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Perceptual fluency contributes to effects of stimulus size on judgments of learning

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ABSTRACT

Studies have demonstrated that perceptual fluency—the ease of perceiving stimuli—does not contribute to higher predictions of future memory performance (judgments of learning; JOLs) for words presented in a larger font (48 pt) than for words presented in a smaller font (18 pt). Here, we investigated whether stimulus size can affect JOLs through another mode of perceptual fluency. We presented stimuli that were initially so small as to be entirely unrecognizable but that gradually increased in size. Stimuli were pictures of common objects (Experiment 1), faces (Experiment 2), and words (Experiments 3 and 4). People indicated when they could identify the stimulus and then made a JOL. The time required for participants to identify each stimulus was our measure of perceptual fluency. In Experiments 1 to 3, we manipulated the speed of the clarification process across trials. Results showed that the less time it took to identify the clarifying stimuli, independent of clarification speed, the higher one's JOLs. Moreover, fast clarification increased JOLs indirectly by decreasing identification time. In Experiment 4, one group of participants (learner group) could base JOLs on both perceptual fluency and beliefs about how stimulus size affects memory performance, while the other group (observer group) could base JOLs only on beliefs. Inverse relations between identification time and JOLs occurred only in the learner group. These results demonstrate that perceptual fluency may produce size effects on JOLs and support the idea that fluency is an important factor in JOLs.

Introduction

Imagine that a student is seated in the back of a large lecture hall. Most probably, lecture slides are small and hard to read from her perspective. Are viewing conditions related to how the student thinks she will perform on a test of this information? Psychological research has shown that perceptual fluency—the ease of perceiving stimuli—influences many human judgments, including judgments of truth, liking, confidence, and familiarity (e.g., Alter & Oppenheimer, 2009; Kelley & Rhodes, 2002; Reber, Winkielman, & Schwarz, 1998; Whittlesea, Jacoby, & Girard, 1990). It has been proposed that perceptual fluency also affects judgments of learning (JOLs)—the likelihood of remembering recently studied information (e.g., Besken & Mulligan, 2013, 2014; Busey, Tunnicliff, Loftus, & Loftus, 2000; Rhodes & Castel, 2008; Susser, Mulligan, & Besken, 2013; Yue, Castel, & Bjork, 2013).

Studies by Besken and Mulligan (2014) and Susser et al. (2013, Experiment 2) support the idea that perceptual fluency influences JOLs. In their studies, JOLs were higher for words heard in an intact form than for words heard in a fragmented form. In contrast, actual memory

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performance was better for fragmented words than for intact words. A similar dissociation occurred with a perceptual-interference manipulation: JOLs were higher but memory performance was worse for words presented intact than for words presented very briefly and immediately followed by a backward mask (Besken & Mulligan, 2013). However, Mueller, Dunlosky, Tauber, and Rhodes (2014) found that an effect widely cited as evidence for perceptual fluency effects on JOLs, that is, the font-size effect, does not rely on perceptual fluency (e.g., Bjork, Dunlosky, & Kornell, 2013; Diemand-Yauman, Oppenheimer, & Vaughan, 2011; Miele, Finn, & Molden, 2011; Undorf & Erdfelder, 2011).

The font-size effect was first demonstrated by Rhodes and Castel (2008), who found higher JOLs for words presented in a larger Arial font (48 pt) than for words presented in a smaller Arial font (18 pt), even though font size did not influence memory performance. This effect was robust across several experimental manipulations and has been replicated repeatedly (Hu, Liu, Li, & Luo, 2016; Kornell, Rhodes, Castel, & Tauber, 2011; McDonough & Gallo, 2012; Miele et al., 2011; Susser et al., 2013). A recent study by Mueller et al. (2014) demonstrated that the font-size effect relied on people's beliefs about how font size influences memory performance rather than on perceptual fluency. Specifically, Mueller et al. found (1) that measures of fluency (i.e., response times in a lexical decision task and self-paced study time) did not differ between 48-pt and 18-pt Arial words, (2) that most people had the belief that larger words are easier to remember than smaller words, and (3) that font-size effects were roughly equal with immediate JOLs and with pre-study JOLs that could not rely on perceptual fluency. Pre-study JOLs were prompted prior to presenting each item with the query "You are about to study a small [large] word, please rate how likely you are to remember it."

We suspect that perceptual fluency did not affect JOLs in previous studies on the font-size effect, because smaller words were about as easy to read as larger words (see also Besken & Mulligan, 2013, 2014). This idea is supported by research showing that people with normal vision can achieve maximum reading speed in print sizes from approximately 0.2–2.0° of visual angle (Legge & Bigelow, 2011). In this so-called *fluent range of print size*, reading speed is fairly constant. Importantly, both 48-pt and 18-pt Arial words lie in the fluent range of print size as long as viewing distances range between approximately 25 and 95 cm.

In sum, contrary to previous conclusions, Mueller et al. (2014) revealed that a font-size manipulation did not influence JOLs through perceptual fluency. Thus there is no evidence that perceptual fluency underlies stimulus size effects on JOLs. From this finding, one might conclude that perceptual fluency's influence on JOLs is the exception rather than the rule. Such an approach would accord with the idea that JOLs mainly rely on metacognitive beliefs (e.g., Mueller, Tauber, & Dunlosky, 2013; Mueller et al., 2014). Alternatively, one might conclude that perceptual fluency's effects on JOLs are pervasive, and the classic font-size effect did not rely on perceptual fluency, because 18-pt words were about as easy to read as 48-pt words. This idea is consistent with a dual-basis view that assumes JOLs to rely on both deliberate applications of metacognitive beliefs and nonanalytic, implicit inferences drawing on fluency (e.g., Koriat, 1997; Koriat, Bjork, Sheffer, & Bar, 2004; Koriat & Ma'ayan, 2005).

To test between these alternatives, one needs a size manipulation that has a large effect on perceptual fluency. Therefore, we used a visual identification procedure (see Bernstein, Loftus, & Meltzoff, 2005; Loftus & Harley, 2005). We presented people with stimuli that gradually increased in size. All stimuli were initially so small as to be entirely unrecognizable but clarified over time. Participants were asked to stop the clarification process as soon as they could identify the stimulus. We manipulated perceptual fluency by varying the speed with which stimuli clarified. In slow trials, stimulus clarification consisted of presenting all 30 images in increasing order of size. In fast trials, stimulus clarification occurred by presenting only every second image, so that maximum size was reached after 15 images. Each image was displayed on screen for an equal time in fast and slow trials.

Using this procedure, we operationally defined perceptual fluency as the time required for people to identify the stimuli: The longer the identification time, the lower the perceptual fluency. It is plausible that stimuli vary in perceptual fluency, because they are entirely unrecognizable in the beginning of the clarification procedure and are clearly visible towards the end. At the same time, the perceptual fluency manipulation is unobtrusive, because the clarification process is perceptually similar in fast and slow trials. There are several reasons for this. First, fast and slow trials began with images of equal size and ended with images of nearly equal size. Second, individual images were onscreen for an equal time in fast and slow trials. Finally, the stimuli's perceptual features introduce variability in identification times within fast and slow trials.

The advantage of this design is that it allows us to evaluate whether perceptual fluency contributes to stimulus size effects on JOLs. Specifically, two predictions follow from the hypothesis that perceptual fluency underlies stimulus size effects on JOLs. First, JOLs should be inversely related to identification time, independent of clarification speed: There should be a negative correlation between identification time and JOLs in both fast and slow trials. Notably, we predict higher JOLs for smaller stimuli than for larger stimuli. The reason for this is that stimulus size gradually increased in our paradigm, meaning that large stimulus size indicates low fluency and hard to remember. Second, identification time should mediate the effect of the experimental manipulation of clarification speed on JOLs: Fast clarification should increase JOLs indirectly through reducing identification time. In contrast, if metacognitive beliefs exclusively underlie stimulus size effects on JOLs, identification time should not mediate the effect of the clarification speed manipulation on JOLs.

Experiment 1

Participants in Experiment 1 identified common objects that clarified either quickly or slowly. Following the identification of each object, participants made a JOL regarding the probability that they would recognize the object on a later test.

