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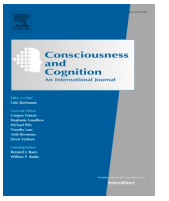

Low working memory reduces the use of mental contrasting

A. Timur Sevincer [b,*], Anne Schröder [a], Alexander Plakides [a], Nils Edler [a], Gabriele Oettingen [c,d]

[a] University of Hamburg, Germany
[b] Leuphana University Lüneburg, Germany
[c] New York University, United States
[d] Zeppelin University, Germany

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ABSTRACT

Mentally contrasting a desired future with reality is a self-regulation strategy that helps people effectively pursue important personal wishes. People with higher self-regulation skills are more likely to spontaneously use mental contrasting. Because one central cognitive function underlying self-regulation is working memory capacity, we investigated whether people with low rather than high working memory capacity are less likely to spontaneously use mental contrasting. Study 1 provided correlational evidence that participants with lower working memory capacity, as measured by the Operation-Span Task, were less likely to use mental contrasting when elaborating an important interpersonal wish. Study 2 provided experimental evidence that manipulating low working memory capacity by inducing cognitive load (vs. no load) led fewer participants to use mental contrasting. The findings have theoretical implications by illuminating the processes that impede mental contrasting, and they have applied implications for understanding how to foster the use of mental contrasting in everyday life.

1. Low working memory reduces the use of mental contrasting

Adam is preparing for an important exam tomorrow. Imagining the desired future of passing the exam (e.g., feeling proud and relieved) and then identifying the crucial inner obstacle that may keep him from preparing for the exam (e.g., being distracted by phone notifications) will make him recognize that he needs to hide his phone and shut off the notifications). Thus, envisioning both the desired future and the critical obstacle will help Adam to prepare for the test and attain his desired future of feeling proud and relieved.

Such mental contrasting of a desired future with a critical obstacle in the present reality is a self-regulation strategy that helps people successfully pursue important goals. Yet, people do not seem to predominantly think in this way about their desired future. Rather they spontaneously engage in other modes of thought than mental contrasting, such as envisioning the desired future only (Sevincer & Oettingen, 2013). We explored one reason why people so often fail to use mental contrasting: People might refrain from mental contrasting when their mind is occupied with other things. In other words, when their working memory capacity is low (vs. high) they should be less likely to mentally contrast and think in other ways instead.

* Corresponding author at: Institute of Psychology, Leuphana University Lüneburg, Germany.
E-mail address: timur.sevincer@leuphana.de (A. Timur Sevincer).

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1.1. Mental contrasting

1.1.1. Mental contrasting: Exercise and effects on goal pursuit

When people use the mental contrasting exercise, they consciously go through a series of three steps. First, they specify an important personal wish ("I would like to get along better with my brother"). They then identify the best outcome of wish fulfilment ("Getting along would make us all so much more relaxed at home") and then vividly imagine that best outcome. Thereafter, they change gears: They identify the most critical inner obstacle in their present reality that may prevent them from realizing their wish ("I always get mad, when my brother teases me"). Such mental contrasting of the desired future with the most critical inner obstacle propels people to invest the needed effort for successful goal pursuit, provided people estimate overcoming the obstacle to be feasible (they have high success expectations). When people estimate overcoming the obstacle to be *not* feasible (they have low success expectations), they have several alternatives: Seeking help, adjusting to go for a more feasible wish, postponing wish fulfilment to a more suitable opportunity, or disengaging from the wish altogether (summaries by Oettingen & Sevincer, 2018; Sevincer & Oettingen, 2020).

Mental contrasting can be used as a cost-effective intervention that fosters successful goal pursuit in numerous domains. An intervention is cost-effective if it can be delivered relatively easily (e.g., online) to a large number of people, and if it has significant effects on important outcomes (Tate et al., 2009). The mental contrasting exercise is relatively brief (e.g., ca. 10 min) and it can be delivered online as a *meta*-cognitive strategy. Interventions using mental contrasting have medium effect sizes on real-life outcomes (*meta*-analyses by Cross & Sheffield, 2019; Wang et al., 2021). For example, mental contrasting helped people eat more healthily, exercise more, study more, and attain better grades (summary by Oettingen et al., 2008).

1.1.2. Mental contrasting: Three further modes of thought

Even though mental contrasting promotes successful goal pursuit, most people do not seem to think in this way (Sevincer & Oettingen, 2013). In fact, fantasy realization theory (Oettingen, 2000; 2012) distinguishes three other ways of thinking people engage in: Indulging, dwelling, and reverse contrasting. In indulging, people imagine having realized their desired future but do not consider potential obstacles on the way. Hence, they do not invest the effort needed to overcome the obstacles. In dwelling, people fail to elaborate on their desired future. Because in dwelling, people consider only their reality without having the desired future in mind, they do not see the reality as a barrier to the desired future. Hence, they lack the direction toward which to invest their effort. In reverse contrasting, people imagine the reality first and then the desired future. Because in reverse contrasting people reflect on the reality first, they reflect on their reality without having the desired future in mind – just like in dwelling. Thus they also fail to see reality as a barrier to the desired future.

In experimental research, mental contrasting participants are asked to specify a wish, specify and imagine the best outcome, and then specify and imagine the critical obstacle standing in the way of fulfilling the wish. In the control conditions, participants are instructed to specify and imagine two positive outcomes only (indulging), two obstacles of reality only (dwelling), or outcome and obstacle in reverse order (reverse contrasting). Thereafter goal pursuit is measured by behavioral (e.g., observed performance), motivational (e.g., self-reported determination), and affective indicators (e.g., anticipated disappointment in case of failure; Oettingen et al., 2001, 2009). Across studies, participants in the mental contrasting (vs. the other three conditions) pursued their wishes as a function of their chances of success (i.e. their subjective success expectations). In short, only mental contrasting led participants to follow their subjective chances of success, whereas participants in the indulging, dwelling, and reverse contrasting conditions either invested too much effort (when chances of success were low) or not enough effort (when chances of success were high). Most research on mental contrasting examined the effect of the modes of thought on goal pursuit. However, there is also research exploring the spontaneous use of mental contrasting.

