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Negative aging stereotypes disrupt
both the selection and the execution of memory encoding strategies in older adults

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Abstract

Age-based cognitive deficits are exacerbated by stereotype threat effects (i.e., the threat of being judged as cognitively incapable due to aging). We tested whether age-based stereotype threat effects can occur via impairing older adults' ability to select the best strategy and/or to execute strategies efficiently. Older adults (age range: 64.3—89.5) were randomly assigned to a stereotype threat or control condition before taking an episodic memory task. They encoded pairs of concrete words and of abstract words, with either a repetition or an imagery strategy, and then took a cued-recall task. Whereas participants in Experiment 1 could choose between these two strategies, those of Experiment 2 were forced to use either the repetition or the imagery strategy. Results showed that age-based stereotype threat disrupts both the selection and the execution of the most efficient, but also most resource demanding, imagery strategy, and that these stereotype threat effects were stronger on concrete words. Our findings have important implications to further understand age-based (and other) stereotype threat effects, and how non-cognitive factors modulate age-related changes in human cognition.

Keywords: Cognitive Aging, Stereotype, Strategies, Episodic Memory.

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Introduction

A number of studies has demonstrated effects of age-based stereotype threat. These effects consist in significant decrements in older adults' cognitive performance when participants experience the threat of being judged as cognitively impaired due to aging. Effects of age-based stereotype threat have been found in a wide variety of cognitive domains and with different experimental procedures (see Armstrong et al., 2017, and Lamont, Swift, & Abrams, 2015, for reviews and meta-analyses). For example, they occur both when stereotypes are explicitly or implicitly activated (e.g., Hess, Hinton, & Staham, 2004; Levy, 1996); they influence controlled processes more than automatic processes (e.g., Mazerolle et al., 2012); they occur when task structure of gains/losses mismatches participants' goals (Barber & Mather, 2013a & b; 2015). Effects of stereotype threat are moderated by a number of task and participant parameters. For example, they are larger in young-older adults, aged 60-70 years, than in old-older adults, age 70+ years, and in more highly than less highly educated older adults (e.g., Hess, Hinson, & Hodges, 2009). The meta-analysis of Lamont et al. (2015) also revealed that domain identification, manipulation types of stereotype threat, and performance domain are important moderators: Age-based stereotype threat effects are indeed stronger when domains are highly valued, when stereotype-based rather than fact-based manipulations are used, and when cognitive/memory rather than motor/skill performance are assessed. Interestingly, previous works found that effects of stereotype threat were eliminated when the memory component of the test was de-emphasized (e.g., Desrichard & Köpetz, 2005; Kang & Chasteen, 2009; Rahhal, Hasher, & Colcombe, 2001) or when the test was presented as age-fair (Hess et al., 2009; Mazerolle et al., 2012, 2015, 2016). Beyond memory tests typically used in lab experiments, stereotype threat has also proved to decrease older adults' performance on short cognitive tests widely used in primary care during the screening for predementia (Barber, Mather, & Gatz, 2015; Mazerolle et al., 2016).

Several mechanisms have been thought to produce effects of stereotype threat, including affective mechanisms like anxiety and stress, motivational mechanisms like decreased performance expectations or changes in motivations to perform best, and cognitive

mechanisms like divided attention or decreased working memory resources (see Barber, 2017; Pennington, Heim, Levy, & Larkin, 2016; Schmader et al., 2008 for reviews). However, if the underlying mechanisms of stereotype threat have been well documented among young adults in several stereotypical domains (e.g., women on math tests, ethnic minorities on intellectual tests; Schmader et al., 2008; Schmader & Beilock, 2012), there is still no consensus regarding why older adults underperform under stereotype threat conditions. Research on older adults indeed offers contradictory or inconclusive findings on some of the otherwise typical mediators of stereotype threat such as working memory, physiological arousal, or anxiety (for reviews, see Barber, 2017; Pennington, Heim, Levy, & Larkin, 2016). For example, whereas some findings suggest that stereotype threat impairs older adults' executive control mechanisms (e.g., Mazerolle et al., 2012), others did not find this (Popham & Hess, 2015). As another example, several studies found that older adults' underperformance is due to the mismatch between the defensive self-regulatory response (a prevention focus) induced by stereotype threat and the implicit gains-based (promotion focus) structure of traditional cognitive tests (e.g., Barber, 2017). However, unknown is whether executive control mechanisms and regulatory focus both or uniquely contribute to effects of age-based stereotype threat, whether other mechanisms also intervene, and, most importantly, whether older adults accomplish the tasks under threat and control conditions with the same mechanisms.

