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Different Impact of Perceptual Fluency and Schema Congruency on Sustainable Learning

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Abstract: Perceptual fluency, that is, the ease with which people perceive information, has diverse effects on cognition and learning. For example, when judging the truth of plausible but incorrect information, easy-to-read statements are incorrectly judged as true while difficult to read statements are not. As we better remember information that is consistent with pre-existing schemata (i.e., schema congruency), statements judged as true should be remembered better, which would suggest that fluency boosts memory. Another line of research suggests that learning information from hard-to-read statements enhances subsequent memory compared to easy-to-read statements (i.e., desirable difficulties). In the present study, we tested these possibilities in two experiments with student participants. In the study phase, they read plausible statements that were either easy or difficult to read and judged their truth. To assess the sustainability of learning, the test phase in which we tested recognition memory for these statements was delayed for 24 h. In Experiment 1, we manipulated fluency by presenting the statements in colors that made them easy or difficult to read. In Experiment 2, we manipulated fluency by presenting the statements in font types that made them easy or difficult to read. Moreover, in Experiment 2, memory was tested either immediately or after a 24 h delay. In both experiments, the results showed a consistent effect of schema congruency, but perceptual fluency did not affect sustainable learning. However, in the immediate test of Experiment 2, perceptual fluency enhanced memory for schema-incongruent materials. Thus, perceptual fluency can boost initial memory for schema-incongruent memory most likely due to short-lived perceptual traces, which are cropped during consolidation, but does not boost sustainable learning. We discuss these results in relation to research on the role of desirable difficulties for student learning, to effects of cognitive conflict on subsequent memory, and more generally in how to design learning methods and environments in a sustainable way.

Keywords: desirable difficulties; pre-existing schemata; prior knowledge; judgement of truth; perceptual interference effect

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1. Introduction

The need for sustainable learning is more prevailing than ever. Learning is both an intrinsic motive to enable cognitive growth and mental progress and an external requirement as we live in a fast-moving time that requires life-long learning. In fact, leading an active lifestyle which promotes continuous exposure to learning opportunities is protective against cognitive decline in older age. We define sustainable learning as the efficient and resource-preserving way of perpetually acquiring and consolidating new information towards personal and societal flourishing. Efficient learning is an important topic in education and in cognitive psychology, and the transfer of knowledge that is gained under well-controlled experimental conditions to the real world is a timely challenge. One of the most relevant findings is that the meaningful processing of study materials such as elaboration, organization, and condensation benefits learning [1–3].

Following from these insights, Bjork (1994) has proposed that creating study situations which pose challenges is the most efficient for student learning [4]. Among these "desirable difficulties" are strategies such as varying the conditions of learning rather than keeping them constant, interleaving the practice of separate topics rather than block learning of the same topic, spacing rather than massing study sessions, and using testing rather than re-reading as study opportunities [5–8].

More recently, it has been proposed that making the perceptual processing of study materials difficult can also create a desirable difficulty. For example, Sungkhasettee et al. (2011) found that inverted words were better remembered [9], Mulligan (1996) found that masked words were better remembered [10], and Rosner et al. (2015) found that blurred words were better remembered than normally presented words [11]. Moreover, Diemand-Yauman et al. (2011) found that both in a well-controlled laboratory setting and in a classroom setting, information presented in hard-to-read fonts was better remembered than information presented in easy-to-read font [12]. These studies suggest that in order to process the hard-to-read information, more resources are recruited which then lead to deeper encoding, thus creating desirable difficulties. Accordingly, perceptual fluency, that is, the ease of processing information, leads to less efficient encoding and memory.

However, other studies with similar methods did not find such beneficial perceptual interference effects [13,14], or even found the opposite pattern [15,16]. In a review of more than twenty experiments with a font fluency manipulation, about half did not reveal any (dis)fluency effects, one third revealed a disfluency effect and one sixth revealed a fluency effect [17]. The latter studies are in line with the findings from studies on the effects of processing cognitive conflict on subsequent memory. There is evidence that conditions, which require additional cognitive control or attentional resources to process the task-relevant stimuli, reduce the working memory resources available for encoding these stimuli and this hurts subsequent memory [18–23]. Thus, perceptual fluency of study materials may be both desirable and undesirable.

As most of the previous studies have tested the effect of fluency vs. disfluency only after a short delay, the goal of this study was to test whether a fluency manipulation may contribute to sustainable learning, that is, a benefit after a longer delay. This would be consistent with findings from Weissgerber and Reinhard (2017), who found delayed recognition memory benefits for hard-to-read text based on a font manipulation compared to both a condition with scrambled letters and a control condition [17]. Here, we focused on testing memory for simple sentences after a 24 h interval. The reason for deciding on a 24 h interval is based on the fact that humans typically sleep during a 24 h period and sleep is important for efficient memory consolidation [24]. We consider memory consolidation as an important process for sustainable learning.

