PARTICIPANT NONNAIVETÉ AND THE REPRODUCIBILITY OF COGNITIVE PSYCHOLOGY

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Abstract

Many argue that there is a reproducibility crisis in psychology. We investigated nine well-known effects from the cognitive psychology literature—three each from the domains of perception/action, memory, and language, respectively—and find that they are highly reproducible. Not only can they be reproduced in online environments but they can also be reproduced with nonnaïve participants with no reduction of effect size. Apparently, some cognitive tasks are so constraining that they encapsulate behavior from external influences such as testing situation and prior recent experience with the experiment to yield highly robust effects.

A hallmark of science is reproducibility. A finding is promoted from anecdote to scientific evidence if it can be reproduced (Lykken, 1968; Popper, 1959). There is a growing awareness that there exist problems with reproducibility in psychology. A recent estimate is that fewer than half the findings in cognitive and social psychology are reproducible (Open Science Collaboration, 2015). In addition, there have several been high-profile preregistered multi-lab failures to replicate well-known effects psychology (Eerland et al., 2016; Hagger et al., 2016; Wagenmakers et al., 2016). A similar multi-lab replication psychology that was considered successful yielded an effect size that was much smaller than the original one (Alogna et al. 2014). These findings have engendered pessimism about reproducibility.

Coincident with the start of the reproducibility debate was the advent of online experimentation. Crowdsourcing websites such as Amazon Mechanical Turk offered the prospect of more efficient, powerful, and generalizable ways of testing psychological theories (Buhrmester, Kwang, & Gosling, 2011). The lower monetary costs and the more time-efficient way of conducting experiments online rather than in a physical lab allow researchers to recruit larger numbers of participants across broader geographical, age, and educational ranges of participants compared to undergraduates (Paolacci & Chandler, 2014). However, online experimentation presents challenges, typically associated with the loss of control over the testing environment and conditions (Bohannon, 2016). Most relevant to the reproducibility debate, online participant pools are large but not infinite, and hundreds of studies are conducted on the same participant pool every day, familiarizing participants with study materials and procedures (Chandler, Mueller, Paolacci, 2014; Stewart et al., 2015). Of particular concern for reproducibility, participants may participate in studies in which they have participated before. A recent preregistered study found sizable reductions in decision-making effects among participants had previously participated in the same studies, suggesting that nonnaïve participants may pose a threat to reproducibility (Chandler et al., 2015). Indeed, nonnaïve participants have been implicated in failures to replicate and declining effect sizes (DeVoe & House, 2015; Rand et al., 2014).

Although concerns with reproducibility span the entire field of psychology and beyond, results in cognitive psychology are typically conceived as comparatively robust (Open Science Collaboration, 2015). We put a sample of these findings to a particularly stringent test by running them under circumstances that are increasingly representative of current practices of data collection but are also documented as challenging for reproducibility. In particular, we conducted the first preregistered replication of a large set of cognitive psychological effects in the most popular online participant pool (see Crump, McDonnell, & Gureckis, 2013 and Zwaan & Pecher, 2012 for non-preregistered replications on MTurk). Most important, we examined whether reproducibility depends on participant nonnaïveté by conducting the same experiments twice on the same participants a few days apart.

Previous research suggests that access to knowledge obtained from previous participation (e.g., from alternative conditions or elaboration) can affect people's responses, and may reduce effect sizes when participants accordingly adjust their intuitive responses towards what is perceived as normatively correct (Chandler et al., 2015). However, studies in cognitive psychology typically have non-transparent research goals, making memory of previous experiences irrelevant. Accordingly, a reduction of effect size due to repeated participation should be close to zero.

We tested the hypothesis that cognitive psychology is relatively immune to nonnaïveté effects in a series of nine preregistered experiments, https://osf.io/shej3/wiki/home/; see Table 1 for descriptions of each experiment. We selected these experiments for the following reasons. First, we wanted a broad coverage of cognitive psychology. Therefore, we selected three experiments each from the domains of perception/action, memory, and language, arguably the major areas in the field of cognitive psychology. Second, we selected findings that are both well known and known to be robust. After all, testing immunity to nonnaïveté effects presupposes that one finds effects in the first place. Third, we selected tasks that lend themselves to online testing. And fourth, we selected tasks that our team had experience with.