The hypothesis tested here is that stereotype threat leads older adults to obtain poorer performance under threat condition because of strategic variations. This hypothesis is based on two lines of research. First, it was suggested by Hess et al. (2003) who assumed that stereotype threat reduces the use of memory strategies while participants are encoding material to be subsequently recalled. However, this has never been directly tested. Only measures of clustering during recall suggests that participants use different memory strategies, as participants used less category-clustering (i.e., recall all fruit items, then all vegetable items, etc.) under threat than under control condition. Note however that measures of clustering are indirect measures of recall strategies and are not independent of participants' performance, and the relationship between stereotype threat and clustering has not been consistently found (e.g., Hess & Hinson, 2006; Hess, Hinson, & Hodges, 2009; Chasteen, Bhattacharyya, Horhota, Tam, & Hasher, 2005). As a consequence, we do not know whether participants use less efficient strategies under stereotype threat, or whether they use the same strategies under threat and control conditions but execute these strategies less efficiently on each item. To test the strategic variations hypothesis, two goals should be pursued. First,

strategies should be assessed on an item-by-item basis to determine relative frequencies of strategy use and collect measures of strategies that are independent of performance. Second, strategy use should be controlled to assess relative efficiency of strategy execution. We pursued these goals in the current experiments.

The second line of research on which our strategy hypothesis is based concerns previous findings in aging and strategic variations. A number of studies showed that participants use several strategies to accomplish most cognitive tasks (Siegler, 2007). A strategy is defined as « *a procedure or a set of procedures to achieve a higher level goal* » (Lemaire & Reder, 1999, p. 365). Young and older adults, as well as older adults across a variety of experimental conditions, differ in which (and how many) strategies they use (strategy repertoire), how often they use available strategies (strategy distribution), and how efficient they are at selecting (strategy selection) and executing (strategy execution) the best strategy on each item. These age- and condition-related differences in strategic variations have been found in a wide variety of cognitive domains, including memory tested here (see Lemaire, 2016, for a review). For example, compared to young adults, older adults tend to use easier strategies (e.g., repetition) more often and more resource-consuming strategies (e.g., imagery) less often, even if easier strategies are less efficient, when they accomplish cognitive tasks (e.g., Craik & Dirks, 1992; Dunlosky & Hertzog, 1997; Tournier & Postal, 2011).

Here, we tested strategy selection in Experiment 1 and strategy execution in Experiment 2. We asked older adults to memorize pairs of words by selecting either the interactive-imagery or the rote-repetition strategy on each item in Experiment 1. In Experiment 2, participants were randomly assigned to one of these two strategies they had to execute on all items. We restricted the number (and type) of available strategies to only these two strategies for three main reasons. First, we wanted to control that effects of stereotype threat on strategy use (Expt. 1) and/or on strategy execution (Expt. 2) are not confounded with differences in the number (and type) of strategies used by participants under threat versus control conditions. Second, imagery and repetition strategies differ in relative difficulty and efficacy. The deeper encoding provided by imagery yields better recall performance and requires more resources than repetition (e.g., Craik & Lockhart, 1972; Hertzog & Dunlosky, 2006; Hertzog et al., 2012). Also, previous works found that (a) participants use imagery more often on concrete than on abstract words, and (b) relative strategy efficiency is larger on concrete than on abstract words such that differences in older adults' memory performance when using imagery are larger for concrete than for abstract words (e.g., Craik & Dirks, 1994; Tournier & Postal, 2011). Finally, testing two strategies that differ in how often older

adults use them and how efficient they execute them enabled us to determine whether effects of stereotype threat influence both easier and harder strategies or only one of them.

The present hypothesis that stereotype threat effects can occur via changes in strategy selection and strategy execution leads to the following main predictions. Older adults were expected to decrease their use of the imagery strategy and to execute it less efficiently, especially on concrete words where it is used most often and it is most efficient. Indeed, stereotype threat uses up some of the available resources, which should lead older adults to use the easier, less resource-demanding, repetition strategy more often (Expt. 1), and to be more impaired while executing the harder, more resource-demanding, imagery strategy (Expt. 2).