Method

Participants and materials

Participants were 29 University of Mannheim undergraduates. Stimuli were 124 line drawings of common objects (e.g., alligator, candle) from the Snodgrass picture set (Snodgrass & Vanderwart, 1980) with a mean name agreement score of .95 ($SD = .09$; Bates et al., 2003). After removing borders, images were scaled to fit within a 306×306 pixel square on a screen with a 1280×1024 resolution. For each object, we created 30 images of different sizes (see Fig. 1 and Appendix A). The smallest images of each object were not identifiable and all participants could easily identify the largest images. After resizing, white space was added to each image to fill a 306×306 pixel square.

Procedure

The experiment consisted of three phases: an object identification task in which participants also made JOLs, a filler task, and a recognition test. Prior to the object identification phase, instructions informed participants that they would identify several objects and would later be asked to recognize them among new objects. Participants were also told that objects were so small as to be entirely unrecognizable in the beginning, but would become gradually clearer.

For each participant, 64 objects were randomly selected for presentation in the object identification phase. Each object began small and progressively clarified. Objects clarified slowly in 32 trials and clarified quickly in the remaining 32 trials. In slow trials, object clarification occurred by presenting all 30 images beginning with the smallest image. In fast trials, only odd-numbered images appeared beginning with the smallest image (i.e., Image 1, 3, ..., 29). Thus, maximum clarity occurred after only 15 images in fast trials. In both fast and slow trials, each image appeared for 1000 ms, immediately followed by the next image (0 ms inter-stimulus interval). Assignment of objects to fast and slow trials and presentation order were randomly determined for each subject. The first four trials (two fast and two slow trials) served as buffers and were discarded from all analyses. Participants were instructed to press the enter key as soon as they could identify the object, and could press the enter key only once. The clarification process stopped when the enter key was pressed. To ensure that participants attended to each object, they were then asked to type the object's name. After a 200-ms blank screen, the JOL prompt "The chance to recognize (0–100%)? ____" appeared on screen and participants estimated the probability of recognizing the object in a final recognition test by typing any whole number from 0 to 100. A 400-ms blank screen preceded the next trial.

Following the object identification phase, participants performed an unrelated filler task for 5 min, which consisted of solving easy but time-consuming mathematical problems. Finally, the largest images of 120 objects, 60 of which had and 60 of which had not been presented in the object identification phase, appeared sequentially on the computer screen in a random order. Participants made a recognition judgment for each object by clicking on buttons labeled "old" or "new" that appeared on screen just below the image.

Results

Table 1 presents means and standard deviations of naming accuracy, identification time[1], image number, JOLs, corrected hit rates P_r (hits minus false alarms; Snodgrass & Corwin, 1988), and bias index B_r (false alarms/[1−(hits − false alarms)]; Snodgrass & Corwin, 1988). It also shows means and standard deviations of within-subjects Goodman–Kruskal gamma correlations between identification time and JOLs.

Naming accuracy did not differ by clarification speed, $t < 1$.[2] As predicted, objects that clarified quickly were identified faster than objects that clarified slowly, $t(28) = 21.06$, $p < .001$, $d = 3.98$. Image number was higher for objects that clarified quickly than for objects that clarified slowly, $t(28) = 9.83$, $p < .001$, $d = 1.86$. Thus, objects that clarified quickly were identified at a larger stage than objects that clarified slowly. JOLs were reliably higher for objects that clarified quickly than for objects that clarified slowly, $t(28) = 2.62$, $p = .014$, $d = 0.49$. In contrast, corrected hit rates P_r did not differ between objects that clarified quickly and slowly, $t < 1$. The same was true for bias index B_r, $t(27)$[3] $= 1.44$, $p = .163$, $d = 0.28$. Gamma correlations between identification time and JOLs were significantly negative for objects that clarified quickly and for objects that clarified slowly. Thus, the less time it took to identify the clarifying objects, independent of clarification speed, the higher one's JOLs. Correlations were virtually identical when image number was used instead of identification time (see Appendix B).

Finally, we conducted mediational analyses to investigate whether the effect of clarification speed on JOLs was mediated by identification time. Therefore, we regressed (a) identification time on dummy-coded clarification speed and (b) JOLs on dummy-coded clarification speed and identification time in two separate multilevel regression models (level 1: items, level 2: participants; cf. Kenny, Korchmaros, & Bolger, 2003; Krull & MacKinnon, 2001). Participants were treated as random effects and clarification speed and identification time were treated as fixed effects in both models. Analyses were conducted using the *R* packages lme4 and lmerTest (Bates, Maechler, & Bolker, 2015; Kuznetsova, Brockhoff, & Christensen, 2015; R Core Team, 2015). Panel A of Fig. 2 shows that, when clarification speed predicted identification time, the unstandardized regression coefficient of clarification speed

[1] An inspection of identification times revealed that there were no very short latencies and that latencies were approximately normally distributed. We therefore report results from untransformed identification times.

[2] None of our results changed when we analyzed only trials on which participants correctly named the object. The same was true for the naming group in Experiment 2, for Experiment 3, and for the learner group in Experiment 4.

[3] B_r could not be calculated for one participant due to a false alarm rate of zero.

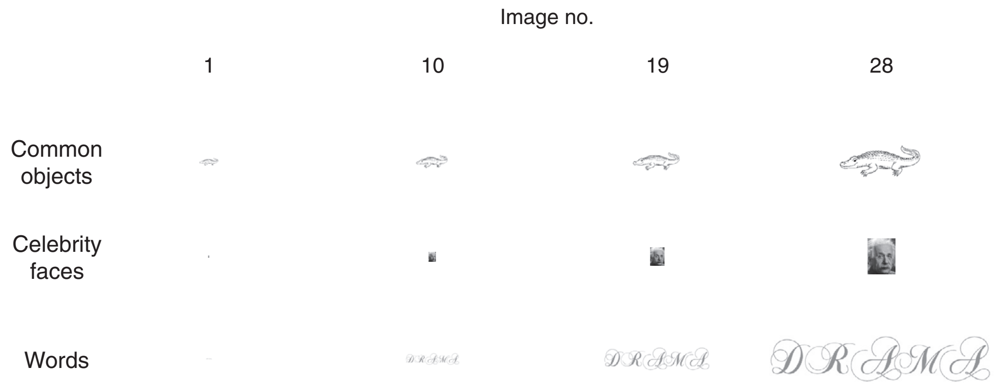

Fig. 1. Examples of the stimuli used in Experiment 1 (common objects), Experiment 2 (celebrity faces), and Experiments 3 and 4 (words). Image number refers to the image size (out of 30 possible image sizes).

Table 1
Descriptive statistics for Experiment 1.

	Clarification			
	Fast		Slow	
	M	*SD*	*M*	*SD*
Naming accuracy	92.76	3.99	92.87	5.02
Identification time (s)	9.41	1.58	15.95	3.00
Image number	18.72	3.15	16.43	2.98
JOL	63.70	13.52	61.45	14.03
P_r	.91	.06	.91	.05
B_r	.56	.36	.47	.30
G(IT, JOL)	−.20***	.28	−.19**	.30

Note. JOL = judgment of learning; P_r = corrected hit rate; B_r = bias index; *G* (IT, JOL) = within-subjects Goodman–Kruskal gamma correlation between identification time and JOLs.
** $p < .01$.
*** $p < .001$.

was −6.55. This means that on average fast clarification reduced identification time by 6.55 s. When clarification speed (Panel B) and identification time (Panel C) predicted JOLs, both regression coefficients were significantly negative. The regression coefficient for clarification speed was −3.54, which means that on average, when identification time was controlled, fast clarification reduced JOLs by 3.54%. The regression coefficient for identification time was −0.88, which means that on average, when clarification speed was controlled, each second of identification time reduced JOLs by 0.88%.

We then estimated the indirect effect of clarification speed on JOLs mediated by identification time using the *R* package mediation (Imai, Keele, & Tingley, 2010; see also Tingley, Yamamoto, Hirose, Keele, & Imai, 2014) with 5000 simulations. The indirect effect was substantial and significant (5.80, 95% CI [4.52, 7.07], $p < .001$), which means that fast clarification increased JOLs indirectly by decreasing identification time. Clarification speed thus had a significantly positive indirect effect on JOLs, whereas its direct effect was significantly negative, as described above. This suggests that indirect and direct effects of clarification speed on JOLs suppressed each other (see MacKinnon, Fairchild, & Fritz, 2007; MacKinnon, Krull, & Lockwood, 2000, for discussions of inconsistent mediation).

