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Puzzles produce strangers: A puzzling result for revelation-effect theories

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ABSTRACT

The revelation effect is a change in response behavior induced by a preceding problem-solving task. Previous studies have shown a revelation effect for faces when the problem-solving task includes attractiveness ratings of the faces. Immediately after this problem-solving task participants judged faces as more familiar than without the problem-solving task. We replicated this result in Experiment 1. Based on the discrepancy-attribution hypothesis, we predicted that a problem-solving task that excludes attractiveness ratings would not elicit a revelation effect. However, we found a reversed revelation effect with a problem-solving task that required participants to solve a puzzle of each face (Experiments 2–3). In Experiments 2 and 3, participants judged faces as *less* familiar after the puzzle task. Our findings support the notion that the revelation effect may manifest as either an increase or a decrease of the experienced familiarity towards the recognition probe. However, our results contradict all current theories of the revelation effect. We discuss implications of our findings for revelation effect theories and provide a possible explanation.

Introduction

One of the most important functions of human memory is the ability to distinguish old from new. Yet, sometimes this ability produces flawed results, as can be seen in the *revelation effect*. In recognition memory experiments, the revelation effect is the increased tendency to respond “old” when a problem-solving task directly precedes the recognition judgment (Watkins & Peynircioglu, 1990). The revelation effect owes its name to a particular problem-solving task, the identification of words that are revealed letter-by-letter (e.g., Bornstein & Neely, 2001; Landau, 2001; Prull, Light, Collet, & Kennison, 1998). However, many other tasks produce the revelation effect too, including solving anagrams (e.g., Bernstein, Godfrey, Davison, & Loftus, 2004; Cameron & Hockley, 2000; Frigo, Reas, & LeCompte, 1999; Major & Hockley, 2007; Mulligan, 2007; Thapar & Sniezek, 2008; Verde & Rotello, 2003; Watkins & Peynircioglu, 1990), mentally rotating the stimulus as a whole or only parts of it (e.g., Watkins & Peynircioglu, 1990), solving arithmetic problems (Niewiadomski & Hockley, 2001), typing a word in reverse order (Luo, 1993), generating synonyms, counting letters, and memory-span tasks (Westerman & Greene, 1998). Despite the revelation effect’s generality, its cause remains unknown.

Among the theories advanced to explain the revelation effect is the *discrepancy-attribution hypothesis* (Whittlesea & Williams, 2001). Whittlesea (1993) showed that participants judge fluently processed stimuli as more familiar (see also Jacoby & Dallas, 1981). There are, however, exceptions to this process. Whittlesea and Price (2001) found that participants fail to attribute processing fluency to prior experience when the stimuli constitute a semantically and perceptually homogeneous category (e.g., a set of pictures depicting various chairs). Additionally, Whittlesea, Jacoby, and Girard (1990) showed that changes in fluency are not necessarily associated with the source of the fluency change. Instead changes in processing fluency

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can be misattributed to supposed causes that are irrelevant to the fluency change but appear salient in the context of the judgment. Whittlesea, Jacoby, and Girard, for example, showed that the degree of masking applied to a stimulus affects judgments of familiarity in the context of a recognition experiment. Further, Whittlesea and Williams (1998) found that feelings of familiarity arise from unexpected fluency, rather than fluency per se. According to these authors a person constantly evaluates the amount of experienced fluency against a currently active standard. If the amount of fluency deviates from this standard, the person infers the source of the unexpected fluency from the context of the judgment. This inference can be erroneous, resulting in misattribution: The person misattributes processing-fluency changes to a salient source that is not responsible for the fluency changes.

Whittlesea and colleagues have suggested that discrepancy attribution underlies the revelation effect: Participants compare the recognition probe against the relatively difficult problem-solving task and, consequently, process the recognition probe surprisingly fluently (Bernstein, Whittlesea, & Loftus, 2002; Whittlesea & Williams, 2001). In revelation studies, a possible source of fluency is prior exposure to the stimulus. The recognition judgment, and in most experiments, a study phase, increases the salience of this possible source of fluency. Indeed, Frigo et al. (1999) found that participants at least need to believe they experienced a study phase for the revelation effect to occur for recognition judgments. Therefore, according to the discrepancy-attribution hypothesis, participants in a revelation study experience surprising fluency for recognition probes following a problem-solving task; in turn, they attribute this surprising fluency to the highly salient study phase, judging the stimuli as ‘‘old.’’