Method

Participants

Experiments 1 and 2 included a total of 56 and 120 older adults, respectively (see Table 1 for participants' characteristics). Participants, recruited from the community, were volunteers who responded to ads posted in different shops and online, and to fliers in different places (university campus, senior centers). All participants lived independently at their home. We did not have groups of young adults as age-based stereotype threat effects are specific to older adults (for whom the stereotype is self-relevant) and typically do not affect young adults' memory performance (e.g., Hess et al., 2003, 2004). In each Experiment, half the participants were randomly assigned in the control group and half in the stereotype threat group. In Experiment 2, half the participants had to use the imagery strategy and the others to execute the repetition strategy on all items.

At the end of the experiments, participants were debriefed about stereotype threat and about the goal of our study to prevent participants' performance in subsequent tests to be influenced by our threat manipulation. Then, participants completed a French version of the Mill-Hill Vocabulary Scale (MHVS; Raven, 1951) to assess their verbal abilities. Also, they were screened for cognitive impairment with the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975), and all achieved a score of over 27.

Our target sample size for Experiment 1 was determined using an a-priori power analysis (G*Power; Faul, Erdfelder, Lang, & Buchner, 2007). With an assumed d of 0.52 when using stereotype-based manipulations as we do here (Lamont et al., 2015), our 2 x 2 mixed design could achieve 80% power with as few as 44 participants, given a modest ($r =$

.30) anticipated correlation between our repeated measures (i.e., type of words). In order to exceed this criterion and achieve greater than 80% power, we recruited 56 participants ($N = 28$ per group).

Our target sample size for Experiment 2 was also determined using an a-priori power analysis (G*Power; Faul et al., 2007). We partially based this analysis on the results from Experiment 1, in which the correlation between our repeated measures was .55. To be conservative, we used a correlation of .50 for the repeated variables. We still used d of 0.52 derived from past stereotype-based manipulations research (Lamont et al., 2015). Given these values, G*Power indicated that with a mixed design with four groups and two repeated measures, we could achieve 80% power to detect the omnibus interaction effect with 48 participants. We decided to collect data until the end of the term, knowing that we would be able to recruit and collect data from at least 48 participants by that time.

Table 1: Participants' characteristics.

Condition	Experiment 1		Experiment2			
			Repetition		Imagery	
Group	Control	Threat	Control	Threat	Control	Threat
N (females)	28 (16)	28 (20)	30 (18)	30 (17)	30 (16)	30 (24)
Mean age (years; months)	73.10	75.4	73.7	72.7	74.2	75.1
Number of years of Education	11.5	11.7	11.8	11.4	11.7	11.8
Age range	67.6-89.5	68.6-87.1	65.11-92.7	66.7-82.6	64.7-87.3	64.3-89.1
MHVS (SD)	24.7 (5.4)	23.5 (5.7)	25.8 (6.3)	28.3 (3.1)	23.2 (6.0)	25.7 (4.8)
MMSE (SD)	28.6 (1.0)	28.3 (1.0)	29.6 (0.7)	29.8 (0.6)	28.4 (1.0)	28.7 (1.0)

Stimuli

The 40 pairs of words, tested in Hinault et al. (2016)'s study, included 20 pairs of concrete words (e.g., *saddle–bear*) and 20 pairs of abstract words (e.g., *saint–weight*). The values of imagery differed for concrete words ($mean = 4.70$; $range = .09$) and abstract words ($mean = 3.38$, $range = .58$), $F(1,78)=202.81$, $MSe=.45$, $\eta^2_p=.72$. Moreover, concrete and abstract words did not differ in mean subjective frequency and emotional valence ($F_s < 1$). Associations between pairs of words were controlled based on Ferrand (2001).

Procedure

Participants were individually tested. We followed Bouazzoui et al. (2016)'s procedure that consists in using two ways to induce stereotype threat effects, a stereotype priming technique (activation questionnaire) and a stereotype threat manipulation (an instructional manipulation). First, participants in the threat group took an ageing stereotype questionnaire (Bouazzaoui et al, 2016), comprising 14 adjectives describing older people, 7 positive (e.g., *wise*) and 7 negative (e.g., *slow*). Participants had to rate the degree to which each adjective was relevant to an older adult on a 4-point scale ranging from "not at all relevant to an older adult" to "very relevant to an older adult". This questionnaire was given to participants in the threat group as exposing older adults to adjectives about ageing was expected to increase activation of the aging stereotype. Then, all participants performed the same memory task. Instructions differed between groups and experiments. For the control group, following previous works (Desrichard & Köpetz, 2005; Kang & Chasteen, 2009; Rahhal et al., 2001), we used non-diagnostic instructions designed to de-emphasize the memory component of the test. Participants were given the following instructions: "You are participating in a study on vocabulary knowledge. You will be presented 40 pairs of words (like *dog-piano*). Each pair of words will be displayed for five seconds. To create a mental representation of each pair of words, you can use only one of two strategies." Instructions then described repetition and interactive-imagery and rote-repetition strategies. For the threat group, we presented the task as a memory test and informed participants that their performance would be compared with that of young adults. Participants were told "You are participating in a study on the effects of age on memory. More specifically, we want to know whether, like other scientific studies in psychology have found, our memory performance tends to decrease with age. We are testing a group of young adults and a group of older adults."