In order to manipulate perceptual fluency, we adopted a method introduced by Reber and Schwarz (1999) [25]. They manipulated perceptual fluency by presenting statements of the form "Town A is in country B" either in more or less visible colors to assess whether fluency affects judgements of truth. Some of the statements involved familiar cities and some involved unfamiliar cities, and critically, only half of the statements were actually true. Reber and Schwarz found a small but significant impact of fluency on judgements of truth. Participants endorsed the highly visible statements slightly above chance and the less visible statements at chance level.

We reasoned that endorsing a statement as true may have a similar beneficial effect on subsequent memory as a "yes" answer in a levels of processing experiment [1,26]. Both kinds of "yes" responses represent semantic elaborations, which can draw on pre-existing knowledge. In a seminal study, Craik and Tulving (1975) showed that when a decision had to be made on a semantic level, that is, whether a particular word matched into the context of a sentence (e.g., "Does the word *field* fit into this sentence: The horse lived in a ____"), memory was better than when the task involved judging whether a word was in upper or lower case [26]. Moreover, this *levels of processing effect* was much larger for "yes" than for no responses. Similarly, we reasoned that if a participant responds "yes" to a statement such as "Roskilde is in Sweden", the city name is integrated more closely with the encoding question, which enhances subsequent memory. There is compelling evidence that material that is congruent to one's knowledge is better remembered than material that is not, an effect that has been labeled the "congruency subsequent memory effect" [27]. In educational contexts, the activation of prior knowledge (i.e., pre-existing schemata) and the optimal match between prior knowledge and current task demands are some of the most critical determinants for efficient learning. Recent studies have suggested that schema-congruent materials lead to better memory than incongruent material, particularly when tested after a delay [28,29]. According to the "schema theory of memory consolidation", this is due to efficient encoding and accelerated consolidation of schema-congruent information [30,31].

Thus, we adopted the method of Reber and Schwarz (1999) for the study phase of our study, and we used the responses of the judgements of truths as indications of schema congruency vs. incongruency for a subsequent test phase. In Experiment 1, we administered a recognition memory test after a 24 h retention interval to test the influence of perceptual fluency (i.e., highly visible vs. less visible colors) and schema congruency (true vs. untrue judgement at study) and their potential interaction. In Experiment 2, we complemented the delayed test with an immediate test in order to replicate and extend the results from Experiment 1. Moreover, we used a font manipulation as a more common manipulation of disfluency [12,14,17].

2. Experiment 1

2.1. Method

2.1.1. Participants

The participants were 159 undergraduate students (29 male and 130 female) from the University of Bern. The age ranged from 18 to 35 years (M = 22.3, SD = 2.8), and they participated in the study for course credits. They were assigned to one of eight stimulus lists. The study was approved by the ethics committee of the University of Bern. All of the participants gave consent by starting the experiments. The data of three participants had to be excluded due to technical problems. One more participant had to be dropped for the recognition memory analysis due to missing data in one of the conditions.

2.1.2. Materials

The material consisted of 64 statements of the form "Town A is in country B" (e.g., "Osorno is in Chile"; "Lima is in Peru"). Two additional statements were used for practice. Half of the statements were true (e.g., "Osorno is in Chile"), and the other half were untrue (e.g., "Oslo is in Sweden"). There were familiar cities (e.g., Lima, Oslo) in half of the statements and unfamiliar cities (e.g., Osorno, Belmopan) in the other half of the statements. In order to manipulate perceptual fluency, in the study phase the statements were presented in highly visible or in moderately visible colors. Highly visible colors included blue (#3333ff) and red (#ff0000), and moderately visible colors included yellow (#f5f500) and light blue (#6699ff). The statements were presented in 20-point serif font (e.g., Times New Roman) against a white background. In the test phase, the statements were presented in grey (#808080) against a white background. Exemplary stimuli are presented in Figure 1a. The conditions were counterbalanced across participants. That is, across participants, each statement appeared in the high vs. low fluency condition, each city appeared in true vs. untrue statements, and each statement appeared as a target vs. a lure in the test phase.

(**a**) (**b**)

Figure 1. Exemplary stimuli for Experiment 1 (**a**) and Experiment 2 (**b**).