In the present study, we test a prediction of the discrepancy-attribution hypothesis with regard to the revelation effect for faces (Bornstein & Wilson, 2004). Faces are perceptually homogeneous stimuli sharing the same features (e.g., mouth, nose, eyes, etc.) and these features are part of the same general configuration (i.e., the nose is located above the mouth, but below the eyes, etc.). Whittlesea and Price (2001) found no attribution of processing fluency to prior experience with stimuli when the stimuli were, for example, different types of chairs (i.e., homogeneous). In contrast, participants attributed processing fluency to prior experience with the stimulus when the authors used stimuli from different categories (e.g., a bird, a pair of scissors, a truck, etc.). Whittlesea and Price maintain that people engage in an analytic strategy when the stimulus material is homogeneous and that people try to recognize specific features and thereby discount changes in processing fluency.

However, Bornstein and Wilson (2004) found a revelation effect for faces as stimuli. In their experiments, participants studied pictures of faces and had to distinguish the previously studied faces from new faces. A problem-solving task preceded half the new and half the old faces. In the revelation condition (i.e., with problem-solving task) participants had to judge the attractiveness of faces that the authors presented in upside-down orientation. Afterwards, the faces appeared in upright orientation and participants provided a recognition judgment. In the intact condition (i.e., without problem-solving task) the stimuli appeared upright and participants provided a recognition judgment. This resulted in a typical revelation effect: Participants more often judged faces in the revelation condition as ‘‘old’’ compared to faces in the intact condition.

Following the concept of fluency attribution there should be no revelation effect for homogeneous stimuli like faces as in Bornstein and Wilson's (2004) study. Why then did Bornstein and Wilson find a revelation effect? These authors used a problem-solving task that includes attractiveness ratings for the faces. Attractiveness ratings largely rely on the symmetry (e.g., Cardenas & Harris, 2006) and averageness (e.g., Potter & Corneille, 2008; Valentine, Darling, & Donnelly, 2004) of a face, thus likely promoting non-analytic- rather than analytic-processing strategies. These non-analytic strategies probably still persist when the face appears upright and participants make a recognition judgment. In light of the non-analytic strategy, the increased processing fluency from the appearance of the face in upright position is then attributed to prior experience with the stimulus. Therefore, if attractiveness ratings induce a non-analytic strategy, finding a revelation effect for faces would be compatible with the discrepancy-attribution hypothesis.

Based on this reasoning, we tested whether the revelation effect found in Bornstein and Wilson's (2004) study was due to the attractiveness ratings in the problem-solving task rather than the presentation of inverted faces. This hypothesis is consistent with the discrepancy-attribution hypothesis but contradicts other revelation effect theories (Hicks & Marsh, 1998; Niewiadomski & Hockley, 2001; Westerman & Greene, 1998) that predict a revelation effect due to the presentation of inverted faces. A similar manipulation for inverted verbal material produces a revelation effect (Frigo et al., 1999; Watkins & Peynircioglu, 1990).

To summarize, we tested whether a revelation effect would occur when a revelation task without attractiveness ratings is employed. Anticipating our findings, we replicated Bornstein and Wilson's (2004) revelation effect for face recognition when attractiveness ratings were part of the problem-solving task (Experiment 1). However, contrary to our expectations and all extant theories, we found a reversed revelation effect (Experiments 2 and 3) when we used another problem-solving task without attractiveness ratings.

General method

Stimulus material

We used pictures of faces as stimulus material. The stimuli were taken from the database of Minear and Park (2004) and consisted of 95 pictures of faces in frontal view. The persons depicted in the pictures were between 18 and 29 years of age, showed neutral facial expressions, and were of different genders and ethnicities. We added a grey frame to each picture (see Fig. 1, right side). The frame covered the hair and ears of the people depicted in order to reduce the distinctiveness of the stimuli. Otherwise distinctiveness could increase conscious recollection of