In Experiment 1, participants had to choose between the interactive-imagery and rote-repetition strategy to encode each pair of words. The imagery strategy was described as creating a mental image linking the words of each pair, preferably in making items interact (e.g., mentally visualizing a dog playing piano for the *dog-piano* pair). The repetition strategy was described as continuously repeating the words as many times as possible during display of pairs of words (e.g., *dog – piano, dog – piano, dog – piano*, etc.). In Experiment 2, participants had to encode all 40 pairs of words with the imagery strategy in one condition or

with the repetition strategy in the other condition. After the instructions, the experimenter ensured that participants understood each strategy. Then, the memory task started in earnest. The experimental stimuli were presented in 54-point bold Courier New font (black color) in the center of a 15.4-inch computer screen. The experiment was controlled with the E-Prime software. Every pair of words was displayed for five seconds. In Experiment 1, after each item, participants had to say which of the two strategies was used. In both Experiments 1 and 2, following encoding, a cued recall task was presented: The first word of a pair (e.g., *dog* – ?) was presented on the computer screen, and participants had to verbally recall the second word. Each pair appeared in a different order from that in which it was encoded.

No ethics approval was sought for this study entitled “Age-based stereotype threat”, since our country does not require it for behavioral studies. However, following the ethical standards laid down in the Declaration of Helsinki, participants were informed at the beginning of both Experiments 1 and 2 that they were free to stop their participation in the experiment whenever they want. Also, at the end of both Experiments, participants were debriefed and explained the goals of our study, and general information about our method (e.g., comparing a stereotype and a control group) and about expected results was provided.

Results

Experiment 1

Two sets of analyses were conducted. We tested the effects of stereotype threat first on memory performance, then on strategy selection. Percentages of correctly recalled words and percentages of use of the interactive imagery strategy (see Table 2) were analyzed with mixed-design ANOVAs, 2 (Group: control, threat) x 2 (Word: concrete, abstract), with repeated measures on the last factor. For memory performance, recalled words were scored as correct if they were previously paired with the cue, and (the very few) variations (e.g., pianos instead of piano) were scored as correct. We focused our analyses of strategy use on percent use of imagery as the imagery strategy is known to be most efficient, and percentages of use of imagery are complementary to percentages of use of repetition.

Table 2: Percentages of Correctly Recalled Words and of Use of Interactive Imagery Strategy in the Threat and Control Groups (Experiment 1). 95% CI in brackets.

Word Type	Control	Threat	Means	Differences
<i>Percentages of Correctly Recalled Words</i>				
Concrete	22.1 [17.4--26.9]	9.6 [4.9--14.4]	15.9 [12.5--19.2]	12.5*
Abstract	12.1 [7.8--16.4]	5.7 [1.4--10.0]	8.9 [5.9--12.0]	6.4*
<i>Means</i>	17.1 [13.2--21.1]	7.7 [3.8--11.6]	12.4	9.5*
<i>Percentages of Use of Interactive Imagery Strategy</i>				
Concrete	65.9 [56.9--74.9]	28.6 [19.5--37.6]	47.2 [40.8--53.6]	37.3*
Abstract	44.1 [36.3--51.9]	16.4 [8.6--24.3]	30.3 [24.7--35.8]	27.7*
<i>Means</i>	55.0 [47.2--62.8]	22.5 [14.7--30.3]	38.8	32.5*

Note. Differences=Control–Threat; * $p < .05$

Performance. All participants recalled more concrete (15.9%) than abstract words (8.9%; $F(1,54)=19.00$, $MSe=71.5$, $p < .001$, $\eta^2_p=.26$). The analysis revealed a main effect of stereotype threat, with participants recalling significantly fewer words in the threat group than in the control group (7.7% vs. 17.1%, respectively; $F(1,54)=11.76$, $MSe=213.3$, $p=.001$, $\eta^2_p=.18$). Although marginally significant, the Group x Word interaction ($F(1,54)=3.61$, $MSe=71.5$, $\eta^2_p=.06$, $p=.063$) revealed that, as expected, effects of stereotype threat were larger on concrete (12.5%, $p < .001$, $\eta^2_p=.21$) than on abstract words (6.4%, $p=.039$, $\eta^2_p=.08$).

