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Effectiveness of Self-Generation During Learning is Dependent on Individual Differences in Need for Cognition

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Abstract

Self-generated information is better recognized and recalled than read information. This so-called generation effect *has been replicated several times for different types of stimulus material, different generation tasks, and retention intervals. The present study investigated the impact of individual differences in learners' disposition to engage in effortful cognitive activities (need for cognition, NFC) on the effectiveness of self-generation during learning. Learners low in NFC usually avoid getting engaged in cognitively demanding activities. However, if these learners are explicitly instructed to use elaborate learning strategies such as self-generation, they should benefit more from such strategies than learners high in NFC, because self-generation stimulates cognitive processes that learners low in NFC usually tend not to engage in spontaneously. Using a classical word-generation paradigm, we not only replicated the generation effect in free and cued recall but showed that the magnitude of the generation effect increased with decreasing NFC in cued recall. Results are consistent with our assumption that learners higher in NFC engage in elaborate processing even without explicit instruction, whereas learners lower in NFC usually avoid cognitively demanding activities. These learners need cognitively demanding tasks that require them to switch from shallow to elaborate processing to improve learning. We conclude that self-generation is beneficial regardless of the NFC level, but our study extends the existing literature on the generation effect and on NFC by showing that self-generation can be particularly useful for balancing the learning disadvantage of students lower in NFC.*

Keywords: desirable difficulties; generation effect; incidental learning; intentional learning; need for cognition

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1. Introduction

Students often assume that learning strategies that are perceived as easy and effortless (e.g., rehearsal, rereading, or underlining) are highly effective. However, extant research suggests that under certain conditions learning is more effective when learners intentionally make the learning process more difficult (Bjork and Bjork 2011). Specific difficulties, such as distributed learning sessions compared to massed learning (e.g., Cepeda et al. 2006), interleaving topics (e.g., Dunlosky et al. 2013), testing new knowledge (e.g., Roediger and Karpicke 2006), and self-generation of information (e.g., McDaniel et al. 1988; Slamecka and Graf 1978), stimulate processes which are beneficial to the learning process. Such difficulties often result in long-lasting memory for the learned material and make it easier to apply the acquired knowledge to new situations. Thus, they are termed *desirable difficulties* (Bjork 1994).

The so-called *generation effect* (learners recall self-generated information better than read information) has been investigated extensively (for a meta-analysis, see Bertsch et al. 2007). Several extant studies used the classical word-generation paradigm by Slamecka and Graf (1978; see also e.g., McDaniel et al. 1988). In these studies, learners were presented with word pairs consisting of a context word and a target word. In the *read* condition, learners read an associated word pair (SADDLE – HORSE). In the *generate* condition, they completed fragmented target words (SADDLE – H_ _ _ _) with the aid of the context word and a specific encoding rule (e.g., find the associated word). In subsequent learning tests, learners recalled and recognized generated target words better than read target words. The learning advantage of generated over read information has been replicated, for example, for different learning measures (recognition, cued recall, and free recall, e.g., McDaniel et al. 1988; Slamecka and Graf 1978), for target and context words (McDaniel and Waddill 1990), for sentences (Graf 1980, 1981), texts (e.g., Doctorow et al. 1978; McDaniel et al. 1986; McDaniel et al. 2002), and numbers (e.g., Gardiner and Rowley 1984). It has been shown for immediate and delayed recall (e.g., Schweickert et al. 1994; Slamecka and Frevreiski 1983), for within- vs. between-subject designs (Fiedler et al. 1992), and for different generation rules (Slamecka and Graf 1978, Exp.1 and 2). Empirical studies like these suggest that self-generation might be a useful supplement to commonly used learning strategies in education.

Despite the extensive body of extant research on the generation effect, its general conditions of occurrence still need further clarification. McDaniel and Butler (2010) pointed out that self-generation is not necessarily beneficial for every learner and not appropriate for every type of learning material and criterial task. Instead, they assume that complex interactions between the type of generation task, learner characteristics, learning material, and criterial task need to be considered when using self-generation to improve learning (see also McDaniel and Einstein 1989, 2005; Einstein et al. 1990). The central claim of McDaniel and Butler's contextual framework is that "desirable difficulties are those that stimulate processing that is not redundant with the processing spontaneously engaged by the learner (which […] will depend on learner characteristics, materials, or both) and that matches the demands of the criterial task" (p.179). In other words, self-generation can improve learning only when the generation task stimulates cognitive processes that go beyond the processes individual learners engage in spontaneously during learning or beyond processes encouraged by specific learning-material characteristics. One widely researched learner characteristic shown to differentially affect the degree that learners spontaneously engage in cognitive processing is a learner's need for cognition. Hence, need for cognition, in turn, is likely to affect the effectiveness of self-generation during learning.