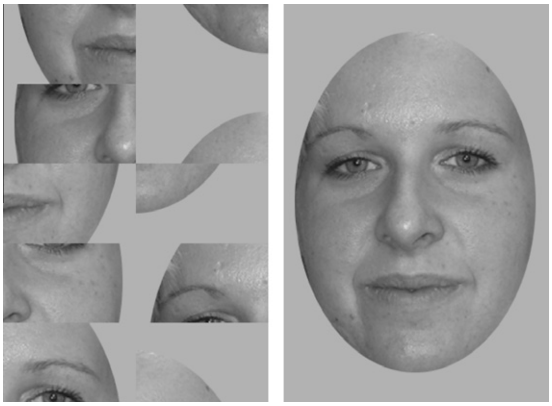

Fig. 1. Example of a stimulus in the puzzle task used in Experiment 2 before (left) and after (right) the puzzle. A similar task was used in Experiment 3 with faces initially shown upside-down and appearing upright after the puzzle.

stimuli which, in turn, would decrease a possible revelation effect (see LeCompte, 1995).

Design

Our experiments followed the basic structure of other revelation-effect experiments. In the study phase participants viewed a list of faces. In the following test phase, we re-presented the faces from the study phase, intermixed with new faces. Additionally, faces in the *intact* condition appeared without a problem-solving task, whereas a problem-solving task preceded faces in the *revelation* condition. Thus, all of our experiments used a 2 (*item status*: old vs. new) × 2 (*revelation condition*: revelation vs. intact) within-subjects design.

Procedure

A computer handled all stimulus presentations and data collection except for Experiment 1 in which participants saw stimuli via a projector and provided their responses on answer sheets. After providing informed consent, participants saw a study list containing 50 faces including five primacy and five recency buffers. Participants memorized each face for a later memory test. Each face appeared for 2 s with a 1 s inter-stimulus interval. In the following test phase participants saw 40 old and 40 new faces in sequential order. In the intact condition participants simply provided recognition judgments, whereas in the revelation condition participants first solved the problem-solving task and then judged recognition. The problem-solving tasks varied between experiments and are explained in detail below. We individually randomized the order of presentation for the stimuli in the study and test phases as well as the assignment of stimuli to the experimental conditions. After participants finished the experiment they received debriefing and course credit. With few exceptions noted below, all experiments followed this general procedure.

Analyses

For all experiments, we performed an analysis of variance for the proportion of "old" responses with regard to the revelation condition and item status. In experiments where we collected confidence ratings instead of old-new responses we dichotomized these ratings into old-new responses beforehand (see, e.g., Verde & Rotello, 2003).

Hicks and Marsh (1998) noted that the revelation effect can be described as a change in response bias. Consequently, we analyzed our data with *signal detection theory* (SDT; Macmillan & Creelman, 2008) to check if response bias shifted in our experiments. We computed measures of sensitivity and response bias for all our experiments. In Experiment 1 participants provided dichotomous old-new responses, as in Bornstein and Wilson's (2004) study. As a measure of sensitivity we computed $d' = z(H) - z(F)$, where H is the hit rate, F the false alarm rate, and z is the inverse of the normal distribution function. Thus, sensitivity is a measure of a person's ability to discriminate old from new stimuli. Furthermore, we computed each participant's response bias with $c = -.5[z(H) + z(F)]$ (cf. Macmillan & Creelman, 2008). Response bias reflects the degree of favoring one response option over the other (e.g., "old" over "new").

Verde and Rotello (2003) noted that the distributions of targets and lures in SDT might not have equal variances. As a consequence the sensitivity and response bias measures calculated from dichotomous responses would be inaccurate. To account for this we collected rating data with 6-point scales in Experiments 2 and 3. Following the procedure of Verde and Rotello, we used maximum likelihood estimation to determine the slope s of each participant's *receiver operating characteristic* in z-space. Afterwards, we computed as a measure of sensitivity $d_a = [2/(1+s)^2]^{.5}[z(H) - sz(F)]$ and as a measure of response bias $c_a = (-2^{.5}s/[(1+s^2)^{.5}(1+s)])[z(H)+z(F)]$ (cf. Macmillan & Creelman, 2008). Both d_a and c_a do not require equal variances of the target and lure distributions. We generally expected slope parameters s to be smaller than 1 in both the revelation and intact condition, in line with Verde and Rotello's findings. A slope parameter smaller than 1 indicates a larger variance of the target compared to the lure distribution.

