Journal of Psychological and
Educational Research
JPER - 2019, 27 (1), May, 7-24

AM I RESPONSIBLE FOR MY LEARNING SUCCESS? A STUDY ABOUT THE CORRELATION BETWEEN LOCUS OF CONTROL AND ATTITUDES TOWARDS AND SELF-REPORTED USE OF DESIRABLE DIFFICULTIES

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Abstract
Desirable difficulties are learning strategies that lead to more effective and durable learning even if the application produces difficulty at the moment of learning (Bjork, 1994). With this study we investigated the question which learner characteristics are linked to perception and application of those effortful strategies in self-regulated learning situations. In doing so we focused on locus of control, a construct that describes the extent to which individuals feel to have control over the outcome which arises from their own behavior (Rotter, 1975). Supporting our assumptions, internals-thus students with a stronger feeling of controllability - showed more positive attitudes towards desirable difficulties, whereas externals-thus students who suppose that external forces like chance/fate or powerful others have control over their behavior - showed no correlation. Furthermore, internals showed increased self-reported use of desirable difficulties. Contrary to prediction, external locus of control also was correlated to self-reported use of desirable difficulties. Results are discussed related to implications for the application of desirable difficulties in a real academic context regarding students with different learning characteristics, as well as to implications for further research.

Keywords: desirable difficulties; locus of control; learning; learner characteristics

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Introduction

Concerning the application of effective learning strategies, individual differences or learner characteristics seem to be very important. While some students use relatively ineffective strategies other students use strategies which are mentally more challenging, but thereby promise a greater success of learning (*e.g.*, Bjork, Dunlosky, & Kornell, 2012; Karpicke, Butler, & Roediger, 2009). Such learning strategies are for instance so called *desirable difficulties.* The application of desirable difficulties leads to a more complex learning situation, but thereby especially benefits long-term effects regarding memory and transfer of the learned knowledge (Bjork, 1994). However, even if desirable difficulties promise greater learning success, most students do not use them in self-regulated learning situations. Instead, the majority prefers more simple strategies like for example repeated reading (Karpicke et al., 2009).

The present study wants to identify factors that are responsible for individual differences concerning the perception and application of desirable difficulties. Thereby, the main focus is on the *locus of control* construct, which is defined as the extent to which an individual perceives to have control over the outcome that arises from their own behavior (Rotter, 1975; Rotter, Chance, & Phares, 1972). Given that the application of desirable difficulties leads to more challenging learning situations - because they elicit more time and cognitive effort - locus of control can be expected as a learner characteristic that promotes the feeling of being able to cope those complex situations because the individual feels confident that his or her learning effort will result in greater learning success (*e.g.*, Prociuk & Breen, 1997).

Desirable difficulties

Desirable difficulties are learning strategies that lead to more effective and durable learning through producing difficulty at the moment of application (Bjork, 1994). Recent research indicated that different forms of desirable difficulties exist, often termed as *spacing*, *interleaving*, *generation* and *testing*. Spacing or distributed learning means to separate specific learning sessions in different units in contrast to learning one topic from beginning to end (*e.g.*, Vlach & Sandhofer, 2012). In some way interleaving contains this strategy but additionally includes that in between the temporary distributed learning units different topics get mixed (*e.g.*, Ziegler & Stern, 2014). For visualizing the

difference, one can imagine that spacing or distributed learning means first learning unit AA, then BB and at least CC, whereas interleaving means learning first A, B, C and then again A, B, C. In particular, both strategies promote long-term memory (*e.g.*, Vlach & Sandhofer, 2012; Ziegler & Stern, 2014). Generation further describes active generation of learning materials and predictions instead of merely (re-)reading and repeating the material which also strengthens long-term memory (*e.g.*, Bertsch, Pesta, Wiscott, & McDaniel, 2007; DeWinstanley & Bjork, 2004; Slamecka & Graf, 1978). Testing requires active memory recall and retrieval rather than simply rehearsing the relevant knowledge (*e.g.*, Karpicke et al., 2009; for recent meta-analyses *see*: Adesope, Trevisan, & Sundararajan, 2017; Rowland, 2014).