2.1.3. Procedure

The experiment was programmed in Lab JS and was run online on a JATOS server [32]. After agreeing to participate, participants received two web links via email. They were instructed to conduct the first part of the experiment on day one and the second part exactly 24 h later. The first link contained the study phase. After clicking the link, participants were instructed to rate the truth of statements of countries and cities (e.g., Teheran is in Iran) as quickly and accurately as possible. They were informed that the statements would be shown in different colors and that we are interested in the impact of colors on reaction times. After two practice trials, 32 statements were presented in randomized order. Each of the eight experimental conditions (e.g., high vs. low fluency, familiar vs. unfamiliar city, true vs. untrue statement) involved four stimuli. Each statement was preceded by a fixation point presented for 500 ms. The interval between the fixation point and the onset of the statement was 200 ms. The statements were presented for 1000 ms, then a screen appeared with two response alternatives. Participants had to decide whether the statement was true by pressing the "c"-button or untrue by pressing the "n"-button.

The test phase, which had to be completed 24 h later, involved a surprise recognition memory test with 64 trials. Thirty-two trials were old (presented in the study phase) and 32 trials were new (lures). The recognition test included an additional remember/know judgement. For each trial, the statement was presented in the middle of the screen until a response key was pressed. Participants had to indicate whether they had seen a stimulus already during the study phase by pressing the "j"-key for old stimuli or the "n"-key for new stimuli. In case of an old-response, they were required to give a remember/know judgement by pressing the "1"-key for remember or the "2"-key for know. The stimuli appeared in randomized order with a response–stimulus interval of 200 ms. After completing the test phase, the participants received the debriefing via email.

2.1.4. Statistical Analyses

For the judgments of truth (JOT), we computed the proportion of "true" responses for each participant and each condition. For the critical JOT scores, that is, for JOT scores of unfamiliar statements, planned contrasts were used to assess the impact of fluency.

For memory performance, the hits (correctly remembered "old" statements) were used as the recognition score. False alarm rates were considered separately because the manipulation of perceptual fluency was not present in new statements. Hit rates were analyzed using a 2 (fluency: fluent vs. disfluent) × 2 (JOT: yes vs. no) design with a repeated measures analysis of variance (ANOVA). Initially, we also analyzed the remember/know responses with the same design; however, as they did not reveal additional insights, we focus on the recognition memory results. For the sake of completeness, the remember/know results are included in the Supplementary Materials. An alpha level of 0.05 was used for all statistical tests.

2.2. Results

2.2.1. Judgements of Truth

The judgements of truth made in the study phase are presented in Table 1. We expected that the statements about unfamiliar cities would more likely be judged as true when presented in the fluent condition compared to the disfluent condition. Although the pattern of results was consistent with this expectation, planned contrasts revealed no significant differences, neither for true statements (M fluent = 0.58 vs. M disfluent = 0.57), t(155) < 1, p = 0.706, d = 0.03, nor when true and untrue statements were collapsed (M fluent = 0.50 vs. M disfluent = 0.49), t(155) < 1, p = 0.624, d = 0.02.

Table 1. Judgements of truth (JOT) as a function of fluency, city familiarity and actual truth of the statement (*M* = Mean, *SD* = Standard deviation).

	Fluent		**Disfluent**	
	M	**SD**	**M**	**SD**
Familiar cities				
true	0.70	0.22	0.71	0.22
untrue	0.34	0.27	0.35	0.30
Unfamiliar cities				
true	0.58	0.26	0.57	0.27
untrue	0.42	0.26	0.41	0.25

2.2.2. Memory Performance

In the test phase, the overall hit rate was *M* = 0.69, *SD* = 0.46 and the false alarm rate was *M* = 0.22, *SD* = 0.12. We used the JOT response of the study phase to create "schema-congruency" as an independent variable. We reasoned that a "yes" response (i.e., the statement was judged as true) reflects that the statement is congruent with one's knowledge, and a "no" response (i.e., the statement was judged as untrue) reflects that the statement is incongruent with one's knowledge. A repeated measures ANOVA with fluency (fluent vs. disfluent) × schema congruency (yes vs. no) revealed no effect of fluency (*M* = 0.69, *SE* < 0.01), F(1,154) < 1, p = 0.876, η_p^2 < 0.01. In contrast, congruent statements were better remembered (*M* = 0.76, *SE* < 0.01) than incongruent statements (*M* = 0.62, *SE* < 0.01), F(1,154) = 88.45, p < 0.001, η_p^2 = 0.37. The interaction between fluency and schema congruency did not reach significance, F(1,154) < 1, η_p^2 < 0.01. These results are depicted in Figure 2.