1.1.3. Mental contrasting: Measurement

The question to what extent people use mental contrasting versus the other three ways of future thought can be assessed by content analysis (Sevincer & Oettingen, 2013). Mirroring the procedure to induce mental contrasting, participants first name an important personal wish. Then they freely associate to their wish and write their thoughts and images down. These mental elaborations are then content analyzed to identify participants' mode of thought. The method has predictive, concurrent, convergent, and discriminant validity (Sevincer & Oettingen, 2013; Sevincer et al., 2015, 2017).

Using this method, researchers identified when people use mental contrasting and who uses it. Because mental contrasting is a self-regulation strategy people should use it when effective self-regulation is called for. Indeed, participants who experienced a high (vs. low) demand to act (e.g., they had a looming deadline) and those who felt high (vs. low) responsibility to act (e.g., they were the sole person accountable) were more likely to mentally contrast (Sevincer et al., 2018, 2020; Tamim et al., 2023). Also, people who reported effectively mastering their daily challenges used more mental contrasting (Sevincer et al., 2017) as did those those who were oriented toward improving rather than just maintaining their current status (i.e., those in a promotion rather than prevention focus; Tamim et al., 2022). Research on the use of mental contrasting also speaks to the cognitive capacities necessary for mental contrasting: Because the mental contrasting exercise is cognitively demanding (Achtziger et al., 2009), participants who were made mentally fatigued were less likely to use it (Sevincer et al., 2015).

Here, we ask what further cognitive capacities may be required for spontaneously using mental contrasting. Answering this question may shed light on why most people fail to use mental contrasting (Sevincer & Oettingen, 2013). Previous research on self-regulatory processes identified working memory capacity as a central component for successful self-regulation (Hofmann et al., 2012). Therefore, we examine whether a lower working memory capacity is related to a reduced use of mental contrasting.

1.2. Working memory

There are several definitions of working memory. These definitions share that working memory is a cognitive system that has limited capacity and allows people to temporarily hold *information active in mind* (Baddeley, 2003; Engle, 2002). This central function of working memory means that working memory predominantly involves conscious components (e.g., visual imagery or inner speech; Baddeley & Hitch, 1974). These conscious components can help mobilize and guide nonconscious routines and resources for problem solving. Thus, recent conceptualizations of working memory acknowledge that working memory involves the interplay between conscious and nonconscious processes (Baars & Franklin, 2003).

Some conceptualizations of working memory highlight that working memory acts as an interface between perceptions, long-term memory, and action. They emphasize that working memory is not only required for storing information but also for processing and modifying the information (Baddeley, 2003). Yet other conceptualizations explicitly posit that the system involves *the conscious direction of attention and thinking* (Cowan, 1999; Engle, 2002). And importantly, it also involves actively *shielding conscious content from interference of intrusive thoughts* (Conway et al., 2003).

The relevance of the working memory system for effective self-regulation of goal pursuit has been recognized early on. For example, successful goal pursuit involves holding goals active in mind and monitoring one's progress towards these goals (test, operate, test, exit; TOTE; Miller et al., 1960). It also involves directing attention away from temptation (Mischel et al., 1989), and shielding one's pursuits from distracting thoughts (Kruglanski et al., 2002; summary by Hofmann et al., 2012). Here, we investigated whether working memory is relevant for people's spontaneous use of mentally contrasting, a self-regulation strategy facilitating goal pursuit.

1.3. Working memory and use of mental contrasting

We investigated whether people are less likely to use mental contrasting when their working memory capacity is low rather than high. We suspected that this could be the case because several working memory features are required to perform the conscious exercise of mental contrasting. Running low on these features should prevent mental contrasting.

First, a higher working memory capacity enables people to better hold goal-relevant information active in mind (e.g., representations of goals and means; Kane et al., 2001; Hofmann et al., 2012). In mental contrasting, people need to hold the desired future as well as the present reality consciously active in mind for mental contrasting effects on selective goal pursuit to occur (Kappes & Oettingen, 2014). Second, a higher working memory capacity allows people to better guide their attention and direct it toward goal-relevant information (Kane et al., 2001; Unsworth & Engle, 2007). In mental contrasting, people need to actively switch from attending the desired future to attending the present reality. Such switching of attending concepts of opposing valence requires the conscious redirection of one's thoughts (Bargh et al., 1996). Third, a higher working memory capacity enables people to better shield relevant information from distraction (Barrett et al., 2004; Hofmann et al., 2009), suppress intrusive thoughts (Brewin & Smart, 2005), and inhibit mind-wandering (Kane et al., 2007). In mental contrasting, people need to focus on their desired future and present reality and keep their mind free from other thoughts.

By contrast, in indulging and dwelling people are not required to hold the future *and* reality active in mind. Neither do they need to switch their attention from the desired future to the present reality. Moreover, because neither indulging nor dwelling facilitates goal pursuit (goal pursuit is unchanged), during indulging or dwelling people do not shield their thoughts from intrusive content. Rather in indulging and dwelling people's stream of conscious thoughts runs off in an associative way (like mind-wandering; Smallwood & Schooler, 2006).

Similarly, reverse contrasting, not leading to changes in goal-pursuit either, seems to be freely associative rather than a purposeful problem-solving strategy like mental contrasting (Kappes & Oettingen, 2014). People think about the present reality and the desired future (in that order). But they do not need to hold the information actively in mind and also do not need to change their interpretation of the reality. Because as indulging and dwelling, reverse contrasting happens by free-association of spontaneous thoughts and is not considered a purposeful problem-solving strategy, people do not need to shield their thoughts from distraction during reverse contrasting. We will return to this point in the General Discussion.

Finally, evidence that working memory is involved in mental contrasting comes from a study that measured brain activity using magnetoencephalography while participants engaged in the conscious mental contrasting exercise (Achtziger et al., 2009). Looking at ten regions of interest, the study predicted and observed more activity during mental contrasting (vs. indulging and resting) in the *prefrontal cortex* and *parietal cortex*. The *prefrontal cortex*, in particular the dorsolateral prefrontal cortex, is a hub for working memory. It plays a role in the executive control of working memory, such as updating, maintaining, and manipulating information. Damage to this area can lead to deficits in working memory (Baddeley, 1992; Fuster, 2008; Koechlin et al., 1999). The posterior *parietal cortex* is involved in the maintenance of visual information (e.g., mental imagery) in working memory. It helps in the manipulation and integration of visual and spatial information during complex mental processes for which working memory is essential (Eriksson et al., 2015). In summary, mental contrasting involves regions similar to working memory tasks.