While positive effects of desirable difficulties on learning success are relatively well understood and seen as rather robust, more research regarding personality variables and learner characteristics that may affect the perception and application of desirable difficulties is still valuable (*e.g.*, Weissgerber, Reinhard, & Schindler, 2016).

Internal and external locus of control

Locus of control describes the individual tendency to attribute causes of life events to one's own behavior or external influences (Rotter, 1975). The origin of this construct lies in *social learning theory* (Rotter et al., 1972). According to this theory there are two extremes - an internal and an external locus of control (scores in between these extremes can of course also exist). Individuals with a more internal locus of control assume a strong connection between their behavior and the thereby resulting outcome. They are often dubbed as *internals*. Individuals with a more external locus of control instead suppose that external forces like chance/fate or powerful others have control over their lives. They are often dubbed as *externals* (Rotter, 1975). Depending on the conceptualization the construct can be measured two-dimensional (*e.g.*, Rotter, 1975) or three-dimensional (*e.g.*, Levenson, 1973) by dividing the external extreme in two different dimensions (i.e. external locus of control because of powerful others or external locus of control because of chance). Rotter further defined locus of control as a *generalized expectancy* which only affects human behavior in complex and ambiguous situations in comparison to specific expectancies which lead individuals' trough familiar situations (Rotter, 1975).

In the past, research has often associated locus of control with specific performance situations (Spector, 1982). Several experiments have shown that internals outperform externals in actively seeking relevant information and in the utilization of those information (*e.g.*, Phares, 1968; Ude & Vogler, 1969; Wolk & DuCette, 1973). Based on this, internals are generally considered to be more successful and effective. Numerous experiments confirmed this assumption by operationalizing professional success for instance in form of salary level or job position (*e.g.*, Valecha, 1972) as well as by judgements of supervisors (*e.g.*, Majumder, MacDonald, & Greever, 1977). Better information seeking and processing behavior as well as greater success (better grades) were also linked with higher internal locus of control in academic context (Prociuk & Breen, 1997). However, within the research body of desirable difficulties - to our knowledge - the construct of locus of control has never been considered before.

The current research

In the following we want to argue why locus of control could be an important factor that may influence individuals' perception and application of desirable difficulties: Given that the application of desirable difficulties lead to cognitively effortful learning processes (Bjork et al., 2012), then, especially in those complex, ambiguous, and relatively unknown situations generalized expectancies like locus of control should determine human behavior (Rotter, 1975). Given that individuals with a more internal locus of control generally act more effective and successful (*e.g.*, Majumder et al., 1977; Prociuk & Breen, 1997; Valecha, 1972), and additionally have better skills in seeking or utilizing relevant information (*e.g.*, Phares, 1968; Ude & Vogler, 1969; Wolk & DuCette, 1973), it can be assumed that for internals the application of desirable difficulties isn't as (mentally) challenging as for externals. Thus, an internal locus of control could facilitate affective and cognitive perception regarding the application of desirable difficulties. Regarding the external dimension, no correlation to attitudes towards desirable difficulties is assumed. Externals don't believe in the effectiveness of their behavior. Therefore, to them it should make no difference which specific learning strategy they use in order to reach their learning goal. In their opinion they are not able to reach it by their own efforts because they perceive it depending on powerful others, luck, chance and/or fate.

Therefore, we first predict that students who score higher in internal locus of control have more positive attitudes towards desirable difficulties (Hypothesis

1a), whereas students who score higher in external locus of control (because of powerful others or chance) show no correlation to attitudes towards desirable difficulties (Hypothesis 1b). Given that assumption, this should implicate an increased application of desirable difficulties only for internals but not for externals. Therefore, we second predict that students who score higher in internal locus of control show increased self-reported use of desirable difficulties (Hypothesis 2a), whereas students who score higher in external locus of control (because of powerful others or chance) show no correlation to self-reported use of desirable difficulties (Hypothesis 2b).

