37. Surprising and funny.
- 815
- 816 38. You have an Aha! experience when understanding connections, thus creating a meaningful
817 image. It can be compared to the good feeling of having finished something that had cost you a lot of

818 time and effort, a positive feeling of understanding.

819

820 39. Beautiful. Surprised. Fulfillment of my ambitions. Cool.

821

822 40. A moment when you think: Ah, that's it! Why didn't I see that before!

823

824 41. An Aha! experience is very satisfying, you think you have finally understood how it works and
825 that you have unmasked the trick. Also in other situations, Aha! experiences feel like that.
826 Immediately, you are completely sure about it.

827

828 42. Suddenly the solution appears quickly in my mind. In most cases, it is quite a different track than
829 I had expected before. All the other steps simply follow.

830

831 43. I have a smaller or greater experience of success when I believe to have understood the trick.

832

833 44. A problem is suddenly understood and solved, it's like a stroke of genius and sometimes you
834 don't even know how you found the solution.

835

836 45. A feeling of great satisfaction, a redeeming, relaxing moment, making me feel happy and
837 satisfied.

838

839 46. A moment that liberates your mind, relieving your mind from strain, you feel enlightened.

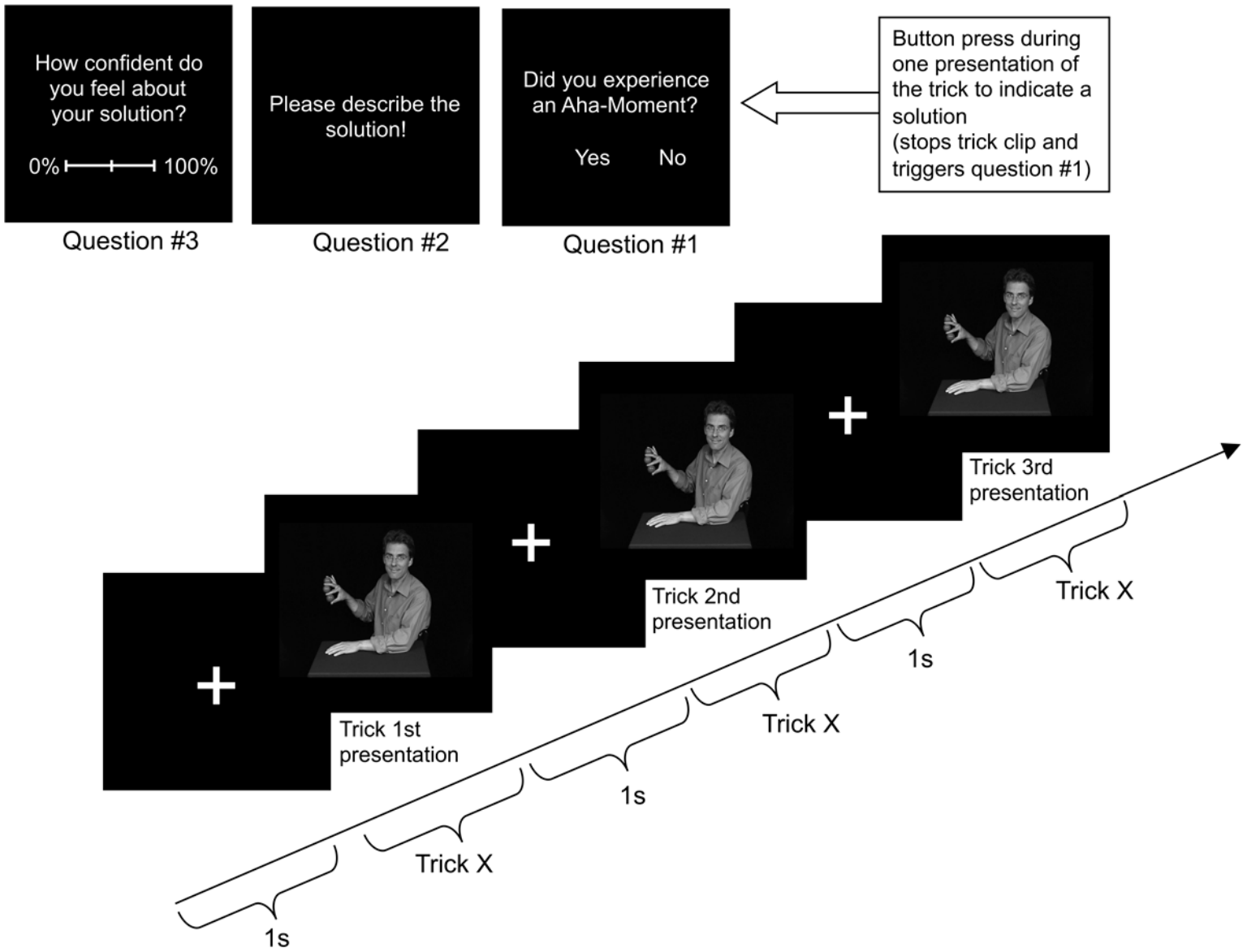
840

841 47. I was ever so pleased about having seen through the trick, respectively a little less pleased.