1.4. The present research

We conducted two studies. Study 1 sought correlational evidence whether participants with a lower (vs. higher) working memory capacity, as measured by the Operation-Span Task (Turner & Engle, 1989), would be less likely to use mental contrasting. Study 2 sought experimental evidence whether manipulating a lower working memory capacity using a cognitive load manipulation (cognitive load vs. no-cognitive-load control) would lead fewer participants to use mental contrasting. In both studies, we measured the use of

mental contrasting using the content-analytic method by Sevincer and Oettingen (2013).

2. Study 1: Correlational study – Relationship between working memory and use of mental contrasting

We examined whether the higher participants' working memory capacity the more likely they are to use mental contrasting (vs. the other modes of thought) when thinking about an important interpersonal wish.

2.1. Method

2.1.1. Participants and design

We recruited 158 student participants (107 female, 48 male, 2 diverse, 1 unidentified, $M_{age} = 25.9$ years, $SD = 8.0$) via the online recruitment system of the university and via an employment website for students (https://www.stellenwerk.de). Participants could choose between receiving course credit or €10, - for taking part. We performed power analyses to detect a small to moderate association between working memory capacity and mental contrasting ($r = 0.25$). Given a critical alpha of 0.05 to detect such a relationship with high power (95 %), we would need about 160 participants (Faul et al., 2007). We used a correlational design. The study was not preregistered.

2.1.2. Procedure

Participants were invited to the lab. They were seated in an experimental cubicle and performed the study on a computer.

2.1.2.1. Assessment of working memory capacity. To assess working memory capacity, we used a German version of the Operation-Span Task (OSpan Task; Rummel et al., 2017; Turner & Engle, 1989; Unsworth et al., 2005). The OSpan Task is one of the three subtasks (operation-span, reading-span, and counting-span) of the Complex-Span Tasks, which are currently one of the most widely used tasks to measure working memory capacity. We used the OSpan Subtask rather than the Reading-Span or the Counting-Span Subtask because the Reading-Span Subtask is not suitable for nonnative German speakers and the Counting-Span Subtask involves visual stimuli and is therefore more difficult to administer than the Ospan Task (Conway et al., 2005). The German version of the OSpan Task has high reliability and validity (Redick et al., 2012; Rummel et al., 2017).

2.1.2.1.1. Operation-span task: Procedure. In the OSpan Task participants were asked to solve mathematical equations while memorizing a series of letters. On the first screen of a trial, participants were presented with a mathematical task (e.g., "(8 * 2) – 8 =?"). On the next screen they were presented with a number (e.g., "7") and were asked to decide whether the number was or was not the solution to the mathematical problem presented directly beforehand. To indicate their choice, participants pressed one button for "correct" or another button for "wrong". After they entered their response, on the following screen they were briefly, for 800 ms, presented with a letter (e.g., "K"). Their task was to memorize the letter and the serial order in which the letter appeared. At the end of a random number between 3 and 7 of such trials (one trial involved solving one mathematical task *and* memorizing one letter in correct order), participants were presented with a 4 X 3 letter matrix that contained all possible letters presented during the trials (e.g., F, H, J, K, L, N, P, Q, R, S, T, and Y). Participants were instructed to click on the presented letters in the correct serial order the letters were presented during the trials. They were also instructed that whenever they could not remember a letter, they should press the blank button. There was no time limit for this memory task. This procedure constituted one block.

The complete task involved 15 such blocks. The blocks had a size between 3 and 7 trials (3, 4, 5, 6, and 7). The 15 blocks were further divided into 3 subblocks, and in each subblock there was one trial of each trial size (3, 4, 5, 6 and 7) presented in random order. Before participants worked on the actual task, they performed 34 practice trials. 15 practice trials with the mathematical task only, 4 with the memory task only, and 15 practice trials with both components (mathematical task and memory task) as in the actual task.

2.1.2.1.2. Operation-span task: Performance. To obtain a score for participants' performance in the OSpan Task, we followed the procedure as recommended by Conway et al. (2015). That is, we looked at participants' performance in the memory task (the letter-memorization component) of the OSpan Task. For each trial, we coded a correct response (i.e., participants recalled a correct letter at the respective position) as 1, and an incorrect response as 0 (i.e., participants could not recall a letter at the respective position, or they recalled an incorrect letter at the respective position). The number of correct responses was then summed up for each block. In the next step, the data was aggregated across blocks. To do this, we used partial-credit unit scoring (PCU; Conway et al., 2015). That is, we calculated the mean proportion of correctly recalled letters from the total number of letters.

2.1.2.2. Assessment of mental contrasting

2.1.2.2.1. Interpersonal wish, expectations, incentive. Following the procedure by Sevincer and Oettingen (2013), participants were first asked to name their currently most important wish directed at initiating or maintaining an interpersonal relationship. Participants named for example "Resolve argument with my friend." Furthermore, we measured participants' success expectations ("How likely is it that you will fulfill your wish?") and the incentive of fulfilling their wish ("How important is it to you to fulfill your wish?"). We used 7-point scales (1 = *not at all*, 7 = *very*).

2.1.2.2.2. Free elaboration. To measure whether participants used mental contrasting, we asked them to freely think about their named interpersonal wish and write down their thoughts and mental images into a designated field. They read:

> Now we would like you to think about your wish. You are free to think about any aspects related to your wish that come to mind. Let the mental images pass by in your thoughts and do not hesitate to give your thoughts and images free rein. Take as much time and space as you need to describe your thoughts.

2.1.2.2.3. Coding of participants' texts. To assess participants' self-regulatory thought, we content-analyzed their written texts using the coding procedure by Sevincer and Oettingen (2013). Specifically, we first segmented the texts into statements. A statement was defined as at least one subject-predicate sequence. Of the 158 participants, 3 (2 %) listed only keywords ("sorrows", "separation"). For those participants, we considered each keyword as one statement. One trained rater blind to participants' OSpan performance then independently coded each statement into one of three categories: (a) desired future, (b) present reality, or (c) other. A detailed description of the employed coding scheme, and examples of the coding are given in Sevincer and Oettingen (2013). One participant elaborated her named wish "Keeping up my long-distance relationship":

> I am thinking a lot about whether my friend and I will manage to keep up our long-distance relationship. I am positive that we will make this work. But what complicates the situation is that we do not know yet when we can be closer to each other again. It is yet unclear how our apprenticeship and work situation will develop.