Methods

Participants

In total 504 participants (54% male) completed our online-survey. Participants mean age was 26.58 (SD=6.83) and ranged from 16 to 68 years. The majority (96%) of the participants were inhabitants of the USA. Participation requirements contained that all subjects were registered students at the moment of questioning. The recruitment took place via Amazon Mechanical Turk.

Measures

All of the measures were administered in English. The IPC-Scale developed by Levenson (1973) was used to measure *locus of control*. Levenson conceptualizes locus of control as a three-dimensional construct by dividing the external extreme in two different categories. The I-Scale serves to measure the internal extreme (α=.788; *e.g.*, „My life is determined by my own actions“). The P-Scale measures perception of external control which arises from individuals feelings that powerful others control their life events (α=.880; *e.g.*, „Getting what I want requires pleasing those people above me“). The C-Scale measures the external fatalistic control which is attributed with luck, fate and chance (α=.878; *e.g.*, „Whether or not I get into a car accident is mostly a matter of luck“). Participants were instructed to rate each statement on a 6-point Likert response scale (1=*strongly disagree* and 6=*strongly agree*).

Dispositional stress as a control variable was assessed by Cohen's and Williams's 10-item Perceived Stress Scale (1988). The questionnaire measures the degree to which specific life events and situations are experienced as stressful. General statements like for example "how often have you felt that

things were going your way" or "how often have you felt nervous and stressed" (α=.859) should be assessed on a 5-point Likert response scale (1=*never* and 5=*very often*) regarding their probability of occurrence during the last month. The measure of stress serves as a control variable to check whether the attitude and the decision to use/not use mentally challenging learning strategies is dependent of a specific level of stress which is common for students in their academic environment (*e.g.*, Abouserie, 1994; Anda et al., 2000; Heins, Fahey, & Leiden, 1984).

S*elf-efficiency beliefs* as a control variable were assessed using the General Self-Efficacy Scale by Schwarzer and Jerusalem (1995). The scale measures the extent to which someone beliefs to be able to handle critical situations by oneself. Ten items (α=.866; *e. g.*, „I can usually handle whatever comes my way") should be rated on a 4-point Likert response scale (1=*not at all true* and 4=*exactly true*).

Attitudes towards and self-reported use of desirable difficulties was assessed with items used by Weissgerber et al. (2016; *see also* Weissgerber, Reinhard, & Schindler, 2018). The scale concentrates on five different desirable difficulties: self-generation of learning contents, labeled as *generation*, generation of predictions, labeled as *predictions*, *self-testing*, *spacing/ interleaving* and *practicing*, which means a mixed form of self-testing with self-generated learning materials. Each of these five different desirable difficulties types is captured with three items. Two items assessed the attitude towards each type of desirable difficulty (*e.g.*, „I like to create my own learning materials"; „I think it is useful to acquire knowledge myself"). Self-reported use in self-regulated learning situations was assessed for each type of desirable difficulty with one item (*e.g.*, „Compared to other learning methods, I work out the subject matter myself"). Participants were instructed to rate each statement on a 7-point Likert response scale (1=*totally disagree* and 7=*totally agree*). Both, the attitudes scale (α=.890) and the self-reported use scale (α=.805) showed good reliability.

Procedure

The survey contained three different parts. After participants gave their permission to participate voluntary and reported that they were registered college or university students, we assessed their demographics (*i.e.*, gender, age, homeland). The second part included the assessment of locus of control, dispositional stress and self-efficiency beliefs in randomized order. During the

third part, the measure of attitudes toward and self-reported use of desirable difficulties took place. At the end of the online survey the respondents were thanked for their participation and got $0.60 as a reward.