Strategy selection. All participants selected imagery more often on concrete (47.2%) than on abstract words (30.2%; $F(1,54)=56.58$, $MSe=142.4$, $p < .001$, $\eta^2_p=.51$). The main effect of stereotype threat was also significant, indicating that imagery was used less often by participants in the threat group (22.5%) than in the control group (55.0%; $F(1,54)=34.64$, $MSe=853.7$, $p < .001$, $\eta^2_p=.39$). As expected, the Group x Word interaction ($F(1,54)=4.57$, $MSe=142.4$, $p=.037$, $\eta^2_p=0.08$) revealed somewhat larger effects of stereotype threat on concrete (37.3%; $F(1,54)=34.31$, $MSe=568.4$, $p < .001$, $\eta^2_p=.39$) than on abstract words (27.7%, $F(1,54)=25.08$, $MSe=427.7$, $p < .001$, $\eta^2_p=.32$).

Mediation analysis. We tested whether the use of interactive imagery strategy mediated stereotype threat effects on recall performance. A simple mediation analysis was conducted on concrete versus abstract words separately¹. Using the PROCESS macro for IBM SPSS (10,000 bootstrapped resamples; Model 4; Hayes, 2013), we regressed recall

performance for concrete (abstract) words on group condition (dummy coded: 0 = Control and 1 = Threat) and entered the use of imagery strategy for concrete (abstract) words as the mediator. As can be seen in Figure 1, for both types of words, participants in the threat group used the imagery strategy less often than those in the control group ($a = -37.32$ for concrete words; $a = -27.68$ for abstract words), and the more participants used the imagery strategy, the better they recalled the words ($b = .19$ for concrete words; $b = .21$ for abstract words). The confidence interval of the indirect effect through imagery did not include zero ($ab = -7.09$ (2.89), 95%CI = [-13.329, -1.827] for concrete words; $ab = -5.72$ (2.28), 95%CI = [-12.522, -.859] for abstract words). There was no evidence that stereotype threat influenced recall performance independent of its effect on imagery use ($c' = -5.35$, $p = .188$ for concrete words; $c' = -.71$, $p = .838$ for abstract words). The use of imagery strategy was thus a significant mediator that accounted for more than half of the total effect ($P_M = .57$ for concrete words, $P_M = .89$ for abstract words).

 Insert Figure 1 About Here

Experiment 2

Performance. Percentages of correctly recalled words were analyzed with a mixed-design ANOVA, 2 (Group: control, threat) x 2 (Strategy: Repetition, Imagery) x 2 (Word: concrete, abstract), with repeated measures on the last factor (see Table 3).

Participants recalled more words (13.5%) after encoding them with imagery relative to repetition strategy (6.5%; $F(1,116)=21.25$, $MS_e = 135.1$, $p<.001$, $\eta^2_p=.15$). All participants recalled more concrete (12.5%) than abstract words (7.5%; $F(1,116)=47.48$, $MS_e = 32.7$, $p<.001$, $\eta^2_p=.29$). Participants recalled fewer words in the threat group than in the control group (7.7% vs. 12.3%, respectively; $F(1,116)=9.33$, $MS_e= 135.1$, $p=.003$, $\eta^2_p=.07$). The Group x Word interaction ($F(1,116)=5.10$, $MS_e= 32.7$, $p=.026$, $\eta^2_p=.04$) revealed larger effects of stereotype threat on concrete (6.3% ; $F(1,116)=12.34$, $MS_e=94.9$, $p=.001$, $\eta^2_p=.10$) than on abstract words (2.9%; $F(1,116)=3.51$, $MS_e=72.8$, $\eta^2_p=.03$, $p=.064$).

Table 3: Percentages of Words Correctly Recalled by Participants in the control and threat groups (Experiment 2). 95% CI in brackets.