This was coded as follows: I am thinking a lot about whether my friend and I will manage to keep up our long-distance relationship (other). I am positive that we will make this work (desired future). But what complicates the situation is that we do not know yet when we can be closer to each other again (present reality). It is yet unclear how our apprenticeship and work situation will develop (present reality). Thus, this participant was identified as mental contrasting.

To determine interrater agreement, a second trained rater, also blind to OSpan performance, coded the elaborations of 50 % of the participants (979 statements in total). Agreement between the two raters was 85 % ($\kappa = 0.88$). Statements on which the raters disagreed were coded into the category "other."

2.1.2.2.4. Identification of self-regulatory thought. A participant was classified as mentally contrasting if the participant generated at least one statement about the desired future and at least one statement about the present reality, starting with the future; if the participant started with the reality, they were classified as reverse contrasting. A participant was classified as indulging if the participant generated at least one statement about the future but none about the reality and as dwelling if they generated at least one statement about the reality but none about the future. If a participant generated only statements categorized as "other," we did not include the participant in the above categories.

2.1.2.2.5. Number of statements. We also recorded the number of generated statements as an indicator for how thoroughly participants elaborated on their wish. This measure allowed us to ensure that the hypothesized relationship between working memory capacity and mental contrasting cannot be explained by the possibility that those with a higher working memory capacity also elaborated more on their wish. To conclude, participants completed a short demographic questionnaire and were fully debriefed. The data, analysis code, and materials of Study 1 and Study 2 are available at: https://shorturl.at/fpwA3.

2.2. Results

2.2.1. Descriptive analyses

2.2.1.1. Operation-span task. Table 1 (first row) depicts the means and standard deviations for the working memory capacity measure, participants' performance on the memory task (the letter-memorization) of the OSpan Task. As described above, memory performance was operationalized by the number of letters remembered in correct position aggregated across trials using partial-credit unit scoring (PCU).

Table 1 (second row) also depicts the means and standard deviations for the mathematical task of the OSpan Task. Mathematical performance was operationalized as the percentage of correctly solved math problems from the total number of math problems. Conway et al. (2015) recommend that the scores for participants who solve less than 85 % of the math problems correctly are discarded. In Study 1, nine participants solved less than this percentage correctly. When we excluded those participants, the pattern of results did not change. We present the results with the excluded participants on Page 1 in the Supplementary Material.

2.2.1.2. Expectations, incentive, number of statement. Table 1 depicts the descriptive statistics for expectations, incentive, and the number of statements. Expectations and incentive were above the midpoint of the 7-point scales, indicating that participants deemed their interpersonal wishes feasible and important. Expectations and incentive correlated positively, $r = 0.29$, $p < .001$.

Neither expectations nor incentive value differed between the four modes of thought (mental contrasting, indulging, dwelling, reverse contrasting), $F(3, 146) < 0.69$, $ps > 0.56$. However, the number of generated statements differed between the modes of thought, $F(3, 146) = 5.27.16$, $p = 002$. A post-hoc test using the REGWQ procedure, as recommended by Howell (2012), yielded that mental contrasting, reverse contrasting, and dwelling participants tended to generate more statements than indulging participants, $p < .05$ (Table 1). Following Sevincer et al., (2015, 2017, 2020), to verify that the hypothesized pattern is not due to variations in expectations, incentive, or the number of statements between the different modes of thought we controlled for these variables in both studies.

2.2.1.3. Self-regulatory thought. Table 2 depicts the number of participants using each mode of thought. In line with Sevincer et al., (2015, 2017, 2018), we excluded participants who generated only statements categorized as "other" from the analyses. We dummy-

Table 1
Studies 1 and 2: Means and Standard Deviations (in Parenthesis) for Memory Performance in the OSpan Task (Study 1), Math Performance in the OSpan Task (Study 1), Success Expectations, Incentive, and Number of Generated Statements (Studies 1 and 2) Between Modes of Thought.

			Self-regulatory thought				
Variable	N	Overall	Mental contrasting	Indulging	Dwelling	Reverse contrasting	Other
				Study 1			
Memory performance	157	0.84 (0.15)	0.89 (0.10)	0.82 (0.12)	0.82 (0.20)	0.84 (0.10)	0.80 (0.25)
Math performance	158	93.06 (4.51)	94.02 (4.02)	92.37(4.48)	93.25 (4.87)	92.56 (4.13)	93.00 (5.87)
Expectation[a]	158	4.74 (1.33)	4.57 (1.25)	4.86 (1.28)	4.64 (1.36)	4.72 (1.40)	5.53 (1.33)
Incentive[a]	158	5.94 (1.27)	6.07 (1.01)	6.03 (1.25)	5.86 (1.42)	5.67 (1.31)	6.54 (1.15)
Number of statements	158	13.65 (8.92)	15.94 (7.18)	9.47 (6.13)	14.24 (9.31)	17.03 (10.68)	6.13 (5.69)
				Study 2			
Expectation	229	4.82 (1.59)	4.82 (1.71)	4.95 (1.55)	4.19 (1.53)	5.24 (1.21)	5.67 (1.76)
Incentive	229	6.10 (1.22)	6.04 (1.41)	6.01 (1.25)	6.11 (1.02)	6.65 (0.65)	5.42 (1.73)
Number of statements	229	5.97 (5.47)	6.75 (3.82)	4.05 (2.31)	5.43 (3.67)	10.97 (10.44)	3.50 (3.34)

Note. [a] The means and SDs for expectations and incentive includes the imputed values (see Footnote 1).

Table 2
Studies 1 and 2: Number of Participants Engaging in Each Mode of Thought. Percentages of the Modes of Thought Within Each Study in Parenthesis.

		Self-regulatory thought				
Study	*N*	Mental contrasting	Indulging	Dwelling	Reverse contrasting	Other
1	158	33 (21)	36 (23)	50 (32)	31 (20)	8 (5)
2	227	50 (22)	78 (34)	53 (23)	34 (15)	12 (5)

coded the categorical self-regulatory thought variable into mental contrasting (0) vs. not mental contrasting (indulging, dwelling, and reverse contrasting combined; 1).