1.1 Need for cognition and the generation effect

Need for cognition (NFC) can be defined as a learner's individual disposition to engage in effortful cognitive activities and to enjoy thinking and being cognitively challenged (Cacioppo and Petty 1982; Cacioppo et al. 1984; Cacioppo et al. 1986). High NFC is associated with thorough processing of arguments and argument quality (Cacioppo et al. 1983; Cacioppo et al. 1986), with thorough processing of task-relevant information (Fleischhauer et al. 2014; Reinhard 2010, Exp. 1 & 2; Reinhard and Dickhäuser 2009; Verplanklen et al. 1992), and thorough processing of learning materials (Sadowski and Gülgöz 1996). Moreover, individuals high in NFC use more efficient learning strategies than learners low in NFC (Cazan and Indreica 2014), they tend to have better self-control during learning (Bertrams and Dickhäuser 2009; Cazan and Indreica 2014), and they are more willing to tackle difficult tasks (See et al. 2009; Weißgerber et al. 2018).

Based on these findings, it is not surprising that individuals high in NFC recall learned information better than individuals low in NFC (Cacioppo et al. 1983; Kardash and Noel 2000). They are more likely to solve complex problems or tasks (Coutinho 2006; Coutinho et al. 2005; Nair and Ramnarayan 2000) and they perform better on learning tests (Heijne-Penninga et al. 2010; Sadowski and Gülgöz 1996). Consequently, individual differences in NFC are associated with academic achievement (Luong et al. 2017). High NFC was found to be associated with course achievements (Bertrams and Dickhäuser 2009; Sadowski and Gülgöz 1996), university GPA (grade point average) (Grass et al. 2017), course grades mediated by difficulty of learning material (Leone and Dalton 1988), and performance in exams mediated by self-regulated learning and deep information processing (Cazan and Indreica 2004). In sum, NFC seems to be directly or indirectly related to learner characteristics relevant for academic success and to different forms of academic performance and achievement measures (for a review see Jebb et al. 2016; see also the meta-analyses by Richardson et al. 2012 and von Stumm and Ackermann 2013).

Learners low in NFC are 'cognitive misers' (Cacioppo et al. 1986; Cacioppo et al. 1996) who usually avoid getting engaged in cognitively demanding activities. Consistent with these findings, low NFC learners are found to be less willing to use elaborate learning strategies such as desirable difficulties in self-regulated learning than high NFC learners (Weißgerber et al. 2018). In other words, learners low in NFC do not expend more cognitive resources on learning than necessary.

However, if learners low in NFC are explicitly instructed to use elaborate learning strategies such as self-generation, they should benefit more from such strategies than learners high in NFC, because self-generation stimulates cognitive processes that learners low in NFC usually tend not to engage in spontaneously (McDaniel and Butler 2010). Learners high in NFC, however, should readily engage in effortful cognitive processing of learning materials even when this is not explicitly required by the task (e.g., when just reading a text). For these learners, self-generation should contribute only weakly to their already elaborate processing. In sum, we assume that self-generation requires learners low in NFC to switch from less demanding shallow processing to elaborate processing, whereas learners high in NFC constantly use more elaborate processing strategies (see e.g., Kardash and Noel 2000). Consequently, self-generation (compared to reading) should improve learning for learners low in NFC more strongly than for learners high in NFC.

2. The present study

Using a modified version of the classical word-generation paradigm by Slamecka and Graf (1978) and McDaniel et al. (1988), the aim of the present study was to investigate the extent that effectiveness of self-generation in learning varies as a function of individual differences in NFC. Learners were presented with word-pairs consisting of a context word and a target word. Half of the presented word pairs consisted of incomplete target words which the learner needed to complete. (1) We aimed to replicate the generation effect, that is, we expected better recall for successfully generated target words than for read target words. (2) We expected to find a more pronounced generation effect for low NFC learners compared to high NFC learners.

Participants were also randomly assigned to one of two different learning settings. Extant research found that the generation effect is more strongly pronounced in incidental than in intentional learning settings (Bertsch et al. 2007). Thus, to optimally investigate the expected interaction of learning condition (generation vs. reading) and individual differences in NFC, half of the participants were not informed about the learning test. However, learning in educational contexts is often intentional, for example when teachers and students purposefully use learning strategies to prepare for a learning test or to enhance the students' learning outcome. Thus, demonstrating that the effectiveness of self-generation differs as a function of individual differences in learners' NFC not only in an incidental but also in an intentional learning setting would be highly relevant for adopting self-generation practices to applied educational contexts. Hence, half of the participants were assigned to an intentional learning setting.