In order to test whether the schema effect occurred for both actual true and actual wrong statements, we calculated a follow-up ANOVA with the factor schema congruency and actual truth, which resulted in a significant interaction, F(1,153) = 20.71, p < 0.001, η_p^2 = 0.11 (one participant did not enter the analysis due to an empty cell). Post hoc comparisons revealed that the schema effect, that is, better memory for yes-responses, occurred for both true and wrong statements, but the size of the effect was stronger for true statements (*M* = 0.79 for yes-responses and *M* = 0.59 for no-responses) than for wrong statements (*M* = 0.71 for yes-responses and *M* = 0.64 for no-responses).

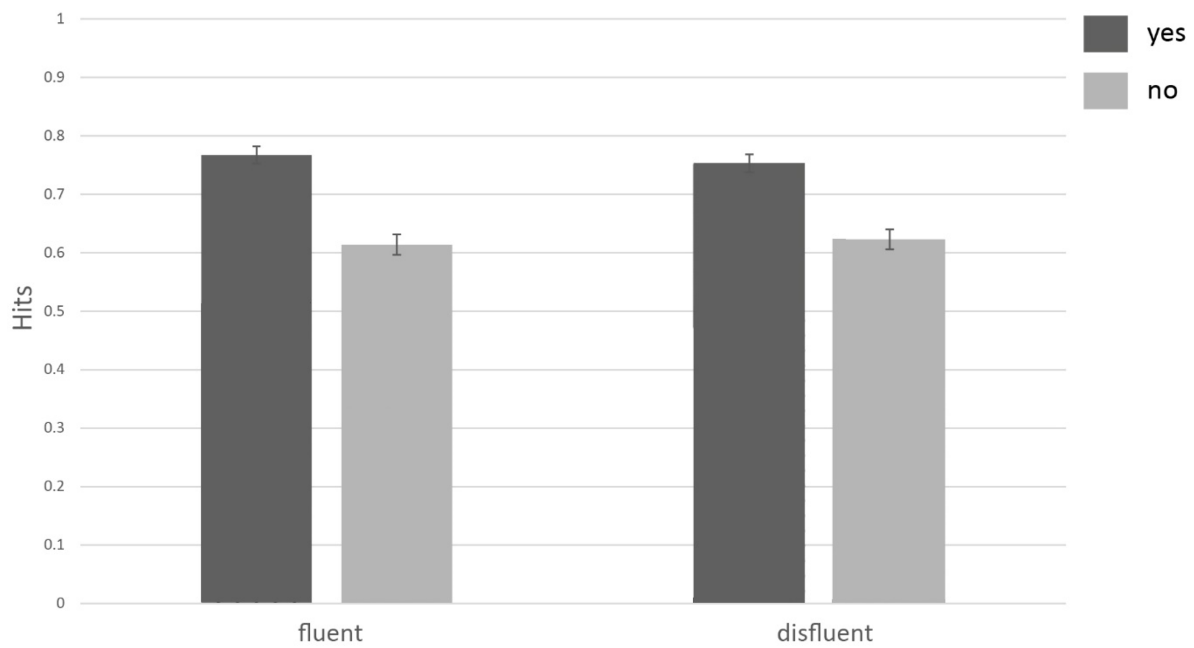

Figure 2. Memory performance for Experiment 1 expressed as mean proportion of hits as a function of perceptual fluency and schema congruency (yes/no). Error bars represent standard errors.

2.3. Discussion

In Experiment 1, we tested the impact of perceptual fluency and schema congruency on subsequent memory after a 24 h retention interval. In line with the hypothesis, the results showed a significant advantage for remembering schema-congruent information, that is, for information that was endorsed as true in the study phase. Perceptual fluency did not affect subsequent memory performance.

Notably, the effect of perceptual fluency in the study phase was not significant, although numerically a small effect was present. Thus, one could argue that the perceptual fluency manipulation did not work at all and thus did not affect subsequent memory. However, as we used the same method as a previous study to induce perceptual fluency [25] and the effect in that study was rather small, but the sample size was much larger, this might rather be a power issue to find the effect of perceptual fluency on judgements of truth. Moreover, Reber and Schwarz conducted a manipulation check by asking a different group of participants to identify words written in the different colors using a clarification procedure as a proxy of perceptual fluency. The results indicated substantially longer identification times for disfluent compared to fluent words. As we used the same colors, the manipulation check can be applied to our study as well.

Accordingly, the fluency manipulation may also have resulted in different reading times. One might argue that longer reading times may have reduced the available time for processing the statements meaningfully, and thus a potential benefit of deeper processing may have been disrupted by the limited time available for processing each statement. One could also ponder that, in the test phase, some participants may have been confused when presented with "old" statements and that they may have rated the truth of the statements again rather than providing recognition judgements, thus distorting the results.