Results

Table 1 shows the means, standard deviations and correlation coefficients among all variables examined in this study. All correlations coefficients were Bonferroni adjusted. The total value for attitudes exhibited a mean value of 5.10 (SD=1.01) and for self-reported use a mean value of 5.05 (SD=1.06). Mean value of internal locus of control was 4.32 (SD=0.70), mean value of external locus of control which arises from the feeling that powerful others hold control above life events was 3.60 (SD=1.02) and mean value of external fatalistic locus control was 3.50 (SD=1.02). Stress showed a mean value of 2.82 (SD=0.70) and self-efficacy beliefs a mean value of 3.09 (SD=0.51).

Internal locus of control correlated significantly with attitudes towards desirable difficulties ($r=.549$, $p<.001$) and with self-reported use of desirable difficulties ($r=.526$, $p<.001$). Thus, internal locus of control is related to positive attitudes towards and increased self-reported use of desirable difficulties. Neither external locus of control because of powerful other, nor the external fatalistic dimension was found to be correlated with attitudes towards desirable difficulties and self-reported use of desirable difficulties. Both external locus of control dimensions also showed no correlation to internal locus of control.

Regarding measured control variables both showed significant correlations with the dependent variables. Stress correlated significantly with attitudes towards ($r=-.220$, $p<.001$) and self-reported use of desirable difficulties ($r=-.193$, $p<.001$), both negatively. Thus, lower levels of stress are related to positive attitudes towards and increased self-reported use of desirable difficulties. Self-efficiency beliefs also showed significant correlations with attitudes towards desirable difficulties ($r=.498$, $p<.001$) and with self-reported use of desirable difficulties ($r=.477$, $p<.001$). Thus, higher values of self-efficiency beliefs are related to positive attitudes towards and increased self-reported use of desirable difficulties. Furthermore, there was a negative correlation between stress and self-efficiency beliefs ($r=-.537$, $p<.001$).

Table 1. Intercorrelations, Means, Standard Deviations and Cronbachs α for Attitudes Toward and Self-Reported Use of Desirable Difficulties, Locus of Control, Stress, and Self-Efficiency Beliefs (N=504)

	1.	2.	3.	4.	5.	6.	7.	M	SD	α
1. Attitudes	1							5.10	1.01	.890
2. Self-reported use	.884**	1						5.05	1.06	.805
3. Internal	.549**	.526**	1					4.32	0.70	.788
4. Powerful others	.051	.096	.095	1				3.60	1.02	.880
5. Chance	.046	.103	.048	.838**	1			3.50	1.02	.878
6. Stress	-.220**	-.193**	-.298**	.474**	.513**	1		2.82	0.70	.859
7. Self-efficiency	.498**	.477**	.581**	-.210**	-.216**	-.537**	1	3.09	0.51	.866

Note: *p<.05 (two-tailed); **p<.001 (two-tailed); all calculated correlations were Bonferroni adjusted; Attitudes=attitudes towards desirable difficulties; Self-reported use=Self-reported use of desirable difficulties; Internal=Internal locus of control dimension; Powerful others=External locus of control dimension because of powerful others; Chance=External locus of control because of chance; Self-efficiency=Self-efficiency beliefs.

Note that a more detailed look to the different kinds of desirable difficulties reveals quiet the same correlations for the specific scores (see Appendix Table A). Correlations with internal locus of control all reached significance and showed a positive direction (r=.566, p<.001 to r=.705, p<.001). Correlations with external locus of control predominantly reached no significance with specific scores of desirable difficulties. Only interleaving / spacing showed a significant correlation with external fatalistic locus of control (r=.161, p<.05).

To test Hypothesis 1a which claimed that students who score higher in internal locus of control have more positive attitudes towards desirable difficulties and Hypothesis 1b which claimed that students who score higher in external locus of control (because of powerful others or chance) show no correlation to attitudes towards desirable difficulties, already the presented correlations indicated support (Table 1). Thus, internal locus of control was positively linked to attitudes towards desirable difficulties (r=.549, p<.001) but neither the external dimension because of powerful others, nor the external fatalistic dimension exhibited significant correlations. To strengthen these findings, a multiple, stepwise regression analysis was conducted. Respectively, attitudes towards desirable difficulties was used as criterium and the three dimensions of locus of control were used as predictors. Additionally, in a second and third step, gender, age, self-efficiency beliefs and stress were added as control variables to test if the effect of internal locus of control would remain robust (Table 2).