Although these findings have proven to be highly reproducible in the laboratory, their robustness in an online environment has not yet been established in preregistered experiments. More importantly, it is unknown whether these findings are robust to the presence of nonnaïve participants. We tested this hypothesis by replicating each study in the most conservative case—in which *all* participants encountered the study before.

General method

Detailed method descriptions for each experiment can be found in the *Supplementary Materials*. Participants were tested in two waves using the Mechanical Turk platform. Approval for data collection was obtained from the Institutional Review Board in the Department of Psychology at Erasmus University Rotterdam. All experiments were programmed in Inquisit. The Inquisit scripts used for collecting the data can be found here: https://osf.io/ghv6m/. At the end of wave 1 of each experimental task participants were asked to provide the following information: Age, gender, native language, education. At the end of both waves we asked the following questions, all of which could be responded to by selecting one of the alternatives "not at all", "somewhat", or "very much": "I'm in a noisy environment", "There are a lot of distractions here", "I'm in a busy environment", "All instructions were clear", "I found the experiment interesting", "I followed the instructions closely", "The experiment was difficult", "I did my best on the task at hand", "I was distracted during the experiment."

In all experiments, different versions of materials and, in some cases, key assignments were created. Different versions ensured counterbalancing of stimulus materials and key assignments. Participants were randomly assigned to one of the versions when they participated in wave 1. Then, upon return three or four days later for wave 2, half of the participants were assigned to the exact same version of the experiment and the other half were assigned to a different version such that there was zero overlap between the stimuli in the first and second wave. Participants who had participated in one of the experiments were not prohibited from participating in the other experiments.

Sampling plan

For each experiment we started with recruiting 200 participants, 100 on Monday and 100 on Thursday. Three or four days after the first participation, each participant was invited to participate again. We aimed to have a final sample size of 80 participants per condition (same items or different items on the second occasion), taking into account non-responses and the exclusion criteria below. Whenever we ended up with fewer than 80 participants per condition, we recruited another batch. Because we expected null effect for the crucial interactions, power analyses could not be used to determine our sample sizes as these analyses require that one predicts an effect and that one has strong arguments for its magnitude. Hence, we decided to obtain more observations than is typically done in previous experiments examining the same effects. By doing so, our parameter estimates are relatively precise.