3. Method

3.1 Participants

Participants were 121 undergraduates, 19 grad students, and 3 non-students recruited at the campus of the University of Kassel (Germany). They came from varying disciplines with only 17 participants being undergraduate (n = 8) or graduate Psychology students (n = 9). None of them surmised the exact purpose of our study. Of the 143 participants in total (75 female, 68 male), 128 were native speakers of German. The age ranged from 17 to 55 with a mean age of 23.87 (SD = 4.73). All participants provided their written consent and were reimbursed with 5€ for their participation.

3.2 Materials and Procedure

Participants were tested individually or in groups of two to six in a laboratory. Tasks and stimuli were presented on notebook computers.

Word-generation task. Each participant was presented with 36 German word pairs in total consisting of a context word (e.g., *KOKON*/ cocoon) and a semantically associated target word (e.g., *RAUPE*/ caterpillar). Each target word belonged to one of six categories: fruit, body parts, clothing, animals, insects, and music instruments. Six target words from each category were presented. Half of the word pairs were complete (KOKON – RAUPE), whereas the other half of the word pairs contained a fragmented target word (KOKON – R_U_E) that participants were required to complete (varied within subjects). The number of slots indicated the number of missing letters in the generate condition. Each word pair was presented in the middle of the notebook screen for a duration of 7 seconds with a 3 second interval between trials. Participants were instructed to record the read and generated target words on a sheet of paper. Half of them were instructed to memorize the target words for a later test (intentional learning setting, n = 71), and the other half was naive about the test (incidental learning setting, n = 72).

Each word pair occurred equally often in the generate and the read condition across participants. To ensure a balanced presentation of word pairs in both conditions, the 36 word pairs were divided into four blocks of nine word pairs. Two blocks (18 word pairs) were presented in the generate and two blocks in the read condition for each participant. Each block was paired equally often with each of the other three blocks in both conditions, which resulted in six stimulus lists. Participants were randomly assigned to one of the six lists. Presentation order of learning condition (generate-read vs. read-generate) was balanced across participants. Word pairs were presented in randomized order within each learning condition. After the presentation of the final word pair, the experimenter collected the sheets of paper with the written target words.

Distractor task. After the word generation task, participants completed a computerized questionnaire on sleeping habits adopted from Horne and Ostberg (1975), which took participants about 5 minutes to complete.

Free and cued recall. Following the distractor task, participants were asked to recall as many target words as possible within 5 minutes (free recall). After the free recall task, context words were presented for an additional 5 minutes in random order, and participants were asked to provide the target word to each context word (cued recall).

Need for cognition. Participants completed the German 33-item need for cognition scale by Bless et al. (1994). They read short statements (e.g., *I really enjoy finding new solutions to problems*; *I prefer my life to be filled with puzzles that I must solve*) and answered on a 7-point Likert scale ranging from 1 (*completely disagree*) to 7 (*completely agree*). Internal consistency of the NFC scale was high (Cronbach's α = .88). A mean NFC score was calculated for each participant (M = 4.84; SD = .68; Min = 3.09; Max = 6.27).

Additional measures. For the purpose unrelated to the present study, we administered the personal and global Belief in a Just World Scale (Dalbert 1999) and the academic self-concept scale (Dickhäuser et al. 2002).

Control measures. Participants in the incidental learning group were asked to indicate whether they had expected a test and prepared for it. In addition, all participants reported on a 7-point Likert scale the extent that they found completing the fragmented target words difficult (ranging from 1 – *not difficult at all* to 7 – *very difficult*), the extent that they were motivated in identifying the fragmented target words in the learning phase and also in recalling the target words in the tests phase (ranging from 1 – *not motivated at all* to 7 – *highly motivated*). Given that NFC is an indicator of an individual's disposition to engage in effortful cognitive activities (e.g., Cacioppo and Petty 1982), NFC was expected to correlate with learners' self-reported task-specific motivation but not with self-reported generation difficulty. Finally, participants were asked to report any additional strategies they used (such as grouping target words into semantic categories or rehearsal) to memorize the target words during the learning phase. Given extant findings that learners higher in NFC use more efficient learning strategies than learners lower in NFC (Cazan and Indreica 2014), we assumed that learners higher in NFC would use not only more strategies than learners lower in NFC but also more elaborate learning strategies. Sociodemographic data were collected via an additional questionnaire.

4. Results

Control measures. As expected, learners' NFC correlated significantly with learners' self-reported motivation for generating target words (r = .24, p = .004) and with their self-reported motivation to recall the target words in the test phase (r = .19, p = .02) but not with self-reported generation difficulty (r = -.14, p = .10). In the intentional learning group, 16 of the 71 learners reported the use of elaborate learning strategies such as grouping target words into categories (fruit, insects, body parts etc.). Five learners reported the use of mnemonic strategies such as rehearsal or rereading of their recorded target words, and 50 learners reported not having used specific learning strategies. Despite the unannounced test, 10 of the 72 learners in the incidental learning group reported to have noticed the semantic categories of the target words and that they tried to make use of the categories to generate target words, 2 rehearsed or reread the target words once, and 60 used no specific processing strategy. No differences in NFC were found among learners who reported the use of elaborate learning strategies, mnemonic strategies, and no strategies.