Table 2. Multiple, Stepwise Regression Analysis with Attitudes Toward Desirable Difficulties as the Criterion and Locus of Control, Gender, Age, Self-Efficiency Beliefs, and Stress as Predictors (N=504)

		Parameter estimates						
Model	Predictors	*B*	*SE*	β	*t*	*p*	R^2	$r_{x(y, z)}$
(1)	Internal	0.821	0.056	.551	14.673	<.001	.303	.548
	Powerful others	-0.060	0.068	-.061	-0.880	.379		-.033
	Chance	0.070	0.068	.070	1.026	.305		.038
(2)	Internal	0.828	0.056	.556	14.712	<.001	.307	.549
	Powerful others	-0.047	0.068	-.047	-0.686	.493		-.026
	Chance	-0.068	0.068	.069	1.011	.312		.038
	Age	-0.003	0.006	-.019	-0.493	.623		-.018
	Gender	-0.131	0.078	-.065	-1.690	.092		-.063
(3)	Internal	0.553	0.069	.371	8.028	<.001	.362	.288
	Powerful others	0.015	0.067	.016	0.232	.817		.008
	Chance	0.090	0.067	.091	1.345	.179		.048
	Age	-0.003	0.005	-.020	-0.541	.589		-.019
	Gender	-0.133	0.075	-.066	-1.773	.077		-.064
	Self-efficiency	0.603	0.099	.306	6.088	<.001		.218
	Stress	0.001	0.071	.000	0.009	.992		.000

Note: $r_{x(y, z)}$=Semipartial correlation coefficients; Internal=Internal locus of control dimension; Powerful others=External locus of control dimension because of powerful others; Chance=External locus of control because of chance; Self-efficiency=Self-efficiency beliefs.

As shown in Table 2 (model 1) internal locus of control significantly predicted attitudes towards desirable difficulties (β=.551, p<.001). The model explained 30.3% of variance, F(3, 500)=72.394, p<.001, R^2=.303, $R^2_{adjusted}$=.299. Gender- or age-effects did not exist. Thus, neither gender nor age did change the effects of internal locus of control as a predictor (model 2). However, it should be pointed out that self-efficiency beliefs (model 3) also had a significant impact on attitudes towards desirable difficulties (β=.306, p<.001). In the shared model (model 3) the impact of internal locus of control decreased but still reached a significant level (β=.371, p<.001). The shared model explained 36.2% of variance, F(7, 496)=40.219, p<.001, R^2=.362, $R^2_{adjusted}$=.353. In all of the three models neither external locus of control because of powerful others, nor external fatalistic locus of control showed a significant effect to attitudes towards desirable difficulties.

To test Hypothesis 2a which claimed that students who score higher in internal locus of control show increased self-reported use of desirable difficulties and Hypothesis 2b which claimed that students who score higher in external locus of control (because of powerful others or chance) show no correlation to self-reported use of desirable difficulties, again, the already presented

correlations indicated support (Table 1). Thus, internal locus of control was positively linked to attitudes towards desirable difficulties (r=.549, p<.001) but neither the external dimension because of powerful others, nor the external fatalistic dimension exhibited significant correlations. For further analysis a multiple, stepwise regression analysis was conducted. Respectively, self-reported use of desirable difficulties was used as criterium and the three dimensions of locus of control were used as predictors. Additionally, in a second and third step, gender, age, self-efficiency beliefs and stress were added as control variables to test if the effect of internal locus of control would remain robust (Table 3).