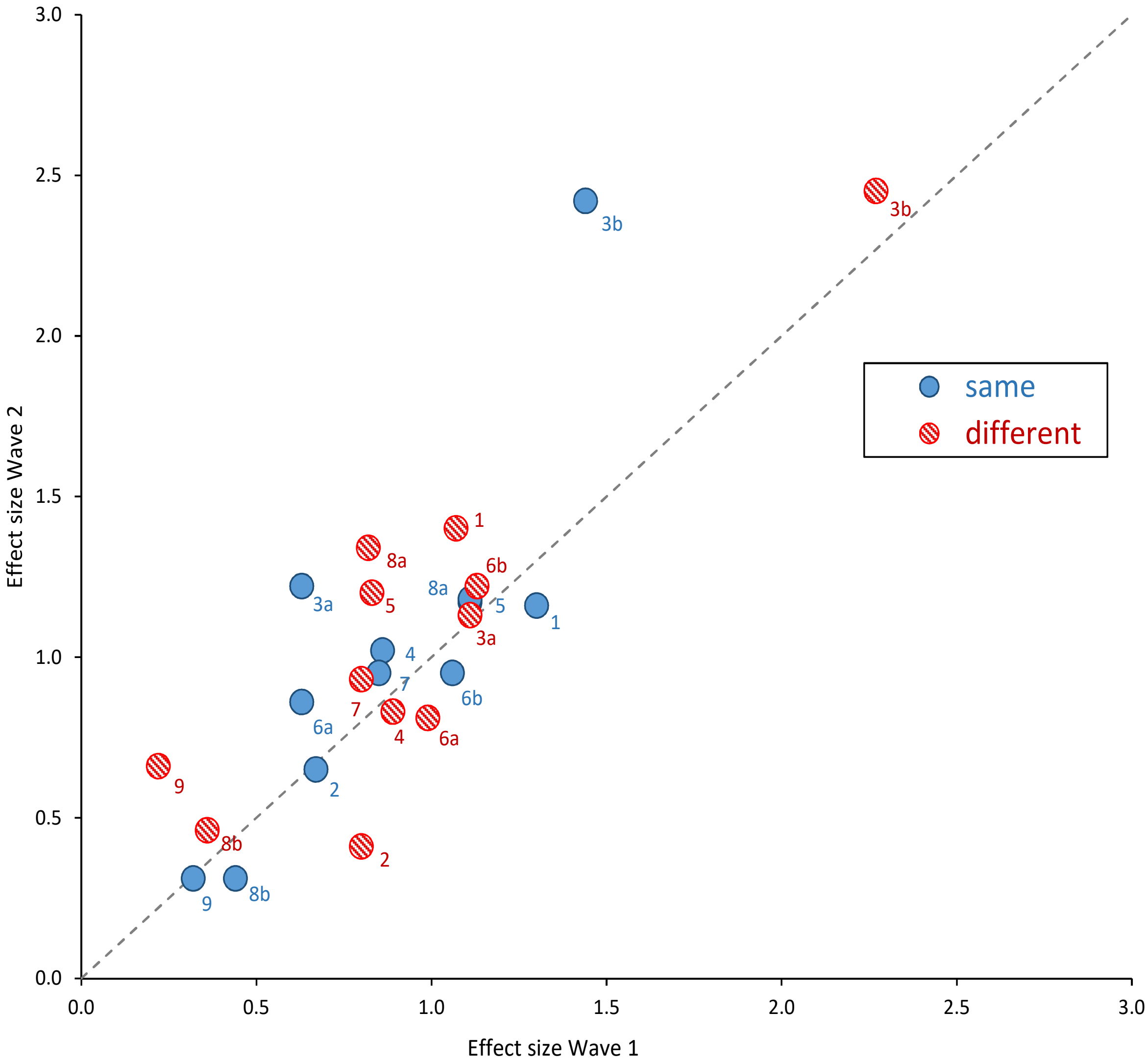
Exclusion criteria

Data from participants with an accuracy <80% in RT tasks or an accuracy <10% in memory tasks or a mean (reaction time) RT longer than the group *M* + 3*SD* were excluded. Data from each participant in the RT tasks were trimmed by excluding trials where the trial RT deviated more than 3*SD* from the subject *M*. From the remainder, participants were excluded (starting with those who participated last) to create equal numbers of participants per counterbalancing version.

Participants were recruited via Amazon Mechanical Turk. The subjects participated in two waves, held approximately three days apart. In the second wave, half of the subjects participated in an exact copy of the experiment they had participated in before; the other half participated in a version that had an identical instruction and procedure but used different stimuli. A recent study demonstrated that certain findings replicated with the same but not with a different set of (similar) stimuli (*19*). Our manipulation allowed us to examine whether changing the surface features of an experiment (i.e., the stimuli) affects the reproducibility of its effect in the same sample of subjects. Each experiment had a sample size of 80 per between-subjects condition (same stimuli vs. different stimuli).

General results

Detailed results per experiment are described in the *Supplementary Materials*. Data for all experiments can be found here: https://osf.io/b27fd/. The results can be summarized as follows. First, the first wave yielded highly significant effects for all nine experiments, with in each case Bayes factors in excess of 10,000 in support of the prediction. Second, each effect was replicated during the second wave. Third, effect size did not vary as a function of wave; Bayes factors showed moderate to very strong support for the null hypothesis. Fourth, it did not matter whether subjects had previously participated in the exact same experiment or one with different stimuli. The main results are summarized in Figure 1. The x-axis displays the wave-1 effect sizes and the y-axis the wave-2 effect sizes. The blue dots indicate the same-stimuli condition and the red dots the different-stimuli condition. The numbers indicate the specific experiment (e.g., 5 = false memory).



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8b

Fig. 1. Wave 1 effect size versus wave 2 effect size (Cohen's *d*). Effect sizes were computed in JASP (JASP Team, 2017). Diagonal line represents equal effect sizes. For each experiment separate effect sizes are plotted for same materials between sessions (blue solid dots) and different materials between sessions (red striped dots). Labels correspond to the different experiments listed in Table 1.