Forty-nine of the 72 incidental learners reported not having expected a test. There was no significant difference in the learners' NFC between those who did and those who did not expect the unannounced learning test. Although 23 incidental learners checked the box *Yes, I did expect a learning test* in the final questionnaire, 19 of these participants reported in the open answer field on strategy use not to have used any learning strategy at all (i.e., they not even tried to memorize the word pairs) or they reported that they did not exactly prepare for a learning test, even if they surmised that the words would be important somehow later in the study. We will return to the four remaining incidental learners who have expected and prepared for the unannounced learning test when we report free and cued recall accuracy.

Accuracy of recording target words. In total, 90.1% of the generated and read target words have been recorded correctly in the learning phase. In the read condition, 96.7% have been recorded correctly. In the generate condition, 83.5% were generated successfully. No differences in generation accuracy were found between learning settings, and the accuracy did not decrease with decreasing NFC. Although learners lower in NFC reported less motivation for generating target words than learners higher in NFC, they made no more errors generating target words than learners higher in NFC.

4.1 Free and cued recall accuracy

Data analysis procedure. We estimated Generalized Linear Mixed Models (GLMMs) with a logit link function (Dixon 2008) for free and cued recall accuracy as dependent variables. One word pair from List 3 (0.4% of the data) was excluded from the analysis, because of a technical error in displaying the word pair. The models were estimated and tested with the software packages *lme4* (Bates et al. 2014) and *lmerTest* for R (Kutznetsova et al. 2014). The number of possible iterations of the optimizer was increased to 100,000 to account for the models' complexity. All significance tests were based on a Type I error probability of .05. Separate models were estimated for free recall accuracy and cued recall accuracy.

To test for differences in learners' free and cued recall performance as a function of learning condition, learning setting, and individual differences in NFC, learning condition and learning setting were included as contrast-coded predictor variables (learning condition: -1=read, 1 = generate; learning setting: -1 = incidental, 1 = intentional) and NFC as continuous grand-mean centered predictor variable in the GLMMs with free and cued recall accuracy as dependent variables. Two-way and three-way interaction effects were estimated for all variables. In addition, the intercept and all main and interaction effects were estimated for target words that were recorded correctly in the learning phase (90.1% of the data). From a theoretical perspective, estimating learning outcomes for incorrectly recorded target words, which could not have been learned properly, would be pointless. Moreover, from an applied educational perspective, teachers who want to use self-generation to improve student learning must ensure that their students are capable of generating the information from the planned lessons (McDaniel and Butler 2010) and that the critical information can be generated successfully. To this aim, accuracy of recording target words was included as another dummy-coded predictor variable with correctly recorded target words being the reference category (0 = correctly recorded target words, 1 = incorrectly recorded target words). Finally, because participants and word pairs were sampled from a larger population, intercepts for persons and word pairs were allowed to vary randomly. Descriptive statistics are provided in Table 1. The parameter estimates for the fixed and random effects are provided in Table 2. In the following sections, we focus on the main and interaction effects of learning condition, learning setting, and NFC for correctly recorded target words only.

Table 1

Descriptive Statistics for Free Recall and Cued Recall for Generated and Read Target Words and NFC During Incidental and Intentional Learning (N=143)

	Incidental			Intentional		
		Generate	Read		Generate	Read
	n	*M* (*SD*)	*M* (*SD*)	*n*	*M* (*SD*)	*M* (*SD*)
Free recall accuracy[a]	72	0.42 (0.49)	0.21 (0.41)	71	0.41 (0.49)	0.24 (0.42)
Cued recall accuracy[a]	72	0.81 (0.39)	0.54 (0.50)	71	0.82 (0.39)	0.56 (0.50)
NFC	72	4.90 (0.61)		71	4.78 (0.74)	

Note. [a]proportions. Means and standard deviations for free and cued recall accuracy are provided for correctly recorded target words.