In order to rule out these possibilities, in Experiment 2, we used a different fluency manipulation and we reduced the amount of information tested in the recognition test. Specifically, we adopted the perceptual fluency manipulation used by Diemand-Yaumann et al. (2011) [12] and we presented the statements in hard-to-read vs. easy-to-read fonts in the study phase. Moreover, in the test phase we only presented the city names rather than the complete statements. We reasoned that even under disfluent conditions, the city name, which was always presented as the first word in each statement, should receive sufficient attentional resources for meaningful processing. In Experiment 2, we also included an immediate test condition. This was particularly relevant because it is possible that the fluency manipulation may only affect performance in the short term, but not after a longer retention interval.

3. Experiment 2

3.1. Method

3.1.1. Participants

A total of 80 undergraduate students (22 male and 58 female; age ranged from 18 to 38 years, $M = 21.8$, $SD = 3.1$) from the University of Bern participated in the study for course credits. The study was approved by the ethics committee of the University of Bern and all participants gave consent. Four participants had to be excluded from the recognition test due to missing data in one of the conditions.

3.1.2. Materials

The material consisted of 128 statements of the form "Town A is in country B" (e.g., Osorno is in Chile; Lima is in Peru). Half of the statements were identical to Experiment 1. In addition, a second list of 64 statements was created in the same way. Two additional statements were used for practice. Again, half of the statements were true, and the other half were not; half of the statements contained familiar cities, the other half contained unfamiliar cities. Critically, in the study phase, perceptual fluency was manipulated by using font types. For the fluent condition, the statements were presented in 20-point Arial pure black font or in 22-point Calibri pure black font. For the disfluent condition, statements were presented in 20-point 60% grayscale Harrington font or in a 24-point 60% grayscale Colonna MT font. In each of the two test phases, city names were shown in a 20-point 80% grayscale Courier New font. Exemplary stimuli are presented in Figure 1b. All the conditions were counterbalanced across participants. The participants were randomly assigned to one of eight stimulus lists.

3.1.3. Procedure

The procedure was similar to Experiment 1 with the following exceptions. First, after the study phase, which consisted of 64 statements, a brief filler task was introduced before an immediate recognition memory test was given for half (i.e., 32) of the city names presented during study and another 32 city names that had not been presented before. The procedure was similar as in Experiment 1, except that only the city name (and not the whole statement) was presented in the middle of the screen. The delayed test phase, which had to be completed 24 h later, was similar and consisted of the other half of the cities from the study phase and another set of 32 city names that had not been presented before.

3.1.4. Statistical Analyses

For the judgments of truth (JOT), we performed the same analysis as in Experiment 1. Similarly, for memory performance, we conducted the same ANOVAs, separately for the immediate and the delayed test. Again, an alpha level of 0.05 was used for the statistical tests.

3.2. Results

3.2.1. Judgements of Truth

The judgements of truth made in the study phase are presented in Table 2. We expected that the statements about unfamiliar cities would more likely be judged as true when presented in the fluent condition compared to the disfluent condition. However, there was no indication of any bias towards judging a statement as true when presented in fluent vs. disfluent font.

Table 2. Judgements of truth (JOT) for Experiment 2 as a function of fluency, city familiarity and actual truth of the statement (*M* = Mean, *SD* = Standard deviation).

	Fluent		Disfluent	
	M	**SD**	**M**	**SD**
Familiar cities				
true	0.70	0.21	0.72	0.20
untrue	0.34	0.21	0.35	0.20
Unfamiliar cities				
true	0.57	0.20	0.59	0.21
untrue	0.43	0.22	0.46	0.22

3.2.2. Memory Performance

Immediate Test

In the immediate test, the overall hit rate was M = 0.62, SD = 0.24 and the false alarm rate was M = 0.19, SD = 0.39. The repeated measures ANOVA with fluency (fluent vs. disfluent) × schema congruency (yes vs. no) revealed a main effect of fluency, F(1,76) = 5.75, p = 0.019, η_p^2 = 0.07, indicating that cities from fluent statements were more often remembered than cities from disfluent statements. There was also a main effect of schema congruency, indicating that schema-congruent cities were more often remembered than schema-incongruent cities, F(1,76) = 9.95, p = 0.002, η_p^2 = 0.12. Critically, the interaction between fluency and schema congruency was also significant, F(1,76) = 4.92, p = 0.030, η_p^2 = 0.06. Follow-up t-tests revealed no significant effect for schema congruency when the cities were presented in fluent statements, t(76) = 1.13, p < 0.263, d = 0.13. However, when the cities were presented in disfluent statements, performance for schema-incongruent stimuli was impaired, t(76) = 3.52, p < 0.001, d = 0.40. These results are depicted in Figure 3.