2.2.2. Working memory capacity predicting self-regulatory thought

2.2.2.1. Working memory capacity predicting mental contrasting. Memory performance in the OSpan Task correlated with the dummy-coded mental contrasting variable, $r = 0.20$, $p = .016$ (point-biserial correlation), indicating that, as predicted, participants with a higher working memory capacity used mental contrasting rather than those with a lower capacity. Of the one-fourth of participants with the highest capacity 31 % used mental contrasting, compared to 11 % of the one-fourth with the lowest capacity.

To control for expectations, incentive, and the number of statements, we conducted hierarchical binary logistic regression analyses with the dummy-coded mental contrasting variable as the dependent variable and memory performance as predictor in the first step. Memory performace predicted mental contrasting. When we added expectations, incentive, and the number of statements as predictors in the second step, memory performance continued to predict mental contrasting. Thus, the pattern was robust when controlling for the added variables.[2] Table 3 provides a summary of the regression analyses.

2.2.2.2. Working memory capacity predicting the other modes of thought. We also conducted exploratory analyses to examine whether working memory capacity was related to mental contrasting only or also to the other modes of thought. We tested whether memory performance in the OSpan task correlated with each of the other modes of thought (indulging, dwelling, reverse contrasting). We dummy-coded each mode of thought as a dichotomous variable (mode thought vs. all other modes of thought combined). We then conducted a series of hierarchical binary logistic analyses with the dummy coded mode of thought variable as dependent variable and condition as predictor in the first step. Memory performance did not predict indulging, $B = 0.90$, $SE\,B = 1.22$, $p = .46$, $OR = 2.47$, 95 % CI [0.23, 27.00], dwelling, $B = 1.93$, $SE\,B = 1.21$, $p = .11$, $OR = 6.85$, 95 % CI [0.64, 73.69], or reverse contrasting, $B = -0.08$, $SE\,B = 1.39$, $p = .25$, $OR = 3.89$, 95 % CI [0.61, 14.18]. When we entered expectations, incentive, and number of statements as predictors in the second step, the pattern of results did not change ($ps > 0.11$).

[1] When we included the participants categorized as 'other' the results did not change. In Study 1, higher working memory capacity predicted mental contrasting, $B = 5.31$, $SE\,B = 2.19$, $p = .015$, $OR = 0.005$, 95% CI [0.00, 0.36]. In Study 2, fewer participants in the cognitive load condition used mental contrasting than in the control condition, $B = 1.09$, $SE\,B = 0.34$, $p = .002$, $OR = 0.34$, 95% CI [0.17, 0.66].

[2] Due to an error, we did not record expectations and incentive for the first 89 participants. Because for the remaining participants, expectations and incentive correlated with their age (expectations: $r = -0.36$, incentive: $r = -0.38$, $ps = 0.002$), we used stochastic regression imputation with age as predictor to impute the missing expectation and incentive values using the normal variates option as recommended by Baltes-Goetz (2003). When we used the nonimputed variables with the missing values as covariates, working memory capacity (PCU) only marginally predicted mental contrasting, $p = .091$. However, due to the missing values, the power was low to detect a significant effect.

Table 3
Studies 1 and 2: Summary of Hierarchical Binary Logistic Regression Analyses for Working Memory Capacity (Measured by Memory Performance in the OSpan Task in Study 1 and Manipulated by Inducing Cognitive Load in Study 2), Expectations, Incentive, and Number of Statements Predicting the Dummy-Coded Mental Contrasting Variable (Mental Contrasting vs. Not).

Predictors	ΔR^2	*B*	*SE B*	*p*	*OR*[a]	95 % CI[b]
			Study 1			
Step 1	0.08*					
Memory performance		−5.52	2.24	0.014	0.004	[0.00, 0.33]
Step 2	0.04					
Memory performance		−6.30	2.36	0.008	0.002	[0.00, 0.19]
Expectations		0.29	0.18	0.11	1.33	[0.93, 1.89]
Incentive		−0.19	0.18	0.27	0.83	[0.58, 1.17]
Number of statements		−0.03	0.02	0.21	0.97	[0.93, 1.02]
			Study 2			
Step 1	0.07*					
Cognitive load condition		−1.03	0.35	0.003	0.36	[0.18, 0.70]
Step 2	0.01					
Cognitive load condition		−1.04	0.35	0.003	0.36	[0.18, 0.70]
Expectations		0.07	0.12	0.54	1.07	[0.86, 1.35]
Incentive		−0.17	0.15	0.26	0.85	[0.64, 1.13]
Number of statements		0.03	0.03	0.32	1.03	[0.97, 1.09]

* $p < .05$.
[a] Odds ratios (ORs) represent the likelihood that participants use mental contrasting with an increase in the predictor variable. For example, the *OR* of 0.004 for the relation between performance in the O-Span task and the use of mental contrasting signifies that with a one-unit decrease in O-Span performance, the likelihood that participants use mental contrasting is 0.004 times as high.
[b] The 95% CI is the confidence interval for the odds ratio. For instance, the confidence interval for the relation between O-Span performance and the use of mental contrasting signifies that with a 95% probability the true value (the population statistic) of the *OR* of 0.004 lies between 0.00 and 0.33.

2.3. Discussion

The worse participants performed on the memory task of the OSpan task, as indicated by the number of letters they correctly recalled, the less likely they were to engage in the mental contrasting exercise when elaborating their interpersonal wish. Thus, the participants with a lower working memory capacity were also those who refrained from mental contrasting. The relationship remained robust when we controlled for participants' success expectations and the incentive of their wish, as well as the number of statements they generated. Study 1 provided correlational evidence that a lower working memory capacity is related to a reduced use of mental contrasting. In Study 2, we used an experimental design to examine whether a reduced working memory capacity causally hampers the use of mental contrasting.

3. Study 2: Experimental study – Effect of reduced working memory on use of mental contrasting

We examined whether experimentally reducing working memory capacity by inducing cognitive load leads fewer participants to use mental contrasting (vs. the other modes of thought) when they think about an important interpersonal wish.

3.1. Method

3.1.1. Participants and design

Participants were 229 persons (124 female, 102 male, 3 diverse, $M_{age} = 30.4$ years, $SD = 0.10.5$). They were students recruited via the online recruitment system of the university where the research was conducted. In addition, the experimenter recruited participants via word of mouth. Participants learned that with their participation they supported research in psychology and students could receive course credit for taking part. Participants were randomly assigned to a cognitive load: yes condition ($n = 116$) or a cognitive load: no control condition ($n = 113$). We preregistered the study on www.aspredicted.com (#73438).[3]

3.1.2. Procedure

The study took place in the lab. Participants performed the study on a computer.