Strategies	Word type	Control	Threat	Means	Differences
Rote-repetition	Concrete	7.8 [4.3--11.4]	8.7 [5.1--12.2]	8.3 [5.8--10.7]	-0.8
	Abstract	5.5 [2.4--8.6]	4.2 [1.1--7.3]	4.8 [2.7--7.0]	1.3
	<i>Means</i>	6.7 [3.7--9.6]	6.4 [3.4--9.4]	6.5 [4.4--8.6]	0.2
Imagery	Concrete	23.5 [20.0--27.0]	10.2 [6.6--13.7]	16.8 [14.3--19.3]	13.3*
	Abstract	12.3 [9.2--15.4]	7.8 [4.7--10.9]	10.1 [7.9--12.3]	4.5 [†]
	<i>Means</i>	17.9 [14.9--20.9]	9.0 [6.0--12.0]	13.5 [11.4--15.6]	8.9*
<i>Means</i>	Concrete	15.7 [13.2--18.2]	9.4 [6.9--11.9]	12.5 [10.8--14.3]	6.3*
	Abstract	8.9 [6.7--11.1]	6.0 [3.8--8.2]	7.5 [5.9--9.0]	2.9 [†]
	<i>Means</i>	12.3 [10.2--14.4]	7.7 [5.6--9.8]	10.0	4.6*

Note. Differences = Control – Threat ; * $p < .05$; [†] $p < .10$

The Group x Strategy ($F(1,116)=8.34$, $MS_e=135.1$, $p=.005$, $\eta^2_p=.07$), Strategy x Word ($F(1,116)=5.10$, $MS_e=32.7$, $p=.026$, $\eta^2_p=.04$), and Group x Strategy x Word ($F(1,116)=13.90$, $MS_e=32.7$, $p<.001$, $\eta^2_p=.11$) interactions were significant.

Breakdown analyses in each strategy condition were conducted with mixed-design ANOVAs, 2 (Group: control, threat) x 2 (Word: concrete, abstract), with repeated measures on the last factor. The difference between abstract and concrete words was larger with imagery ($F(1,58)=29.25$, $MS_e=46.7$, $p<.001$, $\eta^2_p=.34$) than with repetition ($F(1,58)=18.86$, $MS_e=18.6$, $p<.001$, $\eta^2_p=.25$). Participants recalled fewer words encoded with the imagery strategy in the threat group (9.0%) than in the control group (17.9%), ($F(1,58)=14.13$, $MS_e=168.8$, $p<.001$, $\eta^2_p=.20$); but there were no significant effects of stereotype threat when participants encoded words with the repetition strategy ($F < 1$). Finally, the Group x Word interaction was significant when participants encoded words with the imagery strategy ($F(1,58)=12.52$, $MS_e=46.7$, $p=.001$, $\eta^2_p=.18$) but not when they encoded words with the repetition strategy ($F=1.9$, *ns*). When participants encoded words with the imagery strategy, effects of stereotype threat were larger on concrete (13.3%; $F(1,58)=21.39$, $MS_e=124.7$, $p<.001$, $\eta^2_p=.27$) than on abstract words (4.5% ; $F(1,58)=3.34$, $MS_e=90.9$, $\eta^2_p=.05$; $p=.073$).

Discussion

The present experiments tested the hypothesis that age-based stereotype threat occurs via strategic variations. Our findings support this hypothesis. In addition to the usual effects of age-based stereotype threat on memory performance (i.e., older adults' recall performance was lower under threat than control condition), older participants used the better strategy on each item less often and executed the harder, imagery strategy less efficiently when encoding pairs of words for subsequent recall under threat conditions. These findings concur with some previous findings suggesting that effects of stereotype threat occur during memory retrieval via changes in strategic aspects of participants' performance. For example, Barber and Mather (2013b) found that threat led participants to a more conservative response bias during recognition, and Popham and Hess (2015) found that older adults tended to respond more slowly (but more accurately) under stereotype threat condition, while retrieving items from memory. Regarding encoding strategies, previous studies reported mixed evidence for strategies, with some studies findings showing changes in strategies under stereotype threat conditions (e.g., Hess et al., 2003) and others reporting no evidence (e.g., Chasteen et al., 2005). By examining directly which strategies participants used while they encoded pairs of words and how they execute each strategy, this study is the first one to report unambiguous and direct evidence for effects of stereotype threat to occur via strategic variations. Such findings have important implications for further understanding and studying effects of age-based (and other) stereotype threat as well as of aging on human cognition.