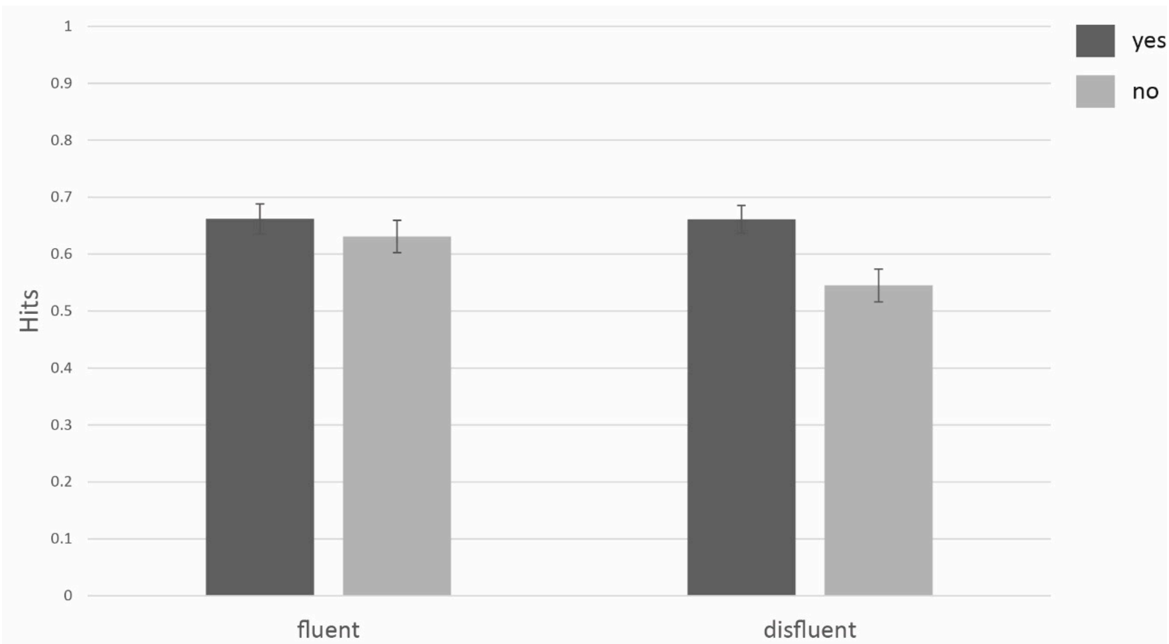

Figure 3. Memory performance for Experiment 2, immediate test, expressed as mean proportion of hits as a function of perceptual fluency and schema congruency (yes/no). Error bars represent standard errors.

In order to test whether the schema effect occurred for both actual true and actual wrong statements, we calculated a follow-up ANOVA with the factor schema congruency and actual truth, which resulted in a significant interaction, F(1,76) = 11.98, p < 0.001, η_p^2 = 0.14. Post hoc comparisons revealed that the schema effect occurred for city names that had been presented in true statements at the study phase (M = 0.68 for yes-responses and $M = 0.54$ for no-responses), but not for wrong statements ($M = 0.62$ for yes-responses and $M = 0.62$ for no-responses).

Delayed Test

In the delayed test, the overall hit rate was $M = 0.46$, $SD = 0.24$ and the false alarm rate was $M = 0.22$ $SD = 0.14$. The 2 × 2 repeated measures ANOVA with fluency (fluent vs. disfluent) × JOT response (yes vs. no) revealed no effect of fluency, $F(1,75) < 1$ $p = 0.596$, $\eta_p^2 < 0.01$. The main effect of congruency was significant, $F(1,75) = 6.13$, $p = 0.016$, $\eta_p^2 = 0.01$, indicating better performance for cities from schema-congruent than incongruent statements. The interaction between fluency and JOT response was not significant, $F(1,75) < 1$, $p = 0.407$, $\eta_p^2 < 0.01$. Thus, the results of the delayed test replicated Experiment 1. These results are depicted in Figure 4.