Discussion

In sum, objects that clarified quickly were identified faster than objects that clarified slowly. Differences in identification time subsequently influenced JOLs, resulting in higher JOLs for objects that clarified quickly. Conversely, the direct effect of clarification speed on JOLs was negative. Fast clarification thus increased JOLs only through reducing identification time. Finally, recognition performance was unaffected by clarification speed. This pattern of results demonstrates that perceptual fluency as measured by identification time can produce stimulus size effects on JOLs: Higher JOLs for objects that clarified quickly were due to perceptual fluency. Results thus support a dual-basis view of JOLs that assumes JOLs to be based on both metacognitive beliefs and fluency. It is possible, however, that naming objects reduced the impact of perceptual fluency on JOLs. We examined this possibility in Experiment 2.

First, though, an unexpected result from Experiment 1 deserves comment: Participants identified objects that clarified quickly at a slightly but significantly larger stage than objects that clarified slowly. At first glance, this result seems to indicate that higher JOLs for objects that clarified quickly may be due to a larger image size at identification rather than to fast identification. However, inverse relations between image number and JOLs rule out this possibility. Nevertheless, we replicated this result in Experiments 2 and 3, and return to this point in the 'General discussion'.

Experiment 2

In Experiment 1, all participants named stimuli before making JOLs. However, it has been argued that people base their JOLs, in part, on the fluency of naming items during study (Sungkhasettee, Friedman, & Castel, 2011; Susser et al., 2013; Tiede & Leboe, 2009; see also Koriat & Ma'ayan, 2005). In Experiment 2, we tested whether naming stimuli attenuated the effect of perceptual fluency on stimulus size effects on JOLs. To this end, one group of participants (naming group) typed the name of each stimulus before making JOLs, as in Experiment 1, while the other group (no-naming group) made JOLs immediately after stopping the clarification process. A second difference from

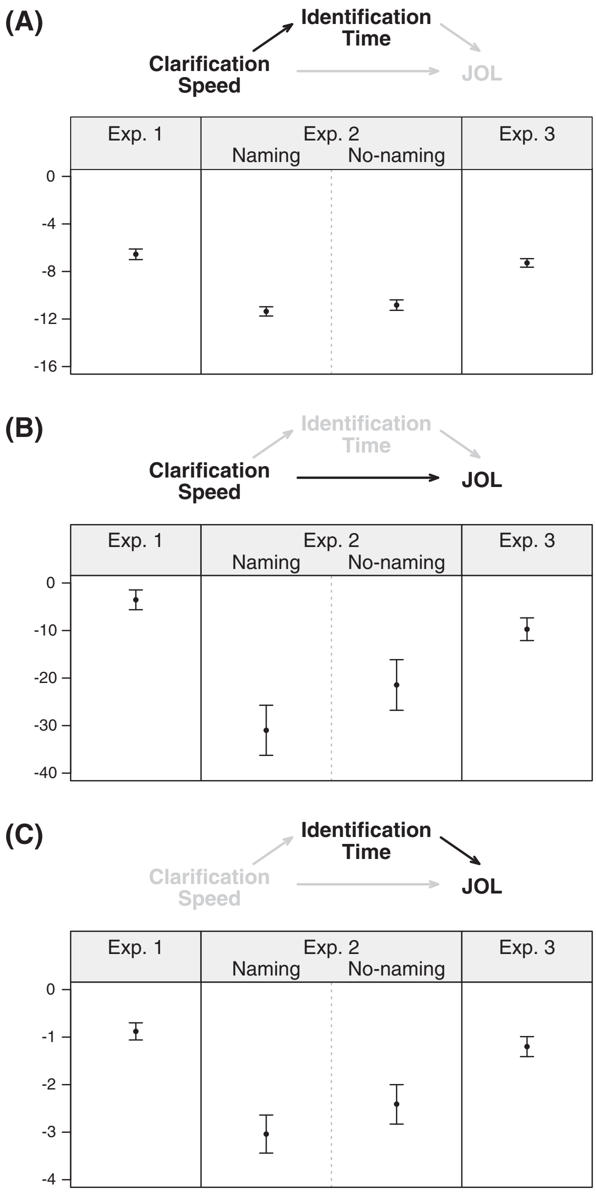

Fig. 2. Unstandardized regression coefficients for direct effects of dummy-coded clarification speed on identification time in seconds (Panel A) and judgment of learning (JOL, Panel B) and of identification time in seconds on JOL (Panel C), presented separately for each condition of Experiments 1–3. Error bars denote 95% confidence intervals. None of the confidence intervals included zero (all p values < .001).

Experiment 1 was that we used a more homogeneous set of pictures: celebrity faces (cf. Loftus & Harley, 2005). Compared with common objects, faces differ less with respect to shape so that identification always requires recognizing perceptual details. Finally, participants completed a free recall test to remove ceiling effects in memory performance.

Method

Participants and materials

Participants were 56 University of Mannheim undergraduates. We omitted data from one participant who did not stop the clarification process for any item. The remaining participants were randomly assigned to either the naming condition ($n = 30$) or to the no-naming condition ($n = 25$). Pictures of the faces of 44 well-known celebrities were obtained from the Internet. They included 9 females and 35 males who were, for instance, actors, musicians, politicians, and sports figures. Each celebrity was recognized by at least 80% of the participants in a pilot study ($n = 12$). All pictures were plain-background photographs that were rendered as gray scale images. As before, we created 30 images of different sizes for each celebrity (see Fig. 1 and Appendix A).

Procedure

The procedure was similar to that of Experiment 1 with the following exceptions. Participants were asked to identify 44 celebrities. Half the celebrity identification trials were fast and slow trials, respectively. In the celebrity identification phase, all participants were instructed to press the enter key as soon as they could identify the celebrity, which stopped the clarification process. Participants in the naming group were then asked to provide the celebrity's name or any other information that indicated them having identified the celebrity (for further details, see Loftus & Harley, 2005). In contrast, participants in the no-naming group were asked to make JOLs immediately after stopping the clarification process. Both groups of participants were asked to estimate the probability of later recalling the celebrity when making JOLs. JOLs were prompted with the query "The chance to recall (0–100%)? ____." Following the same filler task as in Experiment 1, participants were asked to write down as many of the celebrities from the first phase of the experiment as they could remember. They were given 5 min for this free-recall task.

Results

Table 2 presents means and standard deviations of naming accuracy for the naming group and of identification time, image number, JOLs, recall performance, and correlations between identification time and JOLs for the naming and no-naming groups.

In the naming group, naming accuracy did not differ by clarification speed, $t < 1$. Identification time was submitted to a mixed two-way ANOVA with naming group (naming, no-naming) as a between-subjects factor and clarification speed (fast, slow) as a within-subjects factor. A significant main effect of clarification speed revealed that faces that clarified quickly were identified faster than faces that clarified slowly, $F(1,53) = 1800.44$, $MSE = 1.86$, $p < .001$, $\eta_p^2 = .97$. Neither the main effect of naming group nor the interaction was significant, both $F < 1.04$. A 2 (naming group) × 2 (clarification speed) mixed ANOVA on image number revealed that faces that clarified quickly were identified at a larger stage than faces that clarified slowly, $F(1,53) = 6.48$, $MSE = 1.29$, $p = .014$, $\eta_p^2 = .11$. Neither the main effect of naming group nor the interaction was significant, both $F < 1.03$. A 2 (naming group) × 2 (clarification speed) mixed ANOVA on JOLs revealed higher JOLs for faces that clarified quickly than for faces that clarified slowly, $F(1,53) = 9.61$, $MSE = 48.05$, $p = .003$, $\eta_p^2 = .15$. Neither the

Table 2
Descriptive statistics for the naming and no-naming groups of Experiment 2.