Table 2

Fixed Effects and Variance Components in the GLMM for Free Recall Accuracy and Cued Recall Accuracy

Parameter	Free recall accuracy β (*SE*)	Cued recall accuracy β (*SE*)
	Fixed Effects	
Intercept	-0.91 (0.13)*	1.08 (0.24)*
Learning condition[a]	0.51 (0.04)*	0.85 (0.04)*
Learning setting[a]	0.04 (0.06)	0.10 (0.09)
NFC[b]	0.05 (0.06)	0.22 (0.09)*
Learning condition × Learning setting	-0.03 (0.04)	-0.02 (0.04)
Learning condition × NFC	-0.03 (0.04)	-0.09 (0.04)*
Learning setting × NFC	0.13 (0.06)*	-0.07 (0.09)
Learning condition × Learning setting × NFC	-0.03 (0.04)	0.07 (0.04)
Accuracy of recording target words[c]	-2.25 (0.33)*	-1.37 (0.23)*
Accuracy of recording target words × Learning condition	-1.94 (0.32)*	-2.39 (0.23)*
Accuracy of recording target words × Learning setting	-0.04 (0.33)	-0.14 (0.23)
Accuracy of recording target words × NFC	0.49 (0.44)	0.21 (0.25)
Accuracy of recording target words × Learning condition × Learning setting	0.14 (0.32)	-0.20 (0.22)
Accuracy of recording target words × Learning condition × NFC	-0.88 (0.44)*	-0.45 (0.25)
Accuracy of recording target words × Learning setting × NFC	-1.37 (0.44)*	-0.16 (0.25)
Accuracy of recording target words × Learning condition × Learning setting × NFC	0.66 (0.44)	0.17 (0.25)
	Variance Components	
Subjects	0.28 (0.52)	0.84 (0.92)
Items	0.44 (0.67)	1.71 (1.31)

Note. [a]contrast-coded, [b]grand mean-centered, [c]dummy-coded. Learning condition: -1=read, 1=generate; Learning setting: -1=incidental, 1=intentional; Accuracy of recording target words: 0=correctly recorded target words, 1=incorrectly recorded target words.
*p<0.05 (two-tailed)

Free recall accuracy. The GLMM analysis with free recall accuracy as dependent variable revealed a significant main effect of learning condition (β = 0.51, z = 14.34, p < .001) indicating that learners recalled significantly more generated than read target words. Moreover, the analysis revealed a significant two-way-interaction of learning setting and NFC (β = 0.13, z = 2.20, p = .03). Recall for target words increased significantly with increasing NFC when learning was intentional (β = 0.18, z = 2.45, p = .01) but not when learning was incidental (see Figure 1).

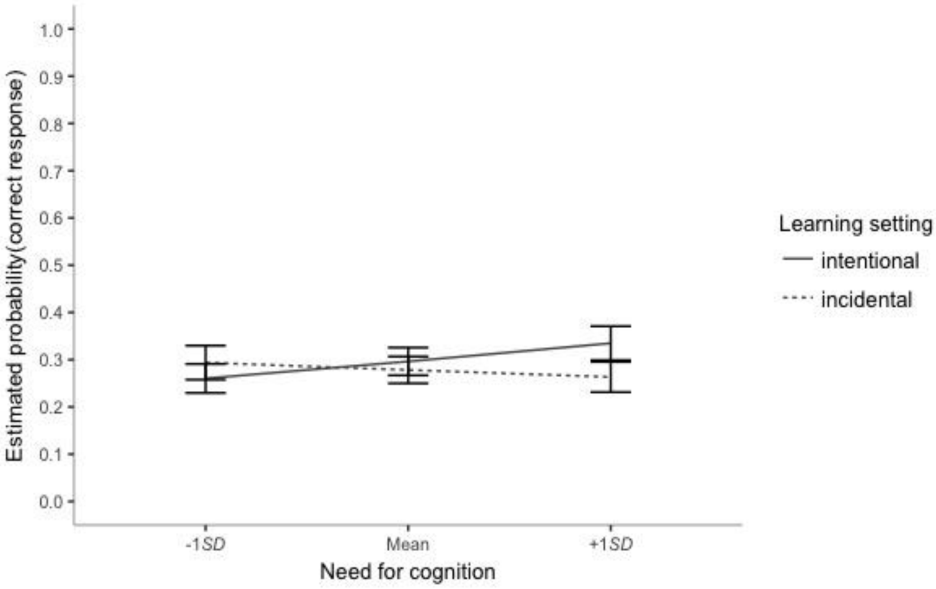

Figure 1. Estimated probability for accurately recalling target words (free recall) for incidental and intentional learning: Simple slopes for need for cognition and differences between learning settings estimated at three different levels of need for cognition.

In sum, we replicated the generation effect (Hypothesis 1), although we found no significant differences in the magnitude of the generation effect as a function of individual differences in NFC (Hypothesis 2). Our findings additionally indicate that learners higher in NFC prepared better for the announced learning test than learners lower in NFC.