In the preregistration we had stated that "Bayesian analysis will be used to determine whether the effect size difference between waves 1 and 2 better fits a 0% reduction model or a 25% reduction model." However, the absence of a reduction in effect sizes from wave 1 to wave 2—the wave 2 effect sizes were, if anything, larger than the wave 1 effect sizes—rendered the planned analysis meaningless. We therefore did not conduct this analysis.

General discussion

Overall, these results present good news for the field of psychology. In contrast to findings in other parts of the field (Chandler et al., 2015), the effects we studied were also reproducible in samples of nonnaïve participants, which are increasingly becoming the staple of psychological research. What the tasks used in this research have in common is that they (1) use within-subjects designs and (2) have opaque goals. Although it is clear that participants may learn something from their previous experience with the experiments (e.g., response times were often faster in wave 2 than in wave 1), this learning did not extent to the nature of the manipulation. We should note that it is not impossible that some of our participants had previously participated in similar experiments. For these participants, wave 1 would actually be wave N+1 and wave 2 would be wave N+2. Nevertheless, it appears that the tasks used in this study are so constraining that they encapsulate behavior from contextual variation and even from recent relevant experiences to yield highly reproducible effects. We should add a note of caution. What we have examined here are the basic effects with each of these paradigms. In the literature, one often finds variations that are designed to examine how the basic effect varies as a function of some other factor, such as manipulations of instructions, stimulus materials (e.g., emotional vs neutral stimuli), subject population (patients vs controls) of the addition of a secondary task. The jury is still out on whether such secondary findings are as robust as the more basic findings we have presented here.

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Author contributions

R.A. Zwaan developed the study concept. All authors contributed to the study design. Testing and data collection were performed by D. Pecher and S. Bouwmeester. D. Pecher and R.A. Zwaan performed the data analysis. R.A. Zwaan, D. Pecher and G. Paolacci drafted the manuscript, and all other authors provided critical revisions. All authors approved the final version of the manuscript for submission. We thank Frederick Verbruggen and Hal Pashler for helpful feedback on a previous version of this paper.

Table 1. Brief descriptions of and references to all replicated experiments.

Number	*Task*	*Description*	*Reference*
1	*Simon task*	Choice-reaction time task that measures spatial compatibility. Responses are faster when a visual target (a red square is presented on the left of the screen) is spatially compatible with the response (pressing the left button) than when the target is spatially incompatible with the response (presented on the right of the screen).	Craft & Simon, (1970).
2	*Flanker task*	Response inhibition task in which relevant information is selected and inappropriate responses in a certain context are suppressed. Responses are faster for congruent trials in which compatible distractors flank a central target (AAAAA) than for incongruent trials in which incompatible distractors flank a central target (AAEAA).	Eriksen & Eriksen, (1974).
3	*Motor priming (a=masked, b=unmasked)*	*A task with a priming procedure in which responses to stimuli (arrow probes <<) are required that are primed by presented compatible (<<) or incompatible (>>) items. Responses are slower for compatible items when primes are masked but faster when primes are visible.*	Forster & Davis, (1984).
4	*Spacing effect*	*Learning task in which learning (of words) is spaced over time. Recall of words is higher for spaced item repetitions with intervening items than for massed items immediately repeated after their first presentation.*	Greene, (1989).
5	*False memories*	*Memory task that assesses false memory of recognition performance of items that have not been presented before in a word list but tend to be recognized as presented before because they are semantically related to the words in the list.*	Roediger & McDermott, (1995).
6	*Serial position (a=primacy, b=recency)*	*Memory task that examines recall probability based on a word's position in a list. Recall is higher for the first and last words in the list and lowest for items in the middle of the list.*	Murdock Jr., (1962).
7	*Associative*	*Implicit memory task which requires a*	Meyer &

	priming	*response to a target word that is preceded by prime word. Responses are faster when the prime is related than when the prime is unrelated.*	Schvaneveldt, (1971).
8	*Repetition priming (a=low frequency, b=high frequency)*	*Implicit memory task in which speed of response depends on previous exposure to an item and the word frequency of that item. Responses are faster for repeated than for new items. This repetition effect is larger for low frequency words than high frequency words.*	Forster & Davis, (1984).
9	*Shape simulation*	*Sentence-verification task that requires a response on whether the object in a picture was present in the previous sentence. Yes responses are faster when the picture matches the implied shape mentioned in sentence than when it mismatches.*	Zwaan et al., (2002).