Table 3. Multiple, Stepwise Regression Analysis with Self-Reported Use of Desirable Difficulties as the Criterion and Locus of Control, Gender, Age, Self-Efficiency Beliefs, and Stress as Predictors (N=504)

		Parameter estimates						
Model	Predictors	*B*	*SE*	β	*t*	*p*	R^2	$r_{x(y,\,z)}$
(1)	Internal	0.826	0.060	.526	13.801	<.001	.284	.522
	Powerful others	-0.063	0.073	-.061	-0.871	.384		-.033
	Chance	0.134	0.072	.128	1.844	.066		.070
(2)	Internal	0.834	0.060	.531	13.836	<.001	.286	.524
	Powerful others	-0.052	0.073	-.050	-0.710	.478		-.027
	Chance	0.133	0.072	.127	1.832	.068		.069
	Age	0.000	0.006	.002	0.062	.950		.002
	Gender	-0.110	0.083	-.052	-1.328	.185		-.050
(3)	Internal	0.532	0.074	.338	7.215	<.001	.345	.262
	Powerful others	0.018	0.071	.017	0.255	.799		.009
	Chance	0.161	0.072	.154	2.248	.025		.082
	Age	0.000	0.006	.001	0.034	.973		.001
	Gender	-0.114	0.080	-.054	-1.425	.155		-.052
	Self-efficiency	0.648	0.106	.312	6.123	<.001		.222
	Stress	-0.020	0.076	-.013	-0.260	.795		-.009

Note: $r_{x(y,\,z)}$=Semipartial correlation coefficients; Internal=Internal locus of control dimension; Powerful others=External locus of control dimension because of powerful others; Chance=External locus of control because of chance; Self-efficiency=Self-efficiency beliefs.

As shown in Table 3 (model 1) internal locus of control significantly predicted self-reported use of desirable difficulties (β=.526, p<.001). The model explained 28.4% of variance, F(3, 500)=66.029, p<.001, R^2=.284, $R^2_{adjusted}$=.279. Gender- or age-effects did not exist. Thus, whether gender nor age did change the effects of internal locus of control as a predictor (model 2). But it should be pointed out that self-efficiency beliefs (model 3) also had a significant impact on

self-reported use of desirable difficulties (β=.312, p<.001) as well as the external fatalistic dimension of locus of control labeled as chance (β=.154, p<.025). In the shared model (model 3) the impact of internal locus of control decreased but still reached a significant level (β=.328, p<.001). The shared model explained 34.5% of variance, F(7, 496)=28.115, p<.001, R^2=.345, $R^2_{adjusted}$=.336.

Hypothesis 1a claimed that students who score higher in internal locus of control have more positive attitudes towards desirable difficulties and Hypothesis 1b claimed that students who score higher in external locus of control (because of powerful others or chance) show no correlation to attitudes towards desirable difficulties. Regression analysis revealed a significant impact of internal locus of control on attitudes towards desirable difficulties - note that the effects remain robust although adding control variables (*i.e.*, gender, age, self-efficiency beliefs, and stress) - and no significant effects of both external dimensions of locus of control (Table 2). Therefore, Hypothesis 1a and 1b can be accepted. Hypothesis 2a claimed that students who score higher in internal locus of control show increased self-reported use of desirable difficulties and Hypothesis 2b claimed that students who score higher in external locus of control (because of powerful others or chance) show no correlation to self-reported use of desirable difficulties. Regression analysis revealed a significant impact of internal locus of control on self-reported use of desirable difficulties - note that the effects remain robust although adding control variables (*i.e.*, gender, age, self-efficiency beliefs, and stress) - but also a significant effect of external fatalistic locus of control (Table 3). Therefore, only Hypothesis 2a can be accepted whereas Hypothesis 2b must be rejected.

Conclusions

This study was initiated to examine the relationship between perceptions of desirable difficulties and personality factors, respectively learner characteristics. Our research project seemed to be necessary because although positive effects of desirable difficulties on learning success are relatively well understood through past research, personality variables that may affect perceptions and applications of such desirable difficulties still need further exploration (*e.g.*, Weissgerber et al., 2018). The present study focused on locus of control, a personality construct that describes the extent to which individuals feel to have control over the outcome that arises from their own behavior (Rotter,

1975). We assumed a more internal locus of control to be linked to positive attitudes towards and increased self-reported use of desirable difficulties, whereas a more external locus of control should not be linked to attitudes towards and self-reported use of desirable difficulties.