Interestingly, threat-related differences in strategy use and strategy execution did not occur similarly for the two strategies investigated here. Older adults decreased their use of the most efficient, but also most resource demanding, imagery strategy, under the threat condition. Thus, stereotype threat led them to use the easier, though less efficient, repetition strategy more often (Expt. 1). This led older adults' performance to decrease under stereotype threat condition, and our mediational analyses revealed that differences in strategy use between threat and control conditions fully mediated performance differences. Similarly, above and beyond stimuli- and strategy-related differences already found in many previous studies on episodic memory (e.g., Dirks & Craik, 1992; Dunlosky & Hertzog, 1998, 2001), Experiment 2 revealed significant effects of stereotype threat on participants' performance on words encoded with imagery, but no effects of threat on words encoded with the easier, repetition strategy. As expected, these effects of threat on the imagery strategy were stronger on concrete words, where this strategy is typically most selected and most efficient, compared

with abstract words. This is consistent with the idea that stereotype threat consumes the resources that individuals rely on to achieve good performance, leading older adults to use the harder, more resource-demanding, imagery strategy less often (Expt. 1) and to execute it less efficiently (Expt. 2). The differential effects of age-based stereotype on concrete versus abstract words might also result from floor effects for abstract words under control conditions. Recall of abstract words was fairly low in the control conditions, which left small room for large effects of stereotype threat, in contrast to recall for concrete words.

These effects of stereotype threat on strategy use and strategy execution are easily accounted for by assuming that stereotype threat taxes working-memory resources (Régner et al., 2010; Schmader et al., 2008), and this interferes more with more demanding strategies, like imagery, relative to less demanding strategies, like repetition. Because stereotype threat taxes working memory, this leaves fewer resources available to select and execute strategies, like imagery, that are known to place heavier demands on executive control resources than easier strategies, like repetition, especially in older adults (e.g., Bouazzaoui et al., 2014; Burger et al., 2017). As a consequence, older participants used the most demanding imagery strategy less often and executed it less efficiently under stereotype threat conditions.

Previous studies (e.g., Hess et al., 2003) on age-based stereotype threat suggested that older adults may call upon different sets of mechanisms while accomplishing a cognitive task under threat conditions. However, no previous studies tested this hypothesis directly and independently of participants' performance. This study is the first to assess strategies on each item (Expt. 1) and to control which strategies are used (Expt. 2). These are necessary conditions to assess the strategy hypothesis and, more generally, to provide a mechanistic account of stereotype threat. The present findings revealed that older adults used different sets of mechanisms (strategies) under stereotype threat versus control conditions. They also showed that, when mechanisms or strategies used to accomplish a cognitive task are controlled, older participants execute them less efficiently under stereotype threat. These findings suggest that it is important to either assess or control which strategies are used by participants when we try to understand how stereotype threat leads participants to underperform. The role of strategic variations in effects of age-based stereotype threat tested here in memory may not be specific to memory. It may generalize to other domains where stereotype threat led older adults to underperform, like general cognitive tests (e.g., Barber et al., 2015) or more domain-specific tests, such as mind wandering tasks (Jordano & Tournon, 2017) or even specific processes within a given task such as encoding versus recall in memory task (e.g., Barber et al., 2013b; Krendl, Ambady, & Kensinger, 2015; Popham &

Hess, 2015). Future research should test the generality of our strategy hypothesis across domains and tasks.

Future research may also test relations between the present strategy perspective and previous theoretical perspectives on effects of age-based stereotype threat, like the regulatory focus approach proposed by Barber and colleagues (e.g., Barber, 2017). According to the regulatory focus theory, stereotype threat changes older adults' motivational approach, task goals, and preferences in processing styles. Also, the regulatory focus theory assumes that people have either a promotion (focus on gains) or a prevention (focus on minimizing losses) approach when they accomplish cognitive tasks. In the present studies, the control (no-threat) condition may have led older adults to adopt a promotion focus, as seen in more frequent use of the imagery strategy (which maximizes gains in encoded items and involves more global processing). In contrast, the stereotype threat condition led older adults to adopt a more prevention motivational focus (as seen in larger use of repetition which entails a more local processing).

The fruitfulness of the present strategy approach may not be limited to understand effects of age-based stereotype threat. This approach could be adopted to investigate mechanisms underlying effects of any type of stereotype threat (e.g., gender, racial) that have been previously widely investigated (see Pennington et al., 2016; Spencer et al., 2016, for reviews). Strategic variations may be a general mechanism involved in all types of stereotype threat. Note that such a general mechanism is not incompatible with involvement of more (population-, domain-, or task-) specific mechanisms in effects of stereotype threat, as recently hypothesized by previous research groups (e.g., Barber, 2017; Popham & Hess, 2015). Determining whether each type of stereotype threat involves both general and specific mechanisms, discovering these mechanisms, and investigating how each type of mechanisms contribute to modulations of effects of stereotype threat, are goals to be pursued in future research if we want to know conditions of occurrence and modulating factors of stereotype threat, as well as to provide mechanistic accounts for how participants' performance decrease under stereotype threat conditions.