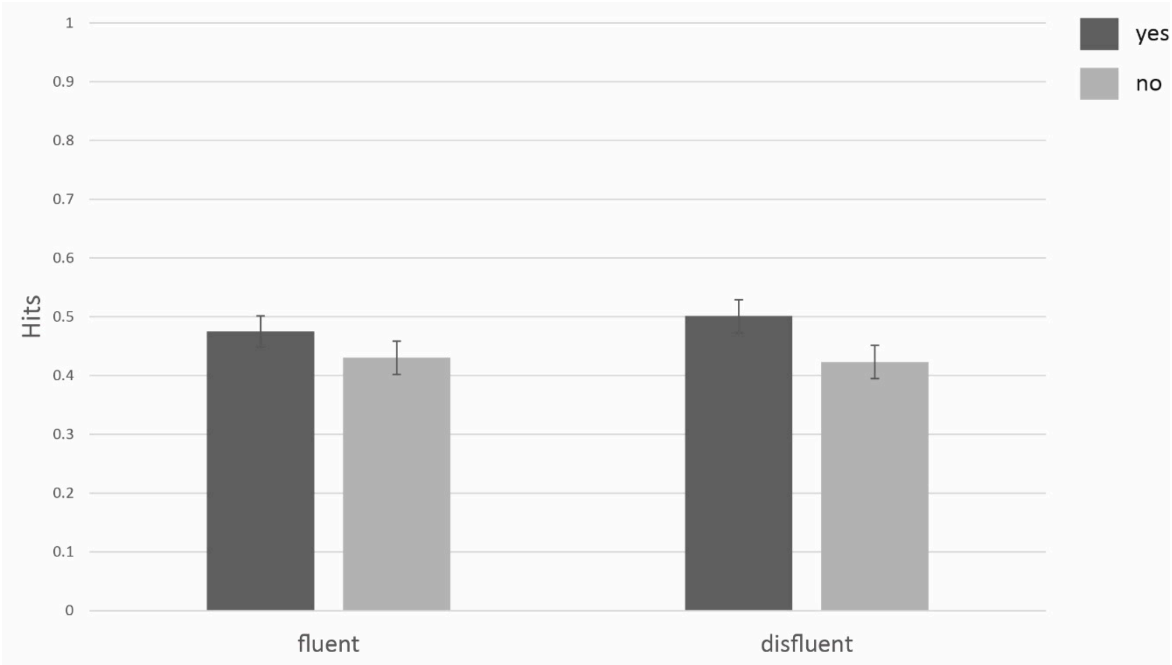

Figure 4. Memory performance for Experiment 2, delayed test, expressed as mean proportion of hits as a function of perceptual fluency and schema congruency (yes/no). Error bars represent standard errors.

In order to test whether the schema effect occurred for both actual true and actual wrong statements, we calculated a follow-up ANOVA with the factor schema congruency and actual truth. As in the immediate test, this resulted in a significant interaction, $F(1,74) = 22.53$, $p < 0.001$, $\eta_p^2 = 0.23$ (one participant did not enter the analysis due to an empty cell). Post hoc comparisons revealed that the schema effect occurred for city names that had been presented in true statements at the study phase ($M = 0.53$ for yes-responses and $M = 0.36$ for no-responses), but not for wrong statements ($M = 0.42$ for yes-responses and $M = 0.46$ for no-responses).

3.3. Discussion

In Experiment 2, we tested the impact of processing fluency and schema congruency on immediate and subsequent memory after a 24 h retention interval. In the immediate test, perceptual fluency compensated the disadvantage of schema-incongruency. That is, statements that were processed in the fluent condition were remembered equally well independent of whether or not they were endorsed as true. In contrast, for statements processed disfluently, a schema congruency effect emerged, which is expressed as better performance for cities from statements endorsed as true in the study phase compared to those judged as untrue. Thus, perceptual fluency can boost initial memory for schema-incongruent memory, most likely due to short-lived perceptual traces, which are cropped during consolidation, but it does not boost sustainable learning.

In the delayed test, in general, the results from Experiment 1 were replicated. They showed a significant advantage for remembering schema-congruent information, that is, for information that was endorsed as true in the study phase. However, in contrast to Experiment 1, in which the statements were presented again at test, in Experiment 2, in which only the city name was presented, memory performance for endorsed city names presented in untrue sentences did not show the congruency effect. This indicates that the memory advantage for schema-congruent untrue statements in Experiment 1 depended on the reinstatement of the study context.

More important, perceptual fluency did not affect subsequent memory performance after 24 h, thus replicating Experiment 1. The latter result rules out the possibility that any of the potential confounds addressed in the discussion of Experiment 1 has affected the impact of (dis)fluency. Together, the results indicate that while schema congruency supports sustainable learning, perceptual fluency (rather than disfluency) boosted memory, but only in the short term.

4. General Discussion

The goal of this study was to evaluate the contribution of perceptual fluency and schema congruency to sustainable learning. We reasoned that for experimental manipulations or learning strategies to be classified as sustainable, they should be effective for at least 24 h in producing a beneficial learning effect. Our results indicated that schema congruency met this criterion by producing a consistent memory advantage across two experiments. In contrast, perceptual fluency only boosted memory performance when learning was tested immediately. In this condition, fluency helped performance specifically for schema-incongruent information, temporarily wiping out the disadvantage of having to remember schema-incongruent information. Notably, in contrast to the hypothesis derived from studies arguing that perceptual *disfluency* might serve as a desirable difficulty and thus boost sustainable learning, in this condition, *fluency* produced a beneficial effect. Our results add to the inconsistent picture and we concur with the conclusion of Weissgerber and Reinhard (2017, p. 216) that “its usefulness is not as straightforward as its easy application suggests”[17].