842

843 48. A relaxing feeling, feels good and at the same time you don't feel as excited as before.

Figure 1.JPEG



Please rate your Aha! experiences!

not surprising |—————|—————| surprising

A horizontal scale consisting of a white line with vertical end caps. A red vertical tick mark is positioned on the line, approximately one-third of the way from the left end.

Figure 3.JPEG

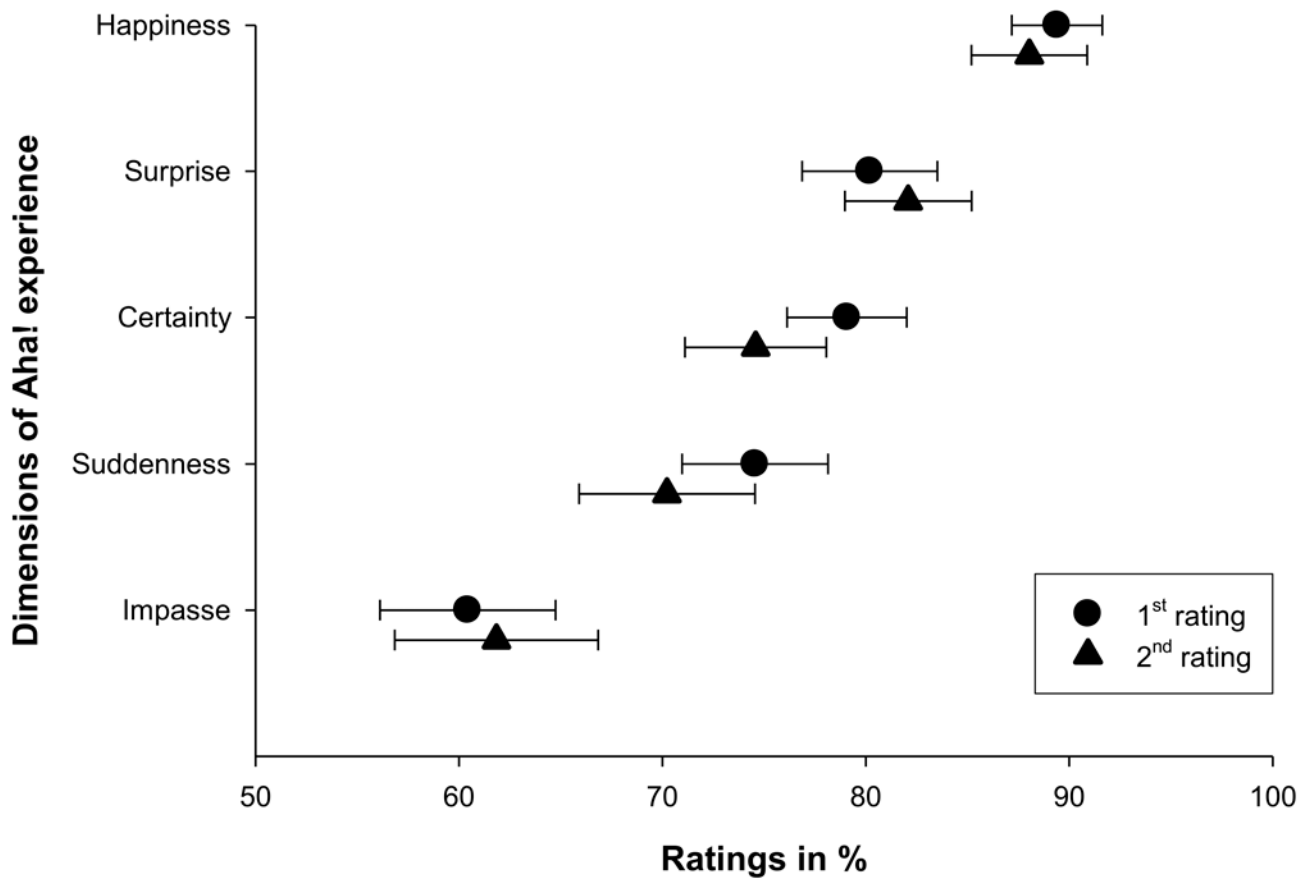


Figure 4.JPEG



Figure 5.JPEG