[3] Because there were no prior studies on the effect of low working memory capacity on the spontaneous use of mental contrasting, we preregistered the study with a planned sample size of 120 participants in total. We determined this sample size by performing power calculations using a medium effect size ($d = 0.06$) as the benchmark. Given a critical alpha of 0.05 to detect such an effect with high power (95%), we would need about 60 participants per condition. However, because due to the end of the COVID-19 pandemic, recruiting and testing participants was easier than we had anticipated, after we had recruited the desired number of participants we decided to extend data collection for another 6 weeks to increase the power of the study. When we analysed the data with only the first 120 participants as preregistered, the difference in the number of mental contrasting participants between conditions was also significant, $B = -1.29$, $SE\ B = 0.49$, $p = .008$, $OR = 0.28$, 95% CI [1.06, 0.72].

3.1.2.1. Interpersonal wish, expectations, incentive. First, all participants were asked to name their currently most important interpersonal wish and indicate their success expectations and the incentive of the wish using the same instructions as in Study 1.

3.1.2.2. Cognitive load manipulation. We embedded the cognitive load manipulation in the measurement of participants' self-regulatory thought. We designed our manipulation based on previous studies using similar manipulations that have been shown to impair conscious processes (Gilbert et al., 1988; Gilbert & Osborne, 1989; Pontari & Schlenker, 2000). In these studies, to induce cognitive load, participants in the experimental condition were presented with information prior to performing a task and asked to rehearse and hold the information in mind while performing the upcoming task. This kind of manipulation thus follows the same reasoning as the OSpan Task employed in Study 1 in that the information that participants are required to hold in mind is assumed to tax working memory capacity. Therefore, holding the information in memory should leave less capacity available to perform other conscious mental activities (Conway et al., 2003; Engle, 2002).

Directly before presenting participants with the instructions to elaborate on their wish, in the cognitive load condition, we informed them that on the next screen they would be presented with an eight-digit number. Using the same instructions as Pontari and Schlenker (2000), we informed them that they should hold the number in their mind until we would later ask them to report the number at the end of the experiment. After participants clicked to the next screen, they saw the number 80321433 and a counter running down for 15 s (Pontari & Schlenker, 2000). During this time, participants could memorize the number. When the time was up the program proceeded automatically to the next screen.

In the control condition, participants received no instructions to memorize a number. They only saw a screen with a counter running down for 15 s. When the time was up the program proceeded automatically to the next screen.

3.1.2.3. Assessment of mental contrasting. To measure participants' self-regulatory thought, on the next screen, all participants were asked to write about their named wish. They saw the same instructions from Sevincer and Oettingen (2013) as in Study 1. We content analyzed the written elaborations using the same coding scheme as in Study 1. One trained rater, blind to conditions, coded the elaborations of all participants. To determine interrater agreement, a second trained rater, also blind to conditions, coded the elaborations of 10 % of the participants (284 statements in total). Agreement between the two raters was 79 % ($\kappa = 0.73$). Statements on which the raters disagreed were coded into the category "other."

3.1.2.4. Manipulation check. To check whether participants in the experimental condition had memorized the number, after they elaborated their wish on the next screen, we asked them to enter the number in the computer. This occurred about 3–10 min after participants were asked to memorize the number, depending on how long they elaborated their wish. To conclude all participants completed a short demographic questionnaire and were fully debriefed.

3.2. Results

3.2.1. Descriptive analyses

3.2.1.1. Expectations, incentive, number of statements. Table 1 depicts the descriptive statistics for expectations, incentive, and the number of generated statements. Expectations and incentive correlated positively, $r = 0.35$, $p < .001$. To examine whether expectations, incentive, and number of generated statements differed between conditions, as recommended by Delacre et al. (2017), we used Welch's T-Test rather than Student's T-Test because Welch's T-Test is generally more robust even if variances between conditions are not significantly unequal. Neither expectations, incentive, nor the number of statements differed between working memory conditions, $ts < 0.32$, $ps > 0.58$. However, expectations, incentive, and the number of statements differed (marginally for incentive) between the four modes of thought (mental contrasting, indulging, dwelling, reverse contrasting; Table 1), $Fs > 2.59$, $ps < 0.055$. Therefore, as in Study 1, we controlled for these variables.

3.2.1.2. Manipulation check. Of the 116 participants in the cognitive load condition, 76 (66 %) entered the correct eight-digit number with the correct order of digits which they were asked to memorize before elaborating their wish. Of the 40 participants who *did not* correctly memorize the number, 8 made one mistake (e.g., they entered a wrong digit or confused the order of two digits), 9 made two mistakes, 21 made three or more mistakes, and 2 did not enter a number. Following our preregistration, we excluded the 2 participants who did not enter a number from the following analyses.[4]

3.2.1.3. Self-regulatory thought. Table 2, lower row, depicts the number of participants using each mode of thought across conditions. Table 4 depicts the number of participants using each mode of thought in each condition. As in Study 1, participants who generated only statements categorized as "other" were excluded and self-regulatory thought was dummy-coded into mental contrasting (0) vs. not (1).

[4] As a more conservative test of our hypothesis, we repeated the analyses after removing all 40 participants who made at least one mistake from the analyses. The pattern of results did not change. The analyses are on Page 2 in the Supplementary Material.

Table 4
Study 2: Number of Participants Engaging in Each Mode of Thought in the Two Conditions. Percentages of the Modes of Thought Within Each Condition in Parenthesis.

		Self-regulatory thought				
Condition	*n*	Mental contrasting	Indulging	Dwelling	Reverse contrasting	Other
Control	113	35 (31)	35 (31)	24 (21)	16 (14)	3 (3)
Cognitive Load	114	15 (13)	43 (38)	29 (25)	18 (16)	9 (8)

3.2.2. Effect of cognitive load on use of mental contrasting.

To test our hypothesis that cognitive load leads fewer participants to use mental contrasting, we compared the number of participants who used mental contrasting between the two conditions (preregistered). Specifically, we conducted hierarchical binary logistic regression analyses with the dummy-coded mental contrasting variable as the dependent variable and condition (no-cognitive-load control vs. cognitive load) as predictor in the first step. Condition predicted mental contrasting (Table 3, lower part) such that in the cognitive load condition, fewer participants used mental contrasting than in the no-cognitive-load control condition (Table 4). Following previous research on mental contrasting (e.g., Sevincer et al., 2020) and analogous to Study 1, we also explored whether the observed effect of the experimental manipulation on the use of mental contrasting remained robust when controlling for expectations, incentive, and number of statements (not preregistered). Indeed, when we added expectations, incentive, and the number of statements as predictors in the second step, the pattern remained the same (Table 3, lower part).