The reported findings could support our first three assumptions: Our results provided significant correlation between internal locus of control and attitudes towards desirable difficulties (Hypothesis 1a), as well as no correlation between external locus of control (because of powerful others or chance) and attitudes towards desirable difficulties (Hypothesis 1b). There was also a significant correlation between internal locus of control and self-reported use of desirable difficulties (Hypothesis 2a). These findings are in line with past research, which mostly demonstrated that individuals with a more internal locus of control generally act more effective and successful (*e.g.*, Majumder et al., 1977; Prociuk & Breen, 1997; Valecha, 1972) and have better skills in seeking or utilizing relevant information (*e.g.*, Phares, 1968; Ude & Vogler, 1969; Wolk & DuCette, 1973). Thus, we assumed that for internals the application of effortful learning strategies isn't as (mentally) challenging as for externals, which in turn could facilitate affective and cognitive perception of such difficulties only for internals but not for externals. Presented correlations (Table 1) and multiple, stepwise regression analyses (Table 2 and Table 3) confirmed these assumptions. Newly - and surely the added value of this study - is the transferability of the results on the learning context respectively the context of attitudes towards and self-reported use of desirable difficulties.

Contrary to our assumptions, the presented regression analysis (Table 3) showed external fatalistic locus of control to be a significant predictor of self-reported use of desirable difficulties. We did not predict this because we theoretically assumed students with a more external locus of control to not believe in the effectiveness of their own behavior, so that they should not show preferences for specific learning strategies. Still, the external fatalistic dimension showed a significant correlation to self-reported use of desirable difficulties so that we cannot support Hypothesis 2b.

Taking a more detailed look at the correlations between external fatalistic locus of control and the specific desirable difficulties, only *interleaving/spacing* reached significance, whereas the other kinds (in line with our expectation) were not correlated with external fatalistic locus of control (*see* Appendix Table A). In comparison to the other specific kinds of desirable difficulties,

interleaving/spacing requires less activity than the other ones because it only consists of mixing different topics throughout different learning sessions. Because less proactivity is needed, maybe this strategy isn't that challenging as the other ones and therefore fatalistic externals believe that they can handle it with luck, fate and chance. Therefore, our hypothesis possibly cannot be applied to this specific kind of desirable difficulties because interleaving/spacing isn't seen as a real difficulty. Further, we advise to be careful by interpreting external fatalistic locus of control as predictor for self-reported-use of desirable difficulties because the external fatalistic dimension only reached significance in a shared/larger model (model 3) within which the control variables stress and self-efficiency beliefs were integrated (Table 3). Thus, it seems that the external fatalistic dimension shares some variance with stress and/or self-efficiency beliefs. Individuals scoring higher on the external fatalistic dimension could possibly be less sensitive to stress, insofar as that they believe their success to be dependent of fatalistic causes like chance and not on their own abilities. Future studies focusing on the relation between external locus of control and stress would be valuable to further explore this linkage.

In general, we want to highlight that internal locus of control significantly correlated with all kinds of desirable difficulties and that regression analyses revealed that the major impact on self-reported use of desirable difficulties emanates from internal rather than external fatalistic locus of control. Due to this, we consider internal locus of control as the more important factor regarding affective and cognitive perception of desirable difficulties. Hence, the following practical implications will only refer to the role of internal locus of control.

Altogether, the findings are relevant for students in self-determined learning situations as well as for teachers whose aim it should be to promote the long-term learning success of their students. Teachers should be aware that different students, with their different learner characteristics, show different learning styles and that students (external) locus of control could be one important factor why some of them use more ineffective strategies, while others make greater use of more effective strategies. Given that internals and externals benefit equal from the application of desirable difficulties, especially insecure students which may feel overstrained (because of their external locus of control) should be sensitized above the superior learning benefits of desirable difficulties. Besides, teacher could help externals as well as internals using desirable

difficulties for instance through presenting them more opportunities to do so in the school or university context.