Cued recall accuracy. The GLMM analysis with cued recall accuracy as dependent variable revealed significant main effects of learning condition ($\beta = 0.85$, $z = 19.69$, $p < .001$) and NFC ($\beta = 0.22$, $z = 2.44$, $p = .01$). Both main effects were further qualified by a significant two-way interaction of learning condition and NFC ($\beta = -0.09$, $z = -2.03$, $p = .04$). Although all learners recalled generated target words significantly better than read target words (generation effect), the simple effect of learning condition was more strongly pronounced for learners lower in NFC (NFC minus 1 *SD*: $\beta = 0.93$, $z=15.11$, $p < .001$) than for learners higher in NFC (NFC plus 1 *SD*: $\beta = 0.76$, $z = 12.61$, $p < .001$). In other words, learners lower in NFC benefited more from generating target words than learners higher in NFC (see Figure 2). Moreover, the simple slope for NFC was significant in the read condition ($\beta = 0.31$, $z = 3.25$, $p = .001$) but not in the generate condition. That is, improved test performance with increasing NFC was found only in the read condition, whereas individual differences in NFC did not affect cued recall accuracy in the generate condition (Figure 2).

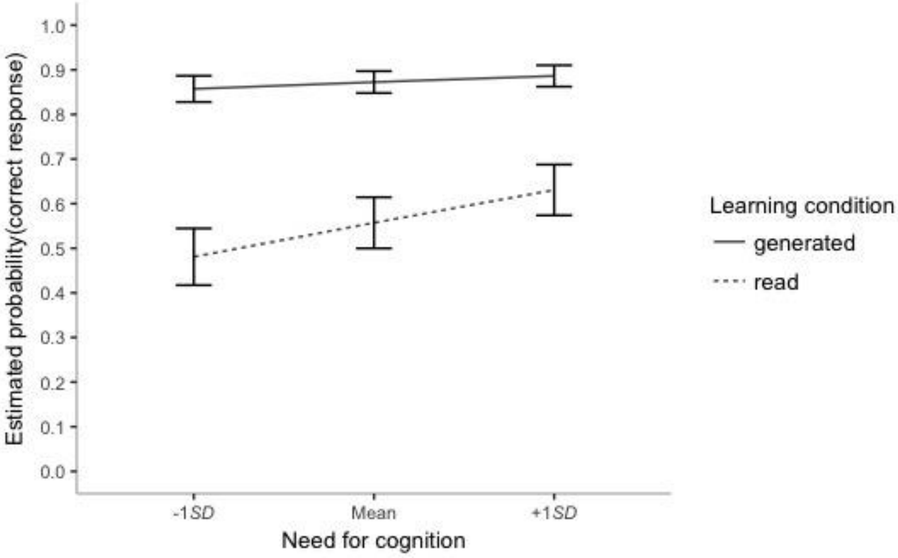

Figure 2. Estimated probability for accurately recalling generated and read target words (cued recall): Simple slopes for need for cognition and differences between learning conditions estimated at three different levels of need for cognition.

In sum, these findings are consistent with Hypotheses 1 and 2. We replicated the generation effect and learners lower in NFC benefited more from the generation effect than learners higher in NFC. Moreover, these findings revealed no differences between learning settings.

Finally, to test if our results were driven or contorted by test expectancy in the incidental learning setting, the four learners who reported to have expected and prepared for a learning test by memorizing the presented word-pairs were treated as intentional learners in additional analyses of free and cued recall accuracy (intentional learning setting: n = 75, incidental learning: n = 68). This did not change the results in terms of levels of significance.

5. Discussion

The aim of the present study was to investigate the moderating effect of individual differences in learners' NFC on the generation effect. We expected (1) to replicate the generation effect and (2) to find a more strongly pronounced generation effect for learners lower in NFC than for learners higher in NFC. The results of the present study supported Hypothesis 1 and corroborated Hypothesis 2 for cued recall accuracy as dependent variable.

Learners recalled more generated target words than read target words with both free and cued recall accuracy as dependent variables. These results are consistent with extant empirical research on the beneficial effects of generation (for an overview, see Bertsch et al. 2007). However, our study extends the existing literature on the generation effect, because our findings showed that individual differences in learners' NFC moderate the magnitude of the generation effect. As expected, the analysis of cued recall accuracy revealed that the generation effect was more strongly pronounced for learners lower in NFC than for learners higher in NFC. That is, learners lower in NFC benefited significantly more from generating target words than learners higher in NFC. This finding is consistent with the idea that desirable difficulties such as self-generation are beneficial when they stimulate cognitive processes that learners tend not to engage in spontaneously (e.g., see