3.2.3. Effect of cognitive load on use of the other modes of thought.

We also explored whether cognitive load affects the use of the other modes of thought (not preregistered). As in Study 1, we dummy-coded each mode of thought as a dichotomous variable (mode of thought vs. all other modes of thought combined). We then conducted a series of hierarchical binary logistic analyses with the dummy coded mode of thought variable as dependent variable and condition as predictor in the first step. Condition did not predict indulging, $B = 0.40$, $SE\ B = 0.29$, $p = .17$, $OR = 1.49$, 95 % CI [0.85, 2.60], dwelling, $B = 0.31$, $SE\ B = 0.32$, $p = .33$, $OR = 1.37$, 95 % CI [0.73, 2.55], or reverse contrasting, $B = 0.20$, $SE\ B = 0.37$, $p = .60$, $OR = 1.22$, 95 % CI [0.58, 2.53]. When we entered expectations, incentive, and number of statements as predictors in the second step, the pattern of results did not change ($ps > 0.20$).

3.3. Discussion

Of the participants who were under cognitive load by being prompted to memorize an eight-digit number while elaborating their interpersonal wish, fewer participants used mental contrasting (vs. the other modes of thought) than of those who were not under cognitive load. Apparently, being under cognitive load prevented people from mental contrasting. The pattern of results remained robust when we controlled for expectations, incentive, and the number of generated statements.

4. General discussion

We investigated whether people are less likely to employ the mental contrasting exercise as compared to other modes of thought when they have low rather than high working memory capacity. In correlational Study 1, the lower participants' working memory capacity the less likely they used mental contrasting when writing about an important interpersonal wish. In experimental Study 2, we manipulated working memory capacity: Participants in whom we induced cognitive load (vs. no load) were less likely to use mental contrasting. The latter finding suggests that a lowered working memory capacity decreases the use of mental contrasting. Combining Studies 1 and 2, our findings suggest that low working memory is associated with a reduced use of mental contrasting when measured as a trait (by the OSpan task) and when ad-hoc induced as a state (by a cognitive load manipulation). The results remained robust when we controlled for participants' expectations of success, the incentive value of their wish, and the number of statements they generated. Thus, the observed results cannot be explained by variations in these variables.

4.1. Mental contrasting: Conscious exercise and nonconscious consequences

Because working memory is more directly relevant for conscious than nonconscious processes (Baddeley & Hitch, 1974), our finding that a low working memory capacity prevented the use of mental contrasting speaks primarily to the conscious processes involved in mental contrasting. The mental contrasting exercise involves multiple conscious tasks such as holding information actively in mind, directing attention to future-relevant information, and shielding active information from intrusion. We did not investigate, however, which of these tasks were impaired by low working memory and thus cannot draw conclusions about which attributes of working memory would need to be strengthened so that people readily use mental contrasting. Future research should examine which of the tasks in mental contrasting are impaired by reduced working memory using cognitive tasks (e.g., sustained or divided attention tasks).

Moreover, the conscious mental contrasting exercise sets-off *nonconscious* cognitive processes that mediate the effect of mental contrasting on goal pursuit. Specifically, experimental studies used lexical decision tasks and sequential priming paradigms to measure

the strength of implicit associative links instilled by the conscious exercise of mental contrasting. These implicit associative links connect the imagined future and obstacle as well as the anticipated obstacle with the means to overcome the obstacle (Kappes & Oettingen, 2014; Kappes et al., 2012). Other studies used implicit categorization tasks to measure the categorization of the reality after mental contrasting. The findings suggest that mental contrasting (vs. relevant control groups) facilitated interpreting the reality as an obstacle to reaching the desired future (Kappes et al., 2013).

According to some conceptualizations of working memory, the conscious procedures that most directly depend on working memory may, at the same time, mobilize nonconscious processes relevant for problem solving (Baars & Franklin, 2003). Thus, future research should test whether low working memory capacity not only undermines the conscious mental contrasting exercise but also the nonconscious consequences triggered by the conscious exercise such as the strengthening of implicit associative future-reality links, and reality-means links (Kappes et al., 2012; Kappes & Oettingen, 2014). For example, one could manipulate low working memory directly *before* inducing mental contrasting to examine whether low working memory prevents the conscious elaboration of the desired future and present reality during mental contrasting and in this way also prevents the strengthening of implicit associative links. One may also manipulate low working memory directly *after* mental contrasting to examine whether low working memory directly prevents the strengthening of implicit associative links.

4.2. Mental contrasting vs. reverse contrasting

Mental contrasting is a purposeful problem-solving strategy that leads to selective (i.e., expectancy-dependent) goal pursuit. In mental contrasting, people hold the desired future and present reality in their mind and switch their attention from the future to the reality. Consciously elaborating the future followed by the reality makes people interpret the reality as an obstacle to attaining the desired future (Kappes et al., 2013), and implicit associative links are formed between the future and reality (Kappes & Oettingen, 2014) and between obstacles and means to overcome the obstacles (Kappes et al., 2012). These new associative links in turn predict expectancy-dependent goal pursuit (Kappes et al., 2012).

In reverse contrasting, as in mental contrasting, people consciously elaborate on the desired future and present reality but in reversed order. However, reverse contrasting involves different conscious processes than mental contrasting. Specifically, in reverse contrasting, people do not direct their attention from the future to the reality. They thus fail to interpret the reality as an obstacle to the desired future. As a consequence, no implicit associative links are strengthened, and no expectancy-dependent goal pursuit ensues after reverse contrasting (Kappes et al., 2012). Our finding that low working memory reduced the use of mental contrasting but not reverse contrasting supports the idea that mental contrasting more than reverse contrasting relies on working memory.