However, one limitation of our study is that we focused on correlations and not on causal effects. Thus, future studies should try to test our results using manipulations and not only observing relations. In line with this, even if our study showed that individuals with a more internal locus of control had more positive perceptions and increased applications of those strategies, it did not automatically evidence that internals also achieve greater learning success per se. The effect of locus of control on learning success due to the application of desirable difficulties has not yet been clarified. Thus, it seems to be interesting for further research to examine if locus of control acts as moderator in the relation between application of desirable difficulties and learning success in a real academic context. If internals and externals for instance don't benefit equally from the application of desirable difficulties - for example because internals show better skills in seeking relevant information (*e.g.*, Phares, 1968; Ude & Vogler, 1969; Wolk & DuCette, 1973) - a new question follows: In this case it seems to be valuable that teachers could be able to shift locus of control of their students to a more internal direction to promote their learning success. Thus, further research should examine if locus of control is changeable in an academic context.

Furthermore, it seems to be important to focus on the difference between locus of control and self-efficiency beliefs. In both multiple regression analyses self-efficiency beliefs showed significant impact on attitudes towards desirable difficulties (however, the effects of internal locus of control remained significant even while controlling for self-efficiency beliefs). Indeed, self-efficiency belief coefficients were even relatively smaller than coefficients of internal locus of control. Hence, further research should focuse on the difference between locus of control and self-efficiency beliefs.

Funding

This research was supported by a LOEWE grant from the Hessian Ministry for Science and the Arts entitled "desirable difficulties; intrinsic cognitive motivation and performance expectancies" awarded to Marc-André Reinhard.

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Received December 4, 2018
Revision February 28, 2019
Accepted May 22, 2019

Appendix

Intercorrelations, Means, Standard Deviations and Cronbachs α for Single Desirable Difficulties, Attitudes, Self-Reported Use, Locus of Control, Stress, and Self-Efficiency Beliefs (*N* = 504)

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	M	SD	α
1.	1.												5.11	1.16	.740
2.	.705**	1.											5.10	1.16	.780
3.	.643**	.706**	1.										5.10	1.24	.825
4.	.566*	.614**	.630**	1.									5.30	1.20	.829
5.	.588**	.606**	.649**	.663**	1.								4.85	1.17	.734
6.	.826**	.855**	.858**	.807**	.806**	1.							5.10	1.01	.890
7.	.770**	.804**	.810**	.798**	.816**	.884**	1.						5.05	1.06	.805
8.	.430**	.480**	.481**	.479**	.470**	.549**	.526**	1.					4.32	0.70	.788
9.	.064	.081	.001	.001	.146	.051	.096	.095	1.				3.60	1.02	.880
10.	.050	.076	.008	-.006	.161*	.046	.103	.048	.838**	1.			3.50	1.02	.878
11.	-.125	-.193**	-.257**	-.185**	-.147	-.220**	-.193**	-.298**	.474**	.513**	1.		2.82	0.70	.859
12.	.375**	.463**	.468**	.438**	.375**	.498**	.477**	.581**	-.210**	-.216**	-.537**	1.	3.09	0.51	.866

Note. $^*p < .05$ (two-tailed); $^{**}p < .001$ (two-tailed); all calculated correlations were Bonferroni adjusted; 1. = Generation, 2. = Prediction; 3. = Self-testing; 4. = Practicing; 5. = Interleaving/Spacing; 6. = attitudes towards desirable difficulties; 7. = Self-reported use of desirable difficulties; 8. = Internal locus of control dimension; 9. = External locus of control dimension because of powerful others; 10. = External locus of control because of chance; 11. = Stress; 12. = Self-efficiency beliefs.