Experiment 1

Before testing whether the revelation effect for faces occurs for a problem solving task that excludes attractiveness ratings, we replicated Bornstein and Wilson's (2004) study with our own stimuli.

Method

Participants

Forty-two Kwantlen Polytechnic University undergraduate students participated for course credit.

Procedure

The procedure of Experiment 1 followed the general method with some exceptions in order to provide a close replication of Bornstein and Wilson's (2004) study. In Experiment 1, two lists of 40 faces each served as study and test lists for half of the participants and vice versa for the other half. Furthermore, five faces each served as primacy buffers, recency buffers, and distracters for practice trials. A projector displayed all instructions and stimulus materials. Participants provided their responses on an answer sheet.

In addition, participants completed 10 practice trials. The practice trials included five buffer faces from the study phase and five distractor faces with intact and revelation trials occurring equally often. In the test phase, faces in the intact condition appeared for 2 s. Participants marked one of two boxes on their answer sheet indicating whether they believed the face was old or new. The faces in the revelation condition initially appeared upside-down for 2 s. Participants rated the attractiveness of each face on a 10-point scale (ranging from 1 = "unattractive" to 10 = "attractive") while the face was upside down. After 2 s, the face automatically appeared upright for another 2 s. Immediately after the face appeared upright, participants provided their recognition response in the same way as in the intact condition.

Following Bornstein and Wilson's (2004) study, we randomized the order of items and experimental conditions in the test phase with the exception that the first and the second half of the test trials contained an equal number of old and new, as well as intact and revealed items, respectively. We also counterbalanced whether an item appeared in the intact or revelation condition across participants. Thus, Experiment 1 resembled Bornstein and Wilson's study with the exception of stimuli only.

Results and discussion

The mean proportions of "old" responses as a function of revelation condition and item status for all our experiments appear in Table 1. As expected, participants judged old faces more frequently as "old" compared to new faces, $F(1,41) = 111.54$, $p < .001$, $\eta^2 = .41$. However more relevant for our purposes, participants showed a revelation effect for faces by responding "old" more often in the revelation condition than in the intact condition, $F(1,41) = 7.89$, $p = .007$, $\eta^2 = .01$. The interaction of revelation condition and item status was not significant $F(1,41) = 2.04$, $p = .16$, $\eta^2 = .003$. Thus, Experiment 1 replicates Bornstein and Wilson's (2004) results: After judging an upside-down face on attractiveness and then immediately seeing it upright, people are more likely to claim that they studied the face before.

The SDT measures of our experiments appear in Table 2. In terms of SDT measures, the revelation effect usually manifests as a more lenient response criterion resulting in more "old" responses in the revelation condition compared to the intact condition. Additionally, revelation is often accompanied by a decrease of the sensitivity parameter when the item in the problem-solving task is identical to the recognition probe (cf. Hicks & Marsh, 1998), as was the case here. However, in Experiment 1, there were no statistically significant effects of revelation on sensitivity, $t(41) = 0.83$, $p = .40$, $d = 0.13$ or response criterion $t(41) = 1.40$, $p = .16$, $d = 0.22$.

Table 1
Proportions of "old" responses as a function of revelation condition and item status.

	Old		New		
	M	*SEM*	*M*	*SEM*	*M*
Experiment 1 (rotation and attractiveness)					
Intact	.56	.023	.27	.026	.42
Revelation	.58	.024	.34	.026	.46
Difference	−.02		−.07		−.04*
Experiment 2 (puzzle)					
Intact	.71	.021	.36	.024	.53
Revelation	.60	.022	.31	.024	.46
Difference	.11		.05		.07*
Experiment 3 (rotation and puzzle)					
Intact	.69	.023	.40	.035	.54
Revelation	.63	.033	.32	.038	.47
Difference	.06		.08		.07*

Note. Difference = intact–revelation; the type of problem-solving task is described in parentheses.
* $p < .05$.