	Naming				No-naming			
	Fast clarification		Slow clarification		Fast clarification		Slow clarification	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Naming accuracy	85.17	12.90	83.17	15.23	–	–	–	–
Identification time (s)	13.11	1.08	24.47	2.52	13.01	1.02	23.84	2.86
Image number	24.42	2.85	24.08	2.60	24.16	2.18	23.38	2.93
JOL	72.52	16.27	68.97	17.81	74.06	14.40	69.38	14.37
% correct	53.33	12.89	54.83	13.55	45.40	14.43	45.20	15.10
G(IT, JOL)	−.39***	.25	−.52***	.29	−.37***	.23	−.45***	.30

Note. JOL = judgment of learning; % correct = percentage of correctly recalled items; *G*(IT, JOL) = within-subjects Goodman–Kruskal gamma correlation between identification time and JOLs.
*** $p < .001$.

main effect of naming group nor the interaction was significant, both $F < 1$. Finally, a 2 (naming group) × 2 (clarification speed) mixed ANOVA on recall performance revealed that actual memory did not differ between faces that clarified quickly and slowly, $F < 1$. Recall performance was, however, significantly higher in the naming than in the no-naming group, $F(1,53) = 7.83$, $MSE = 268.78$, $p = .007$, $\eta_p^2 = .13$. The interaction was not significant, $F < 1$. Correlations between identification time and JOLs were negative for faces that clarified quickly and for faces that clarified slowly in both conditions. Thus, the less time it took to identify the clarifying faces, independent of clarification speed, the higher one's JOLs. Similar correlations appeared when image number was used instead of identification time (see Appendix B). To test whether naming affected correlations between identification time and JOLs, we conducted a 2 (naming group) × 2 (clarification speed) mixed ANOVA. It revealed lower correlations for faces that clarified quickly than for faces that clarified slowly, $F(1,53) = 9.54$, $MSE = 0.04$, $p = .003$, $\eta_p^2 = .15$. Neither the main effect of naming group nor the interaction was significant, both $F < 1$.

As can be seen in Fig. 2, the unstandardized regression coefficients for the direct effects of clarification speed on identification time (Panel A) and JOLs (Panel B) and for the direct effect of identification time on JOLs (Panel C) were all significantly negative. This means that fast clarification significantly reduced both identification time and JOLs and that reductions in identification time increased JOLs. This pattern of results occurred in both the naming and the no-naming group. Mediation analyses revealed a substantial and significant indirect effect of clarification speed on JOLs mediated through identification time both in the naming group (34.55, 95% CI [29.84, 39.27], $p < .001$) and in the no-naming group (26.17, 95% CI [21.56, 30.79], $p < .001$). Clarification speed thus had a significantly positive indirect effect on JOLs, whereas its direct effect was significantly negative. As in Experiment 1, indirect and direct effects of clarification speed on JOLs suppressed each other.

Discussion

In sum, Experiment 2 replicated Experiment 1 in showing that stimuli that clarified quickly were identified faster than stimuli that clarified slowly. As in Experiment 1, differences in identification time subsequently influenced JOLs, resulting in higher JOLs for stimuli that clarified quickly. Again, the direct effect of clarification speed on JOLs was negative. Fast clarification thus increased JOLs only through reducing identification time. As before, memory performance was equal for stimuli that clarified quickly and slowly. However, the overall level of memory performance was reduced in Experiment 2 relative to Experiment 1, because people were asked to recall rather than recognize studied stimuli. Better recall performance in the naming group than in the no-naming group revealed a production effect (e.g., Bodner & MacLeod, 2016; MacLeod, Gopie, Hourihan, Neary, & Ozubko, 2010). However, JOLs did not predict this effect (but see Castel, Rhodes, & Friedman, 2013).

Contrary to the idea that naming stimuli attenuates the influence of perceptual fluency on stimulus size effects on JOLs, the impact of clarification speed on JOLs did not differ between the naming and no-naming groups. The same was true for correlations between identification time and JOLs. Also, mediation analyses revealed that the indirect effect of clarification speed on JOLs was not reduced as a consequence of naming; if anything, the opposite result occurred. This suggests that naming faces did not attenuate the impact of perceptual fluency on stimulus size effects on JOLs.

Taken together, Experiments 1 and 2 demonstrate that perceptual fluency as measured by identification time can produce stimulus size effects on JOLs: Higher JOLs for stimuli that clarified quickly were due to perceptual fluency. They thus support a dual-basis view of JOLs that assumes JOLs to be based on both metacognitive beliefs and fluency. However, another interpretation is that our results are specific to images. That is, perhaps perceptual fluency mediates the effect of image size on JOLs but not the effect of font size on JOLs. We addressed this possibility in Experiment 3.

Experiment 3

For pictures, Experiments 1 and 2 showed that perceptual fluency can produce stimulus size effects on JOLs. It is unclear, however, whether this finding generalizes to words. In Experiment 3, participants viewed words that clarified either quickly or slowly. All words appeared in a hard-to-read font to ensure that participants could see but not read words from the beginning of the clarification procedure. A second aim of Experiment 3 was to explore whether participants' beliefs may account for stimulus size effects in our studies. To this end, participants completed a brief post-experimental questionnaire. Because naming pictures did not reduce the impact of perceptual fluency on stimulus size effects on JOLs in Experiment 2, all participants were instructed to type the words after identification, right before making JOLs.

Method

Participants and materials

Participants were 50 University of Mannheim undergraduates. Stimuli were 48 German 5-letter nouns with two syllables and a mean log frequency of 1.22 (*SD* = 0.54; Baayen, Piepenbrock, & Van Rijn, 1993). Words were written in a gray-colored 58-point Chopin Script font on a white background. All letters were capitals. We converted each word to an image and then created 30 images of different sizes (see Fig. 1 and Appendix A).

Procedure

The procedure was identical to that of Experiment 2 with the following exceptions. Participants were asked to identify 48 words. Half the word-identification trials were fast and slow trials, respectively. In the word identification phase, participants were instructed to stop the clarification process as soon as they could read the word. Participants were asked to type the word and immediately make a JOL. After a filler task, participants were asked to write down as many words from the first phase of the experiment as they could remember. Following the recall test, participants completed a two-item questionnaire. Participants (1) typed what they thought the experiment was about and (2) noted whether they had noticed systematic differences between words.

Results

Table 3 presents means and standard deviations of naming accuracy, identification time, image number, JOLs, recall performance, and correlations between identification time and JOLs.

Table 3
Descriptive statistics for Experiment 3.

	Clarification			
	Fast		Slow	
	M	*SD*	*M*	*SD*
Naming accuracy	83.09	12.99	83.73	10.15
Identification time (s)	11.45	1.17	18.73	2.35
Image number	21.17	2.49	18.28	2.37
JOL	43.60	18.98	44.60	18.98
% correct	29.64	18.83	29.27	19.42
G(IT, JOL)	−.22***	.20	−.15***	.23

Note. JOL = judgment of learning; % correct = percentage of correctly recalled items; *G*(IT, JOL) = within-subjects Goodman–Kruskal gamma correlation between identification time and JOLs.
*** $p < .001$.

Naming accuracy did not differ by clarification speed, $t < 1$. Words that clarified quickly were identified faster than words that clarified slowly, $t(49) = 31.15$, $p < .001$, $d = 4.45$. Image number was higher for words that clarified quickly than for words that clarified slowly, $t(49) = 2.89$, $p < .001$, $d = 0.41$. Thus, words that clarified quickly were identified at a larger stage than words that clarified slowly. JOLs did not differ between words that clarified quickly and slowly, $t < 1$. The same was true for recall performance, $t < 1$. Correlations between identification time and JOLs were significantly negative for words that clarified quickly and for words that clarified slowly. Thus, the less time it took to identify the clarifying words, independent of clarification speed, the higher one's JOLs. Correlations were virtually identical when image number was used instead of identification time (see Appendix B).

As can be seen in Fig. 2, the unstandardized regression coefficients for the direct effects of clarification speed on identification time (Panel A) and JOLs (Panel B) and for the direct effect of identification time on JOLs (Panel C) were all significantly negative. This means that fast clarification significantly reduced both identification time and JOLs and that reductions in identification time increased JOLs. Mediation analyses revealed a significant indirect effect of clarification speed on JOLs mediated by identification time (8.71, 95% CI [7.12, 10.36], $p < .001$). Clarification speed thus had a significantly positive indirect effect on JOLs, whereas its direct effect on JOLs was significantly negative. Thus, as in the previous experiments, indirect and direct effects of clarification speed on JOLs suppressed each other.