Notably, disfluency can be seen as both as a marker that indicates that more resources must be recruited for stimulus processing and as a cognitive conflict that requires cognitive resources to be resolved. When we consider disfluency as a marker that indicates that more resources must be recruited, it is necessary that additional resources are available in the first place. This may be true in situations in which plenty of time is available at encoding. There is evidence that the time available at study can indeed affect the effect of fluency [14]. Probably, in the design of our study in which we instructed the participants to respond as fast as possible, participants did not recruit additional resources. Thus, disfluency may have presented a kind of cognitive conflict because decoding the stimuli required additional cognitive resources, which were not available for stimulus encoding. This interpretation is consistent with studies in which task switching was manipulated at encoding. There is consistent evidence that memory for switch trials, which require additional processes to select the relevant task set, is impaired [19,22,23]. Under which conditions (dis)fluency operates as a memory enhancer or encoding distractor is subject to further research.

For application in the classroom context, other desirable difficulties which rely on semantic processing are much more recommendable. These include varying the conditions of learning, interleaving the practice of separate topics, spacing study sessions, and using testing as study opportunities [4–8]. Desirable difficulties are intended to overcome subjective impressions of familiarity with the study materials which mislead the learner to believe that study materials have already been sufficiently learned. Specifically, varying the conditions of learning is intended to counteract that learning becomes contextualized, that is, that the study materials are easily retrieved only in one specific context. Thus, studying (and retrieving) the same materials in different rooms can lead to increased and more sustainable learning [5]. Moreover, it has been demonstrated that spacing study sessions, in particular by interleaving the practice of separate topics, is an effective way to boost learning [33]. Last, but not least, study materials must be tested not only to control the successful encoding, but also to provide further learning opportunities. Specifically, repeated retrieval practice is more efficient than repeated study [8,34].

Regarding the results of schema congruency, our results are promising for application purposes. They indicate that the activation of prior knowledge enhances subsequent memory in a sustainable way. Activating pre-existing schemata can also enhance opportunities for associating new study materials. In fact, there is ample evidence that advance organizers and advance quizzes benefit learning, and the latter even work when the retrieval attempts are unsuccessful [35–37]. Activating pre-existing schemata can also be accomplished via priming. Interestingly, even rapid serial presentation of concepts may be sufficient to activate pre-existing schemata and to boost learning [38]. Thus, for educational purposes, judgements of truth are beneficial, can be used easily and, conceptually, they can be considered as a kind of "testing as a study opportunity".

Although this study was not intended to test the transfer into the classroom, several elements may be adopted into the educational context. For example, in order to support learning in the context of geography, maps or pictures of cities and countries can be presented at the beginning of a course in order to activate prior knowledge or to create new memories and schemata, respectively [29]. Presenting additional information about these regions at another study session enhances learning because prior knowledge can be activated in which this information can be integrated. Moreover, presenting the information in multiple contexts such as history, culture, and religion can further boost sustainable learning.

Congruency with prior knowledge can also improve second language learning. Specifically, using reading materials of topics that are already familiar in terms of cultural and social information activates pre-existing schemata and allows the better integration of new information presented in the foreign language [39]. To match the pre-existing knowledge of students and to enhance their motivation, students may be instructed to select topics based on their own interests [40]. According to a three-phase model, in the first phase, pictures or movies should be used in order to activate the students' existing schemata. In the second phase, the students should write about their knowledge and discuss it with other students in order to continue to build upon their own existing schemata [39]. In the third phase, the students should integrate this new knowledge in a new schema structure. Thus, this model offers a way how preexisting knowledge can be used in classroom and educational settings.

To conclude, our results suggest that sustainable and effective desirable difficulties are those which draw on semantic processing of the study materials. Following from Neisser's claim that the results from the psychology of memory must be useful in everyday life and thus have ecological validity [41,42], our study is intended to stimulate the exchange between education and cognitive psychology and to transfer knowledge from the laboratory to the field. An important task of experimental cognitive psychology is to test the validity of the supposed interventions. Thus, a main conclusion from the present study is that, despite its appeal, the disfluency manipulation is not yet ready for transfer into the classroom.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/su13137040/s1, Tables S1 and S2.

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Data Availability Statement: The data presented in this study are made openly available in the Research Data Repository of the University of Bern or they can be requested directly from M.C.M.

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