Supplementary Materials:

Materials and Methods, and Results for each experiment

Figures S1-S2

Tables S1-S17

References (*29-30*)

Simon Task

Materials and Methods

Participants were randomly assigned to one of four versions of the task. Upon return they were assigned to either the same version with the same assignment of response keys to color or a different version with different stimuli in different colors. For two versions the stimuli consisted of a red and a blue square. For the other two versions the stimuli consisted of a yellow and green circle. The stimuli were resized to 20% of the screen height. The experiment consisted of 8 practice trials and 92 critical trials. Participants were instructed to respond as accurately and quickly as possible to the color of the stimulus. They used the Z-key on their keyboard for one color and the /-key for the other color. Assignment of color to key was counterbalanced between participants. A trial started with a central fixation cross (+) in the center of the screen for 500 ms. Then the fixation cross was replaced with the stimulus. The stimulus was vertically centered and horizontally placed at 15% from the left or right side of the screen and remained visible until the participant pressed one of the response keys. If the response was incorrect, the message "Incorrect" was displayed for 500 ms. The inter trial interval was 1000 ms. During the practice and critical wave, trials for each color in the left or right position were equally likely and presented in randomized order.

Results

In total 172 participants completed both waves (.61 return rate[1]). We selected the data of the first 20 participants in each counterbalanced version so that the total number of participants included in the analyses was 160 (91 females, 1 other, mean age = 39.9 (range 19-71)).

Mean reaction times for correct responses that fell within three standard deviations of the participant's mean for that wave were included in the analyses (3.72% errors, 1.66% outliers). Mean reaction times per condition are shown in Table S1. A 2 (congruency) by 2 (wave) by 2 (similarity) mixed factor ANOVA showed a congruency effect, participants responded faster on congruent trials than on incongruent trials, $F(1,158) = 406.07$, $p < .001$, *partial* $\eta^2 = .72$. We also calculated the JZS Bayes Factor (*BF*), which is the ratio of $p(D \mid H_0)$, the probability of observing the data under the null hypothesis, and $p(D \mid H_1)$, the probability of observing the data under the alternative hypothesis[2] (Rouder, Speckman, Sun, Morey, & Iverson, 2009), using the JASP software (JASP Team, 2017). This analysis showed very strong evidence for a congruency effect, $BF_{10} > 10{,}000$. Participants were not faster on wave 2 than wave 1, $F(1,158) = 2.45$, $p = .120$, *partial* $\eta^2 = .02$, $BF_{01} = 1.20$. The size of the congruency effect was not affected by wave, $F(1,158) = 0.84$, $p = .360$, *partial* $\eta^2 = .01$, $BF_{01} = 6.63$ nor by similarity, $F(1,158) = 0.84$, $p = .360$, *partial* $\eta^2 = .01$, $BF_{01} = 6.88$, nor by the interaction between wave and similarity, $F(1,158) = 1.59$, $p = .210$, *partial* $\eta^2 = .01$, $BF_{01} = 4.32$.

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[1] Return rates are proportions of participants invited after completing wave 1 who actually returned and finished wave 2.

[2] Throughout this paper we report BF_{01} if the evidence is in favour of H_0 and BF_{10} if the evidence is in favour of H_1. For all analyses we used the default r scale = 1 for random effects.

Flanker Task

Materials and Methods

Participants were randomly assigned to one of four versions of the task. Upon return they were assigned to either the same version with the same assignment of response keys or a different version with different stimuli. Two sets of four letters each were created. Each set consisted of two response sets. One response set consisted of two vowels and the other response set of two consonants, and one response set consisted of letters with straight lines and the other response set consisted of letters with curved lines. In two versions of the task the set consisted of the letters A, E, S, and C; in the other two versions the set consisted of O, U, H, and K. The experiment consisted of 24 practice trials and 96 critical trials. On each trial, a row of five letters from the set was presented. Participants were instructed to respond as accurately and quickly as possible to the letter in the middle. They gave one response to two letters and another response to the other two letters. This target letter was surrounded by four flankers. The four flanker letters were the same, and could be identical to the target letter (Same stimulus condition, e.g., AAAAA), different but from the same response set as the target letter (Same response condition, e.g., EEAEE), or different and from the opposite response set (Different response, e.g., SSASS). Participants used the Z-key on their keyboard for one response set and the /-key for the other response set. Assignment of keys to response sets was counterbalanced between participants. A trial started with a line of the same length as the row of five letters (_____) in the center of the screen for 1000 ms. Then the fixation was replaced with the five letters, which remained visible until the participant pressed one of the response keys. If the response was incorrect, the message “Incorrect” was displayed for 500 ms. The inter trial interval was 1000 ms. During the practice and critical wave, each letter was equally likely as target or flanker, and trials for each condition were equally likely and presented in randomized order.