Table 2
Mean SDT measures as a function of the revelation condition.

	d'		c
Experiment 1 (rotation and attractiveness)			
Intact	1.08		0.37
Revelation	0.91		0.23
Difference	0.17		0.14
	d_a	c_a	Slope
Experiment 2 (puzzle)			
Intact	0.98	−0.08	0.79
Revelation	0.75	0.12	0.92
Difference	0.23*	−0.20*	−0.13
Experiment 3 (rotation and puzzle)			
Intact	0.77	−0.11	0.87
Revelation	0.74	0.05	0.66
Difference	0.03	−0.16*	0.21

Note. Difference = intact–revelation; the type of problem-solving task is described in parentheses.
* $p < .05$.

Experiment 2

In Experiment 2, we used a problem-solving task that does not require attractiveness ratings as in Experiment 1 and closely resembles anagrams often used for verbal stimuli in the revelation effect literature (e.g., Bernstein, Rudd, Erdfelder, Godfrey, & Loftus, 2009). Similar to an anagram, we implemented a puzzle task in Experiment 2. The puzzle task at first shows the stimulus in scrambled form (see left side of Fig. 1). Only by active manipulation of the fragments the intact stimulus emerges. According to the discrepancy-attribution hypothesis and Whittlesea and Price (2001), the homogeneous stimulus material should induce an analytic strategy during the recognition judgment. Consequently, the participants should not attribute changes in processing fluency to familiarity towards the stimulus. As a result we do not expect a revelation effect in Experiment 2 based on the discrepancy-attribution hypothesis.

Method

Participants

Thirty-eight University of Mannheim undergraduate students participated for course credit.

Procedure

The experimental procedure followed the general method. Additionally, in the revelation condition the participants had to solve a puzzle. For this purpose, we divided the faces into 10 equally-sized pieces (see left side of Fig. 1). The participants' task was to move the individual pieces into their correct positions using the computer mouse. The solution of this task was aided by the elliptic frame placed around each face (Fig. 1) which provided additional cues about where to place each piece of the puzzle. None of the participants seemed to have any difficulties with this task or complained about its difficulty. Once the participants placed all pieces correctly and saw the face intact (see right side of Fig. 1), they provided a recognition confidence rating on a 6-point scale (ranging from 1 = "sure new" to 6 = "sure old") in order to allow more advanced SDT analysis.

Results and discussion

As in the previous experiments, participants judged old faces "old" more often than new faces, $F(1,37) = 198.55$, $p < .001$, $\eta^2 = .55$. More importantly, there was a significant effect of revelation on the proportion of "old" judgments, $F(1,37) = 18.51$, $p < .001$, $\eta^2 = .03$. In contrast to Experiment 1, however, participants judged faces in the revelation condition as "new" more often than intact faces. Thus, in Experiment 2, we found a reversed revelation effect. Moreover, the interaction of revelation and item status was significant, $F(1,37) = 4.95$, $p = .03$, $\eta^2 = .005$, due to a significant effect of revelation for old faces, $t(37) = 4.76$, $p < .001$, $d = 0.77$, and a smaller, marginally significant, effect for new faces, $t(37) = 1.96$, $p = .06$, $d = 0.32$.

With regard to SDT analysis (see Table 2) sensitivity was lower in the revelation compared to the intact condition, $t(37) = 2.92$, $p = .006$, $d = 0.47$. Further, response bias was more conservative in the revelation condition than in the intact condition, $t(37) = 4.25$, $p < .001$, $d = 0.69$. Although it is common to find decreased sensitivity in the revelation condition compared to the intact condition (cf. Hicks & Marsh, 1998), the more conservative response tendency corresponds to the unexpected reversed revelation effect. Additionally, the slope parameters were below 1 (see Table 2). Thus, the variance of the target distribution was larger than the variance of the lure distribution. Furthermore, the slope did not differ significantly between revelation conditions, $t(37) = 1.12$, $p = .27$, $d = 0.18$.

In contrast to Experiment 1 and the study of Bornstein and Wilson (2004) we did not find a revelation effect in Experiment 2. Instead we found a reversed revelation effect (increase in "new" responses). This unexpected finding contradicts the discrepancy-attribution hypothesis. Additionally, the reversed revelation effect was more pronounced for old faces. This interaction pattern is rather uncommon (but see Bernstein et al., 2004). Therefore, in Experiment 3, we tested whether the reversed revelation effect and the interaction could be replicated.