In the post-experimental questionnaire, four of 50 participants reported that the experiment was about the link between identification time and memory performance. One of those participants voiced the belief that memory performance increased with increasing identification times, that is, that studying results in learning (cf. Bjork et al., 2013; Kornell & Bjork, 2009). Two of the four participants believed that fast identification is accompanied by increased memory performance, which corresponds to the belief that easily perceived denotes easily remembered (cf. Besken & Mulligan, 2013, 2014). The remaining participant did not specify the direction of the link between identification time and memory performance. Importantly, none of the results reported above changed when we excluded these four participants from the analyses. No participant reported noticing systematic differences between words. The questionnaire data thus indicated two things. First, most people did not report a belief about stimulus size. Second, there is no reason to suspect that people noticed the experimental manipulation of clarification speed.

Discussion

In sum, Experiment 3 replicated Experiments 1 and 2 in showing that stimuli that clarified quickly were identified faster than stimuli that clarified slowly. As in the previous experiments, reductions in identification time increased JOLs. Conversely, the direct effect of clarification speed on

JOLs was negative. Fast clarification thus increased JOLs only through reducing identification time. Again, memory performance was roughly equal for stimuli that clarified quickly and slowly. However, memory performance was worse than in Experiment 2, probably because people were presented with words rather than celebrity faces. Responses to the post-experimental questionnaire in Experiment 3 suggested that our findings are not due to people's beliefs. Together with the results of Experiments 1 and 2, Experiment 3 demonstrates that perceptual fluency as measured by identification time can produce stimulus size effects on JOLs: Higher JOLs for words that clarified quickly were due to perceptual fluency. Experiment 3 thus supports a dual-basis view of JOLs that assumes JOLs to be based on both metacognitive beliefs and fluency. In Experiment 4, we sought to further test the contribution of perceptual fluency to size effects on JOLs.

Experiment 4

Results from Experiment 3 are consistent with the idea that perceptual fluency contributes to stimulus size effects on JOLs. Specifically, the post-experimental questionnaire suggested that people did not have a belief about identification time or clarification speed. However, previous research has revealed that people frequently fail to apply beliefs they have when making JOLs (e.g., Bjork et al., 2013; Koriat et al., 2004; Kornell & Bjork, 2009). The reverse is also plausible; namely, people may not report a belief they use when making JOLs. Thus, Experiment 4 used a learner-observer-judge method to address the contribution of perceptual fluency to stimulus size effects on JOLs (Vesonder & Voss, 1985; for applications to JOLs see, e.g., Koriat & Ackerman, 2010; Matvey, Dunlosky, & Guttentag, 2001; Serra & Ariel, 2014; Undorf & Erdfelder, 2011, 2013). In this experiment, we compared correlations between identification time and JOLs in learner and observer groups. As in Experiment 3, participants in the learner group viewed clarifying words, made JOLs, and completed a recall test. Because the learner group viewed the clarification process, correlations between identification time and JOLs in this group may be based on both perceptual fluency and beliefs. Participants in the observer group were presented with the largest image of each word and the alleged number of images another participant saw of it. They saw at the outset of the experiment one word-identification trial and were told that the other participant was instructed to stop the clarification process as soon as he or she could identify the word. Instructions also explained that the fewer images the other participant saw, the smaller the word was when identified. Because the observer group did not view the clarification process and thus could not experience perceptual fluency, any correlation between identification time and JOLs in this group can be based only on beliefs.

If, as suggested by the previous experiments, perceptual fluency contributes to stimulus size effects on JOLs, correlations between identification time and JOLs should be more pronounced in the learner group than in the observer group. In contrast, if stimulus size effects on JOLs were solely due to people's beliefs, correlations between identification time and JOLs should not differ between the learner and observer groups. An alternative explanation for more pronounced correlations in the learner group could be that participants in the learner group were more engaged in the experiment. To examine this possibility, we asked all participants to indicate their engagement in Experiment 4.

Method

Participants and materials

Participants were 63 University of Mannheim undergraduates. We omitted data from one participant who did not stop the clarification process for any item. The remaining participants were randomly assigned to either the learner condition ($n = 31$) or to the observer condition ($n = 31$). The stimuli were 44 words from Experiment 3.

Procedure

For participants in the learner group, the procedure was identical to that of Experiment 3 with the exception that all 44 word-identification trials were slow trials. This means that maximum clarity always occurred after 30 images. In the observer group, participants were told that they should predict another participant's recall probabilities and would therefore observe how this participant had identified words. To familiarize participants with the procedure, they saw one word-identification trial and observed how the word was named and how a JOL was made. Then, observers were told that the other participant was instructed to stop the clarification process as soon as he or she could identify the word. They were also told that each word reached maximum size after 30 images. It was explained to them (1) that if the other participant saw 30 images of a word, he or she identified the word only at its maximum size and (2) that if the other participant saw fewer images of a word, he or she identified the word at a smaller size. We explicitly instructed participants not to study the words. On each trial, the largest image of a word and the alleged number of images the other participant saw of it appeared on screen for 4 s. After a 200-ms blank screen, the JOL prompt appeared and participants estimated the probability of the other participant recalling the word. A 400-ms blank screen preceded the next trial. All 44 words were presented in a random order for each subject. The very first four trials served as buffers and were discarded from all analyses. Each word was combined with a randomly selected number of images the other participant allegedly saw of it (range = 9–30, $M = 18.43$, $SD = 5.94$). There was no test in the observer group.

At the end of the experiment, all participants typed what they thought the experiment was about and indicated their engagement with the experiment. Specifically, they rated their agreement with the statements "I worked hard in this experiment", "I was actively engaged in this experiment", and "I enjoyed participating in this experiment" on a 7-point scale (where 1 = *strongly disagree* and 7 = *strongly agree*).

Results

For the learner group, Table 4 presents means and standard deviations of naming accuracy, identification time,

Table 4
Descriptive statistics for the learner and observer groups of Experiment 4.

	Learner		Observer	
	M	*SD*	*M*	*SD*
Naming accuracy	86.85	12.33		
Identification time (s)	19.30	3.16		
Image number	18.85	3.21		
JOL	47.58	13.54	56.41	12.75
% correct	31.25	20.23		
G(IT, JOL)	−.10[**]	.20	.04[a]	.44[a]

Note. All trials in the learner group were slow. JOL = judgment of learning; % correct = percentage of correctly recalled items; *G*(IT, JOL) = within-subjects Goodman–Kruskal gamma correlation between identification time and JOLs.
[**] $p < .01$.
[a] Values were obtained by correlating the number of images the other participant allegedly saw with the JOLs made by observers.

image number, and recall performance. For the learner and observer groups, the table shows means and standard deviations of JOLs and correlations between identification time and JOLs. In the observer group, correlations were obtained by correlating the number of images the other participant allegedly saw with the JOLs made by observers.

Correlations between identification time and JOLs were significantly negative in the learner group and numerically but not reliably positive in the observer group. Thus, in the learner group, the less time it took to identify the clarifying words, the higher one's JOLs. Conversely, in the observer group, JOLs were unrelated to the time it took the other participant to identify the clarifying words. The difference in correlations between groups was of medium size and marginal significance, $t(60) = 1.68$, $p = .098$, $d = 0.43$. Correlations were virtually identical when image number was used instead of identification time (see Appendix B).

In the post-experimental questionnaire, 15 of 62 participants (6 from the learner and 9 from the observer group) reported that the experiment was about the link between identification time and memory performance. Three of those participants (2 from the learner group) voiced the belief that studying results in learning. Another participant from the observer group believed that easily perceived denotes easily remembered. The remaining participants (4 from the learner group and 7 from the observer group) did not specify the direction of the link between identification time and memory performance. Importantly, when we excluded these 15 participants from the analyses, correlations between identification time and JOLs were still negative in the learner group, $M = -.12$, $SD = .21$, $t(24) = 2.92$, $p = .008$, $d = 0.60$, and numerically but not reliably positive in the observer group, $M = .09$, $SD = .43$, $t < 1$. Also, correlations now differed significantly between the learner and observer groups, $t(45) = 2.13$, $p = .039$, $d = 0.62$.

Participants in both groups indicated that they had worked hard in the experiment, learner group: $M = 5.52$ ($SD = 1.56$), observer group: $M = 5.84$ ($SD = 1.49$), $t < 1$, were actively engaged in the experiment, learner group: $M = 4.83$ ($SD = 1.34$), observer group: $M = 5.39$ ($SD = 1.31$), $t(59) = 1.63$, $p = 0.108$, $d = 0.42$, and were neutral with respect to how much they enjoyed participating in the experiment, learner group: $M = 4.03$ ($SD = 1.38$), observer group: $M = 4.10$ ($SD = 1.66$), $t < 1$. These results rule out the possibility that lack of engagement is responsible for insignificant correlations between identification time and JOLs in the observer group. If anything, the observer group was more engaged in the experiment than was the learner group.