Results

In total 187 participants completed both waves (.65 return rate). Data from 3 participants were removed because of accuracy below .80. From the remaining 184 participants we selected the data of the first 20 participants in each counterbalanced version so that the total number of participants included in the analyses was 160 (85 females, mean age = 38.5 (range 19-72)).

Mean reaction times for correct responses that fell within three standard deviations of the participant’s mean for that wave were included in the analyses (3.61% errors, 1.18% outliers). Mean reaction times per condition are shown in Table S2. A 3 (congruency) by 2 (wave) by 2 (similarity) mixed factor ANOVA showed an effect of congruency, $F(2,316) = 136.24$, $p < .001$, *partial* $\eta^2 = .46$, $BF_{10} > 10{,}000$. Participants were not faster on wave 2 than wave 1, $F(1,158) = 0.29$, $p = .589$, *partial* $\eta^2 = .00$, $BF_{01} = 8.13$. The congruency effect did not differ between waves, $F(2,316) = 1.03$, $p = .358$, *partial* $\eta^2 = .01$, $BF_{01} = 41.04$, it was not affected by similarity, $F(2,316) = 1.79$, $p = .168$, *partial* $\eta^2 = .01$, $BF_{01} = 22.19$, nor by the interaction between wave and similarity, $F(2,316) = 0.06$, $p = .940$, *partial* $\eta^2 = .00$, $BF_{01} = 13.49$.

Motor Priming

Materials and Methods

Participants were randomly assigned to one of four versions of the task. Upon return they were assigned to either the same version with the same assignment of response keys to the same symbols or a different version with different stimuli. Two sets of left-right symbol pairs were created. In one set the symbols were << for left and >> for right. In the other set they were \ and /. For both sets the mask was created by superimposing the two symbol pairs. The experiment consisted of 2 blocks of 20 practice trials and 2 blocks of 80 critical trials. On masked trials, the prime was presented 16 ms, followed by the mask for 100 ms, a blank screen for 50 ms, and the target. On unmasked trials, the prime was presented for 16 ms, followed by a blank screen for 150 ms, and the target. Primes were identical (compatible condition) or not (incompatible) to the target. Participants were instructed to respond as accurately and quickly as possible to the target by pressing the z (left) or m (right) key. If the response was incorrect, the message "Incorrect" was displayed for 500 ms. If the response was slower than 750 ms the message "Please respond faster" was displayed for 2000 ms. The inter trial interval was 1300 ms. One practice and one experimental block of trials consisted of masked trials, and another practice and experimental block consisted of unmasked trials. The order of blocks was counterbalanced across participants. During the practice and critical wave, trials for each condition were equally likely and presented in randomized order.

Results

In total 185 participants completed both waves (.64 return rate). Data from 3 participants were removed because their accuracy was below 80%. From the remaining 182 participants we selected the data of the first 20 participants in each counterbalanced version so that the total number of participants included in the analyses was 160 (80 females, mean age = 39.9 (range 20-71)).