Experiment 3

In Experiment 3, we replicated Experiment 2 but changed the problem-solving task slightly. This task included showing the faces upside down during the puzzle task, thus including elements from the problem-solving tasks of both Experiments 1 and 2.

Method

Participants

Twenty-two University of Mannheim undergraduate students participated for course credit.

Procedure

The experimental procedure followed the general method. Additionally, the problem-solving task was similar to the task in Experiment 2 except that the face appeared upside down as in Experiment 1. Participants solved the puzzle while the faces appeared upside down. Once participants assembled all pieces of the puzzle in their correct positions, the face appeared upright and participants provided their recognition confidence judgments.

Results and discussion

As in all our experiments so far, there were more "old" responses for old than for new faces, $F(1,21) = 73.14$, $p < .001$, $\eta^2 = .48$. Furthermore, replicating Experiment 2, the puzzle task caused an increase in "new" responses, $F(1,21) = 8.55$, $p = .008$, $\eta^2 = .03$, representing again a reversed revelation effect. Therefore, Experiment 3 establishes that this unexpected reversed revelation effect is robust. The interaction that we observed in Experiment 2 was not significant here ($F < 1$) and, thus, likely represents chance variation.

With regard to SDT analysis (see Table 2) there was no effect of revelation on the sensitivity parameter, $t(21) = 0.28$, $p = .78$, $d = 0.06$. Thus, we only found a decrease in sensitivity in Experiment 2. This is surprising because a similar experimental procedure with words as stimuli usually causes a decrease in sensitivity (Hicks & Marsh, 1998; Verde & Rotello, 2004). As in Experiment 2, the response criterion in the revelation condition was more conservative than in the intact condition, $t(21) = 2.77$, $p = .01$, $d = 0.60$. Slope parameters were again below 1, revealing larger variance of the target distribution compared to the lure distribution. Moreover, slope parameters did not differ between revelation conditions, $t(21) = 1.89$, $p = .07$, $d = 0.40$.

In sum, when participants must unscramble an upright (Experiment 2) or inverted (Experiment 3) face prior to recognizing that face when shown upright, they are more likely to claim the face is "new". Thus, a problem-solving task that includes unscrambling faces reverses the revelation effect.

General discussion

In the present article, we tested a prediction of the discrepancy-attribution hypothesis with regard to the revelation effect for faces. We predicted a revelation effect only when the problem-solving task induces a non-analytic strategy (e.g., with attractiveness ratings), but not when the problem-solving task induces an analytic strategy (i.e., scrambled or upside down faces without attractiveness ratings). First, we replicated Bornstein and Wilson's (2004) revelation effect for faces when the problem-solving task included attractiveness ratings (Experiment 1). Surprisingly, however, we found a reversed revelation effect in Experiments 2 and 3 with a problem-solving task that excluded attractiveness ratings. These results contradict all extant revelation effect theories.

Reversals of the revelation effect as in Experiments 2 and 3 have also been found in two-alternative-forced-choice tasks (2-AFC, Hicks & Marsh, 1998; Major & Hockley, 2007). Although Hockley and Niewiadomski (2001) found a reversal for pronounceable non-words in an old-new-recognition task, they could not replicate this finding and discarded it as chance variation. Together with Hockley and Niewiadomski's experiment, Experiments 2 and 3 are the only studies we know of that demonstrate a reversed revelation effect for response formats other than 2-AFC.