4.3. Use of mental contrasting in real-life

Even though mental contrasting is an effective self-regulation strategy that fosters behavior change (Sevincer et al., 2014, 2023; summary by Sevincer & Oettingen, 2015), few people seem to think in this way when they think about their future (D' Argembeau et al., 2011; D'Argembeau & van der Linden, 2004; Sevincer & Oettingen, 2013). An applied implication of our finding in Study 2 that low working memory capacity, operationalized by cognitive load, impedes the use of mental contrasting is that we should reduce our cognitive load if we want to be equipped to solve our problems. One may also speculate that people's cognitive load during their stressful everyday life may be part of the reason why so few people spontaneously use mental contrasting rather than the other modes of thought. In other words, one should be in a calm state of mind and not be distracted by other activities to ease the use of mental contrasting and subsequently enjoy the self-regulatory benefits of the strategy.

4.4. Relationship with ego-depletion

Our finding that low working memory capacity reduced the use of mental contrasting may resemble previous findings that ego-depletion (Baumeister et al., 1998) reduced the use of mental contrasting (Sevincer et al., 2015). However, these two findings differ in the following ways. In research on ego-depletion and spontaneous mental contrasting (Sevincer et al., 2015), the depletion manipulation occurred *before* participants elaborated their wish, whereas in the present Study 2, the low working memory manipulation occurred *while* participants elaborated their wish (participants had to keep a number active in mind). Thus, whereas the effect of depletion on the use of mental contrasting is an after-effect, the effect of low working memory capacity is an immediate effect (Vosgerau et al., 2008). Moreover, depletion and working memory capacity draw on different underlying resources or processes (Maranges et al., 2017). While ego-depletion either relies on a physiological resource (e.g., glucose, Gaillot & Baumeister, 2007) or on shifts from have-to to want-to motivation (Inzlicht & Schmeichel, 2012), working memory capacity relies on the limited amount of information that one can hold in mind (Engle, 2002). Thus, although both depletion and low working memory capacity reduced the use of mental contrasting they do so by different mechanisms. Ego-depletion impedes mental contrasting by preventing participants to invest the necessary mental effort to employ mental contrasting, which is cognitively demanding and requires overriding a dominant response to indulge or dwell. Low working memory capacity impedes mental contrasting by preventing participants to consciously elaborate and hold necessary information – the desired future and present reality – simultaneously in mind.

4.5. Limitations and future directions

Several limitations of the present research provide directions for future research. First, in Study 1, we measured working memory

capacity in the laboratory. Recent work measured working memory capacity in daily life using an ultra-brief ambulatory assessment via smartphone and found that when participants' working memory capacity was lower than usual they coped less well with daily stressors (Benson et al., 2023). Future work should measure working memory capacity and mental contrasting in daily life using ambulatory assessment.

Second, in both studies, participants named a wish from the interpersonal domain that was personally important. Previous work suggests that the mental contrasting exercise effectively elicits expectancy-dependent goal pursuit for wishes from a wider range of domains. However, for mental contrasting effects to occur, the wishes need to be of high personal importance (Oettingen, 2000). For wishes of low importance, there is no need for the self-regulation of goal pursuit. Future research may solicit wishes from various domains and with various degrees of personal importance to examine to what extent the observed effects of low working memory on the reduced use of mental contrasting generalizes to such wishes as well.

Third, currently, it is unclear whether the use of mental contrasting is more like a trait (i.e., an individual difference) or state (i.e., a context-dependent variable). There is evidence for both: On the one hand mental contrasting correlates with individual differences such as self-regulation skills, need for achievement, and need for cognition (Sevincer et al., 2017, 2014); on the other hand, it is also influenced by contextual factors such as demand to act (Sevincer et al., 2018), felt responsibility (Sevincer et al., 2020), and mental fatigue (Sevincer et al., 2015). Future work should measure mental contrasting repeatedly over a longer period to examine whether individual differences in working memory capacity are related to a repeated use of mental contrasting.

Fourth, in our experimental Study 2, we only manipulated working memory capacity but did not measure baseline working memory capacity Future research should measure baseline working memory capacity to examine whether individual differences in working memory capacity moderate the effect of the cognitive load manipulation on the reduced use of mental contrasting. That is, whether participants with chronically low working memory capacity who are under cognitive load are particularly unlikely to engage in mental contrasting.

Fifth, in Study 2, we manipulated low working memory capacity through a cognitive load manipulation (Gilbert et al., 1988). Before elaborating their wish, participants in the cognitive load condition were presented with an 8-digit number for 15 s and asked to keep the number in mind. The rationale was that keeping the number actively in mind would tax working memory, leaving less capacity available for engaging in mental contrasting. However, rather than actively rehearsing the number during the elaboration, it is also possible that participants stored the number in long-term memory during the 15 s period and retrieved it after elaborating their wish. Because higher working memory capacity has also been linked to better retrieval from long-term memory (Unsworth et al., 2013), participants with higher (vs. lower) working memory capacity may have been more likely to choose retrieval from long-term memory as an alternative route to memorizing the number. However, because we randomly assigned participants to the two conditions, this cannot explain our finding that fewer participants in the cognitive load (vs. control) condition used mental contrasting. Nevertheless, future research should present the number for a shorter period to reduce the likelihood that it will be stored in long-term memory rather than being kept active in working memory.

5. Conclusion

Mental contrasting is a self-regulatory strategy that helps people pursue and attain important personal goals. However, people cannot enjoy these benefits if they fail to use mental contrasting. Being cognitively occupied prevents participants from applying mental contrasting. Thus, to apply the strategy, people should free their mind from distractions in the first place. Going back to the example at the beginning, mentally contrasting the desired future of excelling in the upcoming exam with the obstacle of being distracted from learning will help Adam realize that he needs to turn off his phone notifications. To attain this insight and act accordingly, however, he will benefit from putting himself in a quiet state of mind and conduct the mental contrasting exercise.

6. Author note

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Conflict of interest

We have no known conflict of interest to disclose.

CRediT authorship contribution statement

A. Timur Sevincer: Project administration, Supervision, Writing – original draft, Writing – review & editing. **Anne Schröder:** Data curation, Project administration, Resources, Software. **Alexander Plakides:** Data curation, Project administration, Resources. **Nils Edler:** Project administration, Resources, Software. **Gabriele Oettingen:** Resources, Writing – original draft, Writing – review & editing.

Data availability

We uploaded the data on OSF

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.concog.2024.103644.

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