McDaniel and Butler 2010). Our finding that learners lower in NFC recalled less read target words than learners higher in NFC indicates that learners lower in NFC are cognitive misers who processed the read word pairs shallower than learners higher in NFC. However, the same learners recalled generated target words as accurately as the learners higher in NFC. We assume that especially the learners lower in NFC benefited from the generation task (as indicated by a more strongly pronounced generation effect compared to learners higher in NFC), because self-generation stimulated more elaborate cognitive processing of the word pairs. In other words, self-generation required them to switch from shallow cognitive processing to more elaborate processing (Kardash and Noel 2000). However, with increasing NFC, learners increasingly engaged in elaborate cognitive processing of the learning material (even without explicit instruction) as indicated by increasingly improved recall of read target words. For these learners, self-generation becomes increasingly redundant to the extent that they already show elaborate processing independent of the specific task. Consequently, learners higher in NFC benefit less from the generation task than learners lower in NFC. It is noteworthy that in the generation condition, there was no main effect of NFC. Learners lower in NFC recalled as much target words as learners higher in NFC. In other words, self-generation helped the learners lower in NFC to close the learning gap on learners higher in NFC.

The finding that cued recall accuracy for read target words improved with increasing NFC is consistent with extant empirical findings showing that learners high in NFC recall information better than learners low in NFC (e.g., Cacioppo et al. 1983; Heijne-Penninga et al. 2010; Sadowski and Gülgöz 1996). However, our findings suggest that this disadvantage of learners lower in NFC can be balanced by using generative tasks that stimulate elaborate cognitive processing.

In contrast to cued recall, Hypothesis 2 was not supported by the free recall data. Although we replicated the generation effect for free recall accuracy as dependent variable, individual differences in NFC were not found to moderate the magnitude of the generation effect. Plausible explanations are the different task requirements of free and cued recall and how they match the kind of processing in the learning phase (e.g., see the contextual framework, McDaniel and Butler 2010 or transfer-appropriate processing, Morris et al. 1977). To successfully generate a target word in the learning phase, learners were required to establish a mental link between the context word and the target word. This mental link could then be used as a scaffold to retrieve the generated target words from memory when context words were provided as cues in the cued recall task. In free recall, however, the mental links established during the generation task could not serve as scaffolds for target word retrieval without providing context words (note, in this context, the elaborate processing of the target word still improves learning in the generate compared to the read condition). This idea is supported by the finding that learners recalled about twice as much target words in cued recall compared to free recall (see descriptive statistics in Table 1). Note that learners at all NFC levels should have established elaborate mental links between a context word and the target word in the generate condition (because it was required by the task). In contrast, only learners high in NFC should have established such links between context and target words in the read condition. This interaction between learning condition and NFC, however, can only be seen when the criterial task draws upon these established mental links, that is, in cued but not in free recall.

The idea of self-generation as scaffold to enhance memory for the target word by constructing a mental bridge between context and target word might suggest that self-generation is kind of an *epistemic action* („an external [i.e., not solely mental] action that an agent performs to change his or her own computational state" in contrast to *pragmatic actions* "whose primary function is to bring the agent closer to his or her physical goal", Kirsh and Maglio 1994, pp. 514–515; see also Kirsh 2006). From this perspective, one could argue that self-generation is an external action that alters the environment (here the learning material) and, thereby, adds to problem solving (here target-word memory). As was demonstrated for epistemic actions (Kirsh and Maglio; Maglio and Kirsh, 1996), it is only in hindsight, that the benefit of the additional and putatively unnecessary generation task becomes evident. In contrast to epistemic actions, however, desirable difficulties do not reduce working memory load, the number of cognitive steps involved in processing, or the probability of processing errors (see Kirsh and Maglio). Instead, desirable difficulties are characterized by increasing cognitive effort in a way that is beneficial to learning. They are, by definition, no reduction of complexity. In this way, self-generation is clearly distinct from epistemic actions.

The participants in our study were randomly assigned to one of two learning settings – an incidental and an intentional learning setting. Learning in educational contexts is often intentional, for example when teachers and students purposefully use learning strategies to prepare for a test or to enhance the students' learning outcome. Hence, demonstrating that the two-way interaction of learning condition and NFC shows in an intentional learning setting would further corroborate the practical relevance of our findings. As expected, the finding that the generation effect was more strongly pronounced for learners lower in NFC than for learners higher in NFC (cued recall) did not differ between learning settings. Neither the main effect of learning setting nor the interaction effects of learning setting with learning condition and NFC became significant. This result suggests that the compensatory effect of self-generation on target word memory of learners lower in NFC occurs independently of the learning setting in cued recall.

In free recall, we found that learners higher in NFC recalled more target words than learners lower in NFC when learning was intentional. This finding suggests that learners higher in NFC voluntarily invested more cognitive resources on preparation for a test than learners lower in NFC (even when test performance had no actual consequences for their studies). This interpretation is consistent with extant studies demonstrating that learners higher in NFC are more willing to tackle difficult tasks than learners lower in NFC (See et al. 2009; Weißgerber et al. 2018). We assume that (in addition to establishing mental links between context and target words) they might have tried to explicitly memorize the target words to be prepared for later recall. Since free recall (in contrast to cued recall) assesses context-free retrieval of target words, deeper processing of target words in the learning phase led to increased recall accuracy for learners higher in NFC independent of learning condition. In sum, the different findings for free and cued recall obtained in our study can be explained by different task requirements of both criterial tasks and how each of them matched the kind of processing in the learning phase.