No revelation-effect theory predicts the reversed revelation we found in Experiments 2 and 3. According to the *criterion-flux theory* (Niewiadomski & Hockley, 2001) the problem-solving task displaces important task information in working memory and one adopts a more lenient default criterion (i.e., is more likely to respond "old"). Our results, however, suggest that the problem-solving task induced a more conservative criterion. The notion of a generally lenient default criterion is insufficient to explain our results. Similarly, the *familiarity-decrement theory* (Hicks & Marsh, 1998) postulates a revelation-based activation of conflicting stimuli in memory. As a result, task difficulty increases and one uses a more lenient response criterion. However, the reversed revelation effect cannot be explained without assuming that the face puzzle task actually decreased difficulty—an implausible assumption, because our puzzle task likely activated face fragments in memory just like an anagram task activates word fragments. For the latter, however, researchers typically observe a revelation effect (e.g., Frigo et al., 1999). In a similar vein, the *global-matching theory* (Westerman & Greene, 1998) assumes a revelation-induced activation of memory traces. This activation still persists at the time of the recognition judgment and contributes to a feeling of familiarity. If this is true, then it is unclear why participants in Experiments 2 and 3 judged stimuli to be "new" more often after revelation. Obviously, the problem-solving task would have to reduce activation of memory traces. We do not see how this can be assumed with regard to the problem-solving tasks used in Experiments 2 and 3. Finally, we did not predict the reversed revelation effect based on the discrepancy-attribution hypothesis either. The findings of Whittlesea and Price (2001) suggested that in Experiments 2 and 3 participants would engage in an analytic strategy because of the homogeneous stimulus material. As a result, fluency changes would not affect recognition judgments. This prediction is incompatible with the reversed revelation effect we found in these experiments. However, the 2-AFC task Whittlesea and Price used is insensitive to response tendencies. If Whittlesea and Price had used an old-new recognition task, they might have observed a response tendency towards "new" responses analogous to Experiments 2 and 3.

Moreover, it is unlikely that a specific property of the stimuli in Experiments 2 and 3 caused the reversed revelation effect alone. Bornstein and Wilson (2004) found a revelation effect with pictures of faces, which we replicated in Experiment 1. However, based on our results we cannot exclude the possibility that a property of faces (e.g., perceptual and conceptual homogeneity) contributes to the reversed revelation effect in combination with other factors. A shared property of the problem-solving tasks in Experiments 2 and 3 is that they both disrupt the holistic processing of faces. In both tasks, faces initially appear scrambled, preventing the perception of faces as a Gestalt (Maurer, Le Grand, & Mondloch, 2002). Under such conditions recognition performance has been found to decrease (e.g., Tanaka & Farah, 1993). In contrast, the revelation effect manifests as a change in response tendency, sometimes accompanied by a decrease in sensitivity. Therefore, the surprising reversed revelation effect we found in Experiments 2 and 3 cannot be explained in terms of holistic processing alone.

A possible explanation of the reversed revelation effect may be derived from the findings of Oppenheimer (2004). According to Oppenheimer and many others, participants are sometimes aware that changes in fluency might bias their judgment (see Jacoby & Whitehouse, 1989). However, in an attempt to discount the biasing influence of the fluency change participants tend to over-discount, effectively producing a bias in the opposite direction of the fluency change. In principle, over-discounting could explain the reversed revelation effect in combination with discrepancy-attribution hypothesis. However, this raises the question why Experiments 2 and 3 caused over-discounting and the vast majority of revelation effect studies did not. A possible explanation for the reversed revelation effect is that the problem-solving tasks in Experiments 2 and 3 made the fluency changes more salient than most other tasks causing participants to over-discount.

There are at least three reasons why the fluency change in Experiments 2 and 3 might have been more salient compared to other tasks (e.g., anagrams). First, unlike mentally solving an anagram, the puzzle task forces participants to visualize the manipulation of the stimulus, making the manipulation more salient. Second, in the puzzle task, intermediate solutions do not need to be memorized but are present on the screen at all times, likely requiring fewer cognitive resources than mentally solving an anagram. This would probably also relieve meta-cognitive monitoring processes and increase the likelihood of noticing the change in processing fluency. Third, the change in processing fluency for an anagram is sudden, as in an "aha" moment (cf. Dougal & Schooler, 2007), whereas the completion of the face puzzle occurs in several steps. This basically increases the number of opportunities to become aware of the fluency change caused by the task. This, admittedly post hoc, hypothesis would explain why there is a reversed revelation effect for the puzzle task (Experiments 2 and 3) but not for other tasks. In conclusion, over-discounting together with discrepancy-attribution hypothesis provides a framework to explain our results.

In sum, our results challenge all existing revelation-effect theories. None of the theories predicted a reversal of the revelation effect. There are also implications for applied research. For example, other work shows that the particular task that one solves before making a recognition judgment can both increase and decrease recognition in an eyewitness identification paradigm (Macrae & Lewis, 2002; Perfect, Weston, Dennis, & Snell, 2008). Future research should address the factors that determine whether a revelation effect or its reversal follows a problem-solving task and what processes underlie these phenomena.

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