Finally, the present findings have important implications for understanding effects of aging on human cognition. Previous studies examining cognitive factors revealed the important role of strategies used to accomplish cognitive tasks to understand how cognition changes during adulthood (see Lemaire, 2016, for a review). Effects of stereotype threat showed that non-cognitive factors can amplify or decrease age-related differences in cognitive performance. The present findings suggest to further examine the role of strategies in how

non-cognitive factors (e.g., stereotype, personality, motivation, emotion, physical activities) modulate deleterious effects of age on human cognition, a suggestion that future research may investigate using the present item-by-item strategy assessment and strategy-instructions procedure.

Footnotes

¹ We also conducted a simple mediation analysis with concrete and abstract words averaged for the mediator (strategy use) and the outcome (recall performance). Similar results were obtained. Participants in the threat group used imagery less often than those in the control group ($a = -32.50, p < .001$), and the more participants used imagery the better they recalled the words ($b = .23, p < .001$). The confidence interval for the indirect effect through imagery did not include zero ($ab = -7.57 (2.41), 95\%CI = [-12.683, -3.332]$). There was no evidence that stereotype threat influenced recall performance independent of its effects on use of imagery ($c' = -1.89, p > .250$). The use of imagery thus fully mediated the effect of stereotype threat on recall performance and accounted for a substantial part of the total effect, $P_M = .80$.

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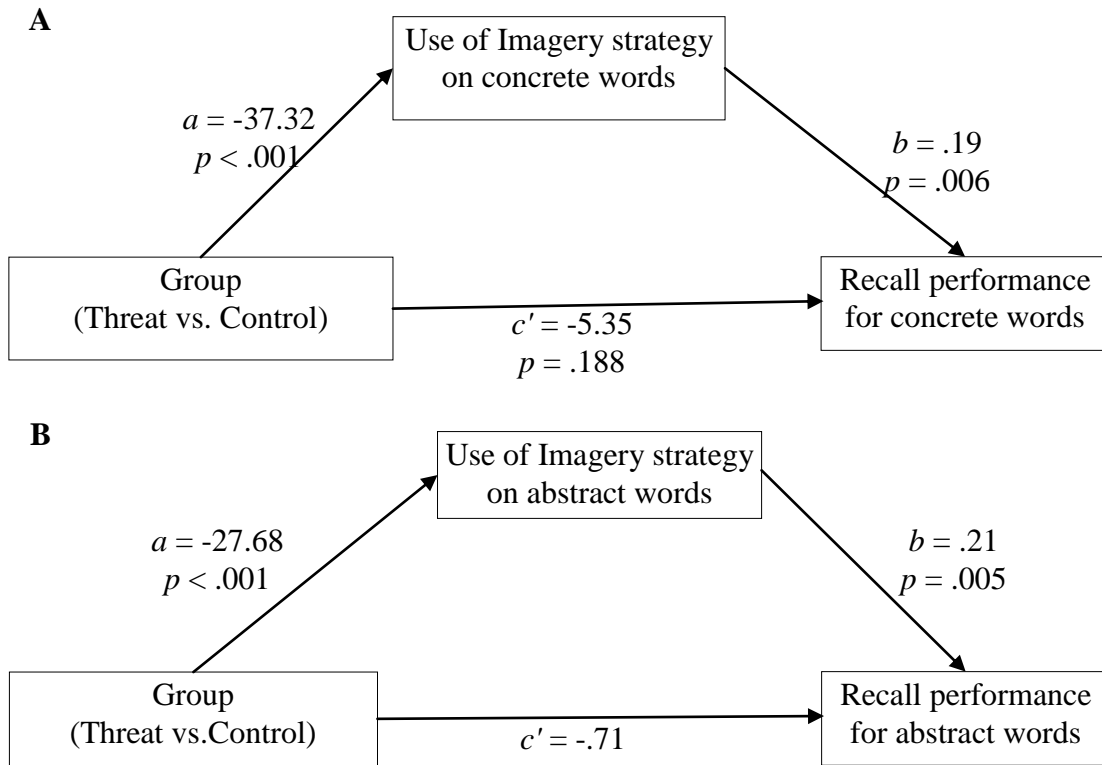


Figure 1. Simple mediation models for the use of imagery strategy. Panel A: model for concrete words. Panel B: model for abstract words.