Finally, extant studies showed that learners higher in NFC use more efficient learning strategies than leaners lower in NFC (Cazan and Indreica 2014). Hence, we assumed that learners higher in NFC would use more elaborate learning strategies than learners lower in NFC. However, participants self-reported use of elaborate, less elaborate, and no additional learning strategies did not vary as a function of individual differences in NFC. A likely explanation for this finding is that 7 seconds of word-pair presentation and 3 seconds of inter-stimulus interval are too short a time for most participants to properly administer additional learning strategies, let alone elaborate ones. This might be different for more complex learning material such as texts or algebraic word problems and remains to be investigated in future research.

The findings reported in this study should be interpreted with possible limitations in mind. In everyday life, learners usually deal with learning material that is much more complex than isolated word pairs. Moreover, most of the time, learners are unaware of the kind of criterial task for which to prepare, and when preparing for a test or exam, retention intervals are usually longer (several days or weeks) than just a few minutes as in most laboratory studies on the generation effect.

Despite these limitations, the findings of the present study have important theoretical and practical implications. The finding that learners recalled three times as much target words in the generate condition as they recalled in the read condition (see descriptive statistics, Table 1) strongly suggests that self-generation might be a useful supplement to commonly used learning strategies in education. The findings of the present study, however, also indicate that educators should be prepared to find individual differences in the effectiveness of generative activities depending on learners' characteristics. We demonstrated for the first time that the generation effect differs as a function of individual differences in NFC. For those high in NFC, self-generation contributes comparatively little to learning. It can, however, be highly beneficial for learners low in NFC (both in incidental and intentional learning settings). This suggests that self-generation can be used to systematically improve learning for those who are likely to fall behind their peers due to low engagement in effortful cognitive processing. Since NFC is easily and quickly accessed in single learning settings as well as in classrooms, learners low in NFC and, thus, in special need for cognitively demanding learning instructions can (and should) be effortlessly identified.

Another important practical implication of our study is that the compensatory effect of self-generation becomes visible only when the generation task matches the requirements of the criterial task. When adopting self-generation as a learning strategy in educational contexts (e.g., school classes, educational books, or computerized learning environments), teachers, authors, and programmers should ensure that the generation task encourages cognitive processes relevant to the test, exam, or task for which the learners prepare (McDaniel and Butler 2010).

The results of the present study raise some interesting future research questions. First, future research needs to replicate and extend the reported findings with more complex and naturalistic learning materials (e.g., math problems or expository texts), in more naturalistic settings (such as classrooms or in collaborative action learning), with different types of generation and criterial tasks and longer retention intervals. Moreover, when using more complex learning material such as texts, other learner characteristics such as working memory, reading ability, creativity, learning goals, and openness to ideas should be considered alongside NFC to account for mutual variance that these components might share with NFC and to account for possible moderating effects to further optimize the use of self-generation in everyday learning settings. Finally, the interaction of self-generation and NFC raises not only the question which further learner characteristics might affect the effectiveness of self-generation, but also which other desirable difficulties might be affected by individual differences in NFC. A possible candidate to look at might be the testing effect. Access to and alteration of knowledge structures during learning, relearning, and retesting might be differential for learners high in NFC and those low in NFC.

6. Conclusion

The present study replicated the generation effect with a version of the classical word-generation paradigm by Slamecka and Graf (1978) and McDaniel et al. (1988). Learners recalled generated target words better than read target words. Moreover, our study demonstrated for the first time that individual differences in learners' NFC moderate the effectiveness of self-generation during learning. Learners lower in NFC benefited significantly more from generating target words than learners higher in NFC when retrieval cues were provided in the test phase. This finding corroborates McDaniel and Butler's (2010) explanation that desirable difficulties such as self-generation are only beneficial when they stimulate cognitive processes that learners tend not to engage in spontaneously. We assume that learners higher in NFC voluntarily engage in elaborate cognitive information processing even without explicit instruction, whereas learners lower in NFC need a cognitively demanding task that requires them to switch from shallow to elaborate cognitive processing to improve learning. The reported findings suggest that using self-generation in educational contexts is beneficial for learners at all levels of NFC, but it could be systematically used to improve learning for learners with a weak disposition to engage in cognitively demanding learning processes.

Keypoints

- Desirable difficulty
- Generation effect
- Incidental learning
- Intentional learning
- Need for cognition

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