Discussion

In sum, Experiment 4 replicated the previous experiments in showing that, in the learner group, reductions in identification time increased JOLs. Conversely, identification time and JOLs were unrelated in the observer group. Because the learner group viewed the clarification process, correlations between identification time and JOLs in this group could be based on both perceptual fluency and beliefs. Conversely, correlations between identification time and JOLs could be based only on beliefs in the observer group. Experiment 4 therefore demonstrates that perceptual fluency as measured by identification time can indeed produce stimulus size effects on JOLs, meaning that higher JOLs for stimuli that clarified quickly were due to higher perceptual fluency. Thus, it supports a dual-basis view of JOLs that assumes JOLs to be based on both metacognitive beliefs and fluency.

General discussion

The present experiments examined whether perceptual fluency mediates the effect of stimulus size on people's predictions of future memory performance. We presented successive displays of visual stimuli that were initially so small as to be entirely unrecognizable but that clarified (i.e., increased in size) over time. Clarification proceeded either quickly or slowly. In Experiments 1–3, the time required in seconds for participants to identify the image was inversely related to JOLs, independent of clarification speed. Moreover, fast clarification increased JOLs indirectly through identification time. Conversely, direct effects of clarification speed on JOLs were significantly negative. Across experiments, clarification speed did not affect memory performance. Taken together, these results suggest that stimulus size increases JOLs through perceptual fluency, which we operationally defined as identification time. This is true not only for pictures of common objects (Experiment 1) and faces (Experiment 2) but also for words (Experiment 3). Further evidence for the idea that perceptual fluency can produce effects of stimulus size on JOLs comes from a fourth experiment. In Experiment 4, a comparison of learner and observer groups revealed that inverse relations between identification time and JOLs occurred only when participants viewed the clarification process and could therefore base their JOLs on perceptual fluency.

In Experiment 2, the contribution of perceptual fluency to JOLs did not differ between participants who named stimuli prior to making JOLs and participants who made their JOLs immediately after stimulus identification. This argues against the idea that JOLs are primarily based on naming fluency when people are instructed to name items during study (Sungkhasettee et al., 2011; Susser et al., 2013; Tiede & Leboe, 2009).

Each of our experiments revealed that stimuli that clarified quickly were identified at a slightly larger stage than stimuli that clarified slowly. Does this mean that JOLs for stimuli that clarified quickly were higher because of a larger image size at identification? In fact, inverse relations between image number and JOLs preclude this possibility. Nevertheless, the finding that stimuli that clarified quickly were identified at a larger stage was unexpected. Bernstein et al. (2005) and Loftus and Harley (2005) found a *perceptual interference effect*, meaning that stimuli were identified at a smaller stage when they began moderately, as opposed to very, small and then clarified (e.g., Bruner & Potter, 1964; Schulkind, 2002; Snodgrass & Hirshman, 1991; Wang & Reinitz, 2001).[4] Presumably, the current experiments did not reveal a perceptual interference effect because we held the size of the first picture constant (cf. Luo & Snodgrass, 1994; Wang & Reinitz, 2001).

Our research suggests that perceptual fluency can produce stimulus size effects on JOLs. Thus, it demonstrates that perceptual fluency's effects on JOLs are pervasive. This is consistent with previous studies showing that perceptual fluency affects JOLs for aurally and visually presented words (Besken & Mulligan, 2013, 2014; Susser et al., 2013; see also Besken, 2016). Because perceptual and conceptual fluency can have distinct effects on judgments (e.g., Whittlesea, 1993; but see also Alter & Oppenheimer, 2009), the current results extend previous research that showed effects of conceptual fluency on JOLs (e.g., Benjamin, Bjork, & Schwartz, 1998; Koriat & Ma'ayan, 2005; Matvey et al., 2001; Undorf & Erdfelder, 2011, 2013, 2015). At a theoretical level, our research provides evidence for a dual-basis view that assumes JOLs to be based on both metacognitive beliefs and fluency (Koriat, 1997; Koriat & Ma'ayan, 2005; Koriat et al., 2004). Conversely, the current findings argue against the idea that JOLs mainly rely on deliberate applications of people's metacognitive beliefs (e.g., Mueller et al., 2013, 2014). Therefore, investigating how metacognitive beliefs and fluency combine to influence JOLs is an important direction for future research. Regarding the classic font-size effect, our work suggests that perceptual fluency did not contribute to that effect because smaller words were about as easy to read as larger words (see also Besken & Mulligan, 2013, 2014).

There is one final issue we would like to discuss. The procedures used in the current experiments resemble procedures used in experiments on the revelation effect. The revelation effect occurs when items on a recognition test are more likely to be judged as old if they are somehow degraded or obscured and then revealed or if they are preceded by a word that is degraded (Watkins & Peynircioglu, 1990; Westerman & Greene, 1998). For instance, Watkins and Peynircioglu (1990) presented words that unfolded letter by letter in a recognition test (e.g., _ _ _ _ _, _ _ b _ _, _ _ b _ a, z _ b _ a, zeb _ a, zebra). Participants identified the words and, when the complete version appeared, judged whether they had studied the words. Results revealed more old judgments for words that had to be identified than for intact words. Similarly, Bornstein and Wilson (2004) found a revelation effect for clarifying images of faces (but see Aßfalg & Bernstein, 2012). However, unlike prior work on the revelation effect in which identification of degraded stimuli occurred at test (for an exception, see Mulligan & Lozito, 2006), identification occurred at study in the current experiments. An intriguing avenue for research will be to explore whether the apparent similarities in procedures also result in similar cognitive processes beyond identification of clarifying stimuli.

To conclude, the current findings support a dual-basis view of JOLs that assumes JOLs to be based on both metacognitive beliefs and fluency by showing that perceptual fluency's effects on JOLs are pervasive. Returning to the earlier example of a student viewing lecture slides from the back of a large room, our findings suggest that poor viewing conditions will reduce the student's predictions of learning but will not affect actual learning. Future work should explore how differences in perceptual fluency influence regulation of study and eventual test performance.

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Appendix A

In Experiment 1, images of common objects were resized according to the equation

$$p_i = 0.02 + \text{scale}(e^{i/150}) \times .20, \tag{A1}$$

with *i* ranging from 1 to 30 and scale as the function relating size to image numbers described by Loftus and Harley (2005).

In Experiment 2, images of celebrity faces were resized according to the equation

$$p_i = -0.01 + \text{scale}(e^{i/150}) \times .20, \tag{A2}$$

with *i* ranging from 1 to 30 and scale as the function described by Loftus and Harley.

In Experiments 3 and 4, images of words were resized according to the equation

$$p_i = -0.02 + \text{scale}(e^{i/150}) \times .18, \tag{A3}$$

with *i* ranging from 1 to 30 and scale as the function described by Loftus and Harley.

[4] The perceptual interference effect (or Bruner-Potter effect) in object identification is not the same as the perceptual interference effect in episodic memory (see Introduction). The perceptual interference effect in episodic memory refers to the finding that interfering with perception during stimulus encoding can enhance later memory performance (e.g., Hirshman & Mulligan, 1991; Mulligan & Lozito, 2004; Nairne, 1988). Typically, this finding is obtained when people are asked to encode words that are both very briefly presented and then backward masked (perceptual-interference condition) and words that are presented for a longer duration with no backward mask (intact condition).

Table B1
Within-subjects gamma correlations between image number and judgments of learning.

Experiment and condition	Clarification			
	Fast		Slow	
	M	*SD*	*M*	*SD*
Experiment 1	−.19**	.30	−.19**	.31
Experiment 2, naming group	−.50***	.29	−.54***	.29
Experiment 2, no-naming group	−.47***	.31	−.47***	.25
Experiment 3	−.23***	.22	−.15***	.24
Experiment 4, learner group			−.11**	.21
Experiment 4, observer group			.04[a]	.44[a]

Note. In Experiment 4, all trials were slow.
** $p < .01$.
*** $p < .001$.
[a] Values were obtained by correlating the number of images the other participant allegedly saw with the JOLs made by observers.

Appendix B

Table B1 shows means and standard deviations of gamma correlations between image number and JOLs in Experiments 1–4. The table reveals that correlations were negative in all conditions but the observer group of Experiment 4. As reported in the Results section of each experiment, the same pattern of results was found with correlations between identification time and JOLs.

References

Alter, A. L., & Oppenheimer, D. M. (2009). Uniting the tribes of fluency to form a metacognitive nation. *Personality and Social Psychology Review, 13*(3), 219–235. http://dx.doi.org/10.1177/1088868309341564.

Aßfalg, A., & Bernstein, D. M. (2012). Puzzles produce strangers: A puzzling result for revelation-effect theories. *Journal of Memory and Language, 67*(1), 86–92. http://dx.doi.org/10.1016/j.jml.2011.12.011.

Baayen, R. H., Piepenbrock, R., & Van Rijn, H. (1993). *The CELEX lexical database on CD-ROM. Linguistic Data Consortium*. Philadelphia, PA: Linguistic Data Consortium.

Bates, E., D'Amico, S., Jacobsen, T., Székely, A., Andonova, E., Devescovi, A., ... Tzeng, O. (2003). Timed picture naming in seven languages. *Psychonomic Bulletin & Review, 10*(2), 344–380. http://dx.doi.org/10.3758/BF03196494.

Bates, D. M., Maechler, M., & Bolker, B. (2015). *lme4: Linear mixed-effects models using S4 classes (R package version 1.1-6) [Software].*

Benjamin, A. S., Bjork, R. A., & Schwartz, B. L. (1998). The mismeasure of memory: When retrieval fluency is misleading as a metamnemonic index. *Journal of Experimental Psychology: General, 127*(1), 55–68. http://dx.doi.org/10.1037/0096-3445.127.1.55.

Bernstein, D. M., Loftus, G. R., & Meltzoff, A. N. (2005). Object identification in preschool children and adults. *Developmental Science, 8*(2), 151–161. http://dx.doi.org/10.1111/j.1467-7687.2005.00402.x.

Besken, M. (2016). Picture-perfect is not perfect for metamemory: Testing the perceptual fluency hypothesis with degraded images. *Journal of Experimental Psychology: Learning, Memory, and Cognition*. http://dx.doi.org/10.1037/xlm0000246. Advance online publication.

Besken, M., & Mulligan, N. W. (2013). Easily perceived, easily remembered? Perceptual interference produces a double dissociation between metamemory and memory performance. *Memory & Cognition, 41*(6), 897–903. http://dx.doi.org/10.3758/s13421-013-0307-8.

Besken, M., & Mulligan, N. W. (2014). Perceptual fluency, auditory generation, and metamemory: Analyzing the perceptual fluency hypothesis in the auditory modality. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 40*(2), 429–440. http://dx.doi.org/10.1037/a0034407.

Bjork, R. A., Dunlosky, J., & Kornell, N. (2013). Self-regulated learning: Beliefs, techniques, and illusions. *Annual Review of Psychology, 64*, 417–444. http://dx.doi.org/10.1146/annurev-psych-113011-143823.

Bodner, G. E., & MacLeod, C. M. (2016). The benefits of studying by production... and of studying production: Introduction to the special issue on the production effect in memory. *Canadian Journal of Experimental Psychology/Revue Canadienne de Psychologie Expérimentale, 70*(2), 89–92. http://dx.doi.org/10.1037/cep0000094.

Bornstein, B., & Wilson, J. (2004). Extending the revelation effect to faces: Haven't we met before? *Memory, 12*(2), 140–146. http://dx.doi.org/10.1080/09658210244000289.

Bruner, J. S., & Potter, M. C. (1964). Interference in visual recognition. *Science, 144*(3617), 424–425. http://dx.doi.org/10.1126/science.144.3617.424.

Busey, T. A., Tunnicliff, J., Loftus, G. R., & Loftus, E. F. (2000). Accounts of the confidence accuracy relation in recognition memory. *Psychonomic Bulletin & Review, 7*(1), 26–48. http://dx.doi.org/10.3758/BF03210724.

Castel, A. D., Rhodes, M. G., & Friedman, M. C. (2013). Predicting memory benefits in the production effect: The use and misuse of self-generated distinctive cues when making judgments of learning. *Memory & Cognition, 41*(1), 28–35. http://dx.doi.org/10.3758/s13421-012-0249-6.

Diemand-Yauman, C., Oppenheimer, D. M., & Vaughan, E. B. (2011). Fortune favors the bold (and the italicized): Effects of disfluency on educational outcomes. *Cognition, 118*(1), 111–115. http://dx.doi.org/10.1016/j.cognition.2010.09.012.

Hirshman, E., & Mulligan, N. W. (1991). Perceptual interference improves explicit memory but does not enhance data-driven processing. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17*(3), 507–513. http://dx.doi.org/10.1037/0278-7393.17.3.507.

Hu, X., Liu, Z., Li, T., & Luo, L. (2016). Influence of cue word perceptual information on metamemory accuracy in judgement of learning. *Memory, 24*(3), 383–398. http://dx.doi.org/10.1080/09658211.2015.1009470.

Imai, K., Keele, L., & Tingley, D. (2010). A general approach to causal mediation analysis. *Psychological Methods, 15*(4), 309–334. http://dx.doi.org/10.1037/a0020761.

Kelley, C. M., & Rhodes, M. G. (2002). Making sense and nonsense of experience: Attributions in memory and judgment. *Psychology of Learning and Motivation, 41*, 293–320. http://dx.doi.org/10.1016/S0079-7421(02)80010-X.

Kenny, D. A., Korchmaros, J. D., & Bolger, N. (2003). Lower level mediation in multilevel models. *Psychological Methods, 8*(2), 115–128. http://dx.doi.org/10.1037/1082-989X.8.2.115.

Koriat, A. (1997). Monitoring one's own knowledge during study: A cue-utilization approach to judgments of learning. *Journal of Experimental Psychology: General, 126*(4), 349–370. http://dx.doi.org/10.1037/0096-3445.126.4.349.

Koriat, A., & Ackerman, R. (2010). Metacognition and mindreading: Judgments of learning for self and other during self-paced study. *Consciousness and Cognition, 19*(1), 251–264. http://dx.doi.org/10.1016/j.concog.2009.12.010.

Koriat, A., Bjork, R. A., Sheffer, L., & Bar, S. K. (2004). Predicting one's own forgetting: The role of experience-based and theory-based processes. *Journal of Experimental Psychology: General, 133*(4), 643–656. http://dx.doi.org/10.1037/0096-3445.133.4.643.

Koriat, A., & Ma'ayan, H. (2005). The effects of encoding fluency and retrieval fluency on judgments of learning. *Journal of Memory and Language, 52*(4), 478–492. http://dx.doi.org/10.1016/j.jml.2005.01.001.

Kornell, N., & Bjork, R. A. (2009). A stability bias in human memory: Overestimating remembering and underestimating learning. *Journal of Experimental Psychology: General, 138*(4), 449–468. http://dx.doi.org/10.1037/a0017350.

Kornell, N., Rhodes, M. G., Castel, A. D., & Tauber, S. K. (2011). The ease-of-processing heuristic and the stability bias: Dissociating memory, memory beliefs, and memory judgments. *Psychological Science, 22*(6), 787–794. http://dx.doi.org/10.1177/0956797611407929.

Krull, J. L., & MacKinnon, D. P. (2001). Multilevel modeling of individual and group level mediated effects. *Multivariate Behavioral Research, 36*(2), 249–277. http://dx.doi.org/10.1207/S15327906MBR3602_06.

Kuznetsova, A., Brockhoff, P. B., & Christensen, R. H. B. (2015). *lmerTest: Tests for random and fixed effects for linear mixed effect models (lmer objects of lme4 package) (R package version 2.0-6) [Software].*

Legge, G. E., & Bigelow, C. A. (2011). Does print size matter for reading? A review of findings from vision science and typography. *Journal of Vision, 11*(5), 1–22. http://dx.doi.org/10.1167/11.5.8.

Loftus, G. R., & Harley, E. M. (2005). Why is it easier to identify someone close than far away? *Psychonomic Bulletin & Review, 12*(1), 43–65. http://dx.doi.org/10.3758/BF03196348.

Luo, C. R., & Snodgrass, J. G. (1994). Competitive activation model of perceptual interference in picture and word identification. *Journal of Experimental Psychology: Human Perception and Performance, 20*(1), 50–60. http://dx.doi.org/10.1037/0096-1523.20.1.50.

MacKinnon, D. P., Fairchild, A. J., & Fritz, M. S. (2007). Mediation analysis. *Annual Review of Psychology, 58*, 593–614. http://dx.doi.org/10.1146/annurev.psych.58.110405.085542.

MacKinnon, D. P., Krull, J. L., & Lockwood, C. M. (2000). Equivalence of the mediation, confounding and suppression effect. *Prevention Science, 1*(4), 173–181. http://dx.doi.org/10.1023/A:1026595011371.

MacLeod, C. M., Gopie, N., Hourihan, K. L., Neary, K. R., & Ozubko, J. D. (2010). The production effect: Delineation of a phenomenon. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 36*(3), 671–685. http://dx.doi.org/10.1037/a0018785.

Matvey, G., Dunlosky, J., & Guttentag, R. (2001). Fluency of retrieval at study affects judgments of learning (JOLs): An analytic or nonanalytic basis for JOLs? *Memory & Cognition, 29*(2), 222–233. http://dx.doi.org/10.3758/BF03194916.

McDonough, I. M., & Gallo, D. A. (2012). Illusory expectations can affect retrieval-monitoring accuracy. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 38*(2), 391–404. http://dx.doi.org/10.1037/a0025548.

Miele, D. B., Finn, B., & Molden, D. C. (2011). Does easily learned mean easily remembered? It depends on your beliefs about intelligence. *Psychological Science, 22*(3), 320–324. http://dx.doi.org/10.1177/0956797610397954.

Mueller, M. L., Dunlosky, J., Tauber, S. K., & Rhodes, M. G. (2014). The font-size effect on judgments of learning: Does it exemplify fluency effects or reflect people's beliefs about memory? *Journal of Memory and Language, 70*(1), 1–12. http://dx.doi.org/10.1016/j.jml.2013.09.007.

Mueller, M. L., Tauber, S. K., & Dunlosky, J. (2013). Contributions of beliefs and processing fluency to the effect of relatedness on judgments of learning. *Psychonomic Bulletin & Review, 20*(2), 378–384. http://dx.doi.org/10.3758/s13423-012-0343-6.

Mulligan, N. W., & Lozito, J. P. (2004). Self-generation and memory. In B. H. Ross (Ed.), *The psychology of learning and motivation: Advances in research and theory* (pp. 175–214). San Diego, CA: Elsevier Academic Press.

Mulligan, N. W., & Lozito, J. P. (2006). An asymmetry between memory encoding and retrieval: Revelation, generation, and transfer-appropriate processing. *Psychological Science, 17*(1), 7–11. http://dx.doi.org/10.1111/j.1467-9280.2005.01657.x.

Nairne, J. S. (1988). The mnemonic value of perceptual identification. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 14*(2), 248–255. http://dx.doi.org/10.1037/0278-7393.14.2.248.

R Core Team (2015). *R: A language and environment for statistical computing [Software]*. Vienna, Austria: R Foundation for Statistical Computing.

Reber, R., Winkielman, P., & Schwarz, N. (1998). Effects of perceptual fluency on affective judgments. *Psychological Science, 9*(1), 45–48. http://dx.doi.org/10.1111/1467-9280.00008.

Rhodes, M. G., & Castel, A. D. (2008). Memory predictions are influenced by perceptual information: Evidence for metacognitive illusions. *Journal of Experimental Psychology: General, 137*(4), 615–625. http://dx.doi.org/10.1037/a0013684.

Schulkind, M. D. (2002). Feature modulation search: A novel memory search model that extends the perceptual interference effect to musical stimuli. *Journal of Experimental Psychology: Learning, Memory and Cognition, 28*(2), 346–352. http://dx.doi.org/10.1o37//0278-7393.28.2.346.

Serra, M. J., & Ariel, R. (2014). People use the memory for past-test heuristic as an explicit cue for judgments of learning. *Memory & Cognition, 42*(8), 1260–1272. http://dx.doi.org/10.3758/s13421-014-0431-0.

Snodgrass, J. G., & Corwin, J. (1988). Pragmatics of measuring recognition memory: Applications to dementia and amnesia. *Journal of Experimental Psychology: General, 117*(1), 34–50. http://dx.doi.org/10.1037/0096-3445.117.1.34.

Snodgrass, J. G., & Hirshman, E. (1991). Theoretical explorations of the Bruner-Potter 1964 interference effect. *Journal of Memory and Language, 30*(3), 273–293. http://dx.doi.org/10.1016/0749-596X(91)90037-K.

Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory, 6*(2), 174–215. http://dx.doi.org/10.1037/0278-7393.6.2.174.

Sungkhasettee, V. W., Friedman, M. C., & Castel, A. D. (2011). Memory and metamemory for inverted words: Illusions of competency and desirable difficulties. *Psychonomic Bulletin & Review, 18*(5), 973–978. http://dx.doi.org/10.3758/s13423-011-0114-9.

Susser, J. A., Mulligan, N. W., & Besken, M. (2013). The effects of list composition and perceptual fluency on judgments of learning (JOLs). *Memory & Cognition, 41*(7), 1000–1011. http://dx.doi.org/10.3758/s13421-013-0323-8.

Tiede, H. L., & Leboe, J. P. (2009). Illusions of competence for phonetically, orthographically, and semantically similar word pairs. *Canadian Journal of Psychology/Revue Canadienne de Psychologie, 63*(4), 294–302. http://dx.doi.org/10.1037/a0015717.

Tingley, D., Yamamoto, T., Hirose, K., Keele, L., & Imai, K. (2014). mediation: R Package for Causal Mediation Analysis. *Journal of Statistical Software, 59*(5), 1–38. http://dx.doi.org/10.18637/jss.v059.i05.

Undorf, M., & Erdfelder, E. (2011). Judgments of learning reflect encoding fluency: Conclusive evidence for the ease-of-processing hypothesis. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 37*(5), 1264–1269. http://dx.doi.org/10.1037/a0023719.

Undorf, M., & Erdfelder, E. (2013). Separation of encoding fluency and item difficulty effects on judgements of learning. *The Quarterly Journal of Experimental Psychology, 66*(10), 2060–2072. http://dx.doi.org/10.1080/17470218.2013.777751.

Undorf, M., & Erdfelder, E. (2015). The relatedness effect on judgments of learning: A closer look at the contribution of processing fluency. *Memory & Cognition, 43*(4), 647–658. http://dx.doi.org/10.3758/s13421-014-0479-x.

Vesonder, G. T., & Voss, J. F. (1985). On the ability to predict one's own responses while learning. *Journal of Memory and Language, 24*(3), 363–376. http://dx.doi.org/10.1016/0749-596X(85)90034-8.

Wang, Q., & Reinitz, M. (2001). Effects of number and strength of competing solutions on the perceptual interference effect. *Journal of Experimental Psychology: Human Perception and Performance, 27*(1), 22–31. http://dx.doi.org/10.1037/0096-1523.27.1.22.

Watkins, M. J., & Peynircioglu, Z. F. (1990). The revelation effect: When disguising test items induces recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16*(6), 1012–1020. http://dx.doi.org/10.1037/0278-7393.16.6.1012.

Westerman, D. L., & Greene, R. L. (1998). The revelation that the revelation effect is not due to revelation. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 24*(2), 377–386. http://dx.doi.org/10.1037/0278-7393.24.2.377.

Whittlesea, B. W. A. (1993). Illusions of familiarity. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19*(6), 1235–1253. http://dx.doi.org/10.1037/0278-7393.19.6.1235.

Whittlesea, B. W. A., Jacoby, L. L., & Girard, K. (1990). Illusions of immediate memory: Evidence of an attributional basis for feelings of familiarity and perceptual quality. *Journal of Memory and Language, 29*(6), 716–732. http://dx.doi.org/10.1016/0749-596X(90)90045-2.

Yue, C. L., Castel, A. D., & Bjork, R. A. (2013). When disfluency is—and is not—A desirable difficulty: The influence of typeface clarity on metacognitive judgments and memory. *Memory & Cognition, 41*(2), 229–241. http://dx.doi.org/10.3758/s13421-012-0255-8.