Mean reaction times for correct responses that fell within three standard deviations of the participant's mean for that wave were included in the analyses (4.33% errors, 0.91% outliers). Mean reaction times per condition are shown in Table S3. A 2 (compatibility) by 2 (masking) by 2 (wave) by 2 (similarity) mixed factor ANOVA showed an interaction between masking and compatibility, $F(1,158) = 1068.41$, $p < .001$, *partial* $\eta^2 = .87$, $BF_{10} > 10{,}000$. When primes were masked, participants responded slower to compatible than to incompatible targets, $F(1,158) = 190.43$, $p < .001$, *partial* $\eta^2 = .55$, $BF_{10} > 10{,}000$. In contrast, when primes were unmasked, participants responded faster to compatible than to incompatible targets, $F(1,158) = 895.72$, $p < .001$, *partial* $\eta^2 = .85$, $BF_{10} > 10{,}000$. Participants were faster on wave 1 than wave2, $F(1,158) = 11.85$, $p < .001$, *partial* $\eta^2 = .07$, $BF_{10} = 479.02$. The interaction between compatibility and masking was not affected by wave, $F(1,158) = 0.12$, $p = .726$, *partial* $\eta^2 = .00$, $BF_{01} = 3.63$, nor by similarity, $F(1,158) = 0.98$, $p = .325$, *partial* $\eta^2 = .01$, $BF_{01} = 5.07$, nor by the interaction between wave and similarity, $F(1,158) = 0.01$, $p = .938$, *partial* $\eta^2 = .00$, $BF_{01} = 6.86$.

Spacing Effect

Materials and Methods

A set of 80 words of low to medium frequency (M = 33.0 per million, range = 0.4 –223.6 in SUBTLEX-US, Brysbaert & New, 2009) and average length of 6.1 letters (range = 4-8) were used as experimental stimuli. Of these, 59 were taken from the set used by Godbole, Delaney, Verkoeijen (2014). Additional sets of 48 filler words (frequency: M = 26.5, range = 5.5-95.2, length: M= 5.8, range = 3-8) and 10 practice words (frequency: M =13.1, range = 5.3-26.3, length: M= 5.5, range = 3-7) were selected. The experimental words were divided over 4 lists of 20 items each for counterbalancing, and the fillers were divided over two lists of 24 each for the two waves. To ensure that items in the massed and spaced conditions had equal average serial positions in the list, an item sequence template with 104 slots was created. The sequence started and ended with 5 fillers as primacy and recency buffers. The remaining 14 filler items were used to fill up slots among the experimental items. Massed items were repeated immediately after their first presentation, and spaced items were repeated after 6 intervening items. The four sets of experimental items were rotated over conditions and waves so that across participants all items were presented equally often in each condition and wave. For each participant, items within a set were assigned randomly to slot positions.

Participants were told that we wanted to study how well they could remember words and then were instructed to perform a continuous recognition task. On each trial, a word was presented for 3000 ms, followed by a 500 ms blank screen. If the word was new, participants should press the Z key, and if the word was old, they should press the / key. They were told that even though their key press did not have noticeable effects to them, their response was recorded. After the 10 practice trials feedback on their percentage correct responses was given. After the experimental list, participants again received summary feedback, and instructions for a final free recall test. They were given 2 minutes to type in as many words from the study list as they could remember.

Results

In total 223 participants completed both waves (.66 return rate). Data from 45 participants were removed because their accuracy was below 10%, and data from 1 participant were incomplete for unknown technical reasons. From the remaining 177 participants we selected the data of the first 20 participants in each counterbalanced version so that the total number of participants included in the analyses was 160 (97 females, 2 other, mean age = 40.5 (range 19-71)).

The proportions of correctly recalled items (including misspellings) are shown in Table S4. The recall data were analyzed in a 2 (spacing) by 2 (similarity) by 2 (wave) mixed factor ANOVA. Participants recalled spaced items at a higher rate than massed items, $F(1,158) = 221.41$, $p < .001$, *partial* $\eta^2 = .58$, $BF_{10} > 10{,}000$. The spacing effect was not affected by wave, $F(1,158) = 0.00$, $p = 1.000$, *partial* $\eta^2 = .00$, $BF_{01} = 7.45$, similarity, $F(1,158) = 2.73$, $p = .100$, *partial* $\eta^2 = .02$, $BF_{01} = 2.67$, or the interaction between wave and similarity, $F(1,158) = 1.97$, $p = .162$, *partial* $\eta^2 = .01$, $BF_{01} = 3.47$. Recall was higher overall on the second wave, $F(1,158) = 21.65$, $p < .001$, *partial* $\eta^2 = .12$, $BF_{10} = 1741.88$, and this effect of wave was larger for participants who studied the same items in the two waves than for those who studied different items, $F(1,158) = 9.69$, $p = .002$, *partial* $\eta^2 = .06$, $BF_{10} = 72.94$. Follow up tests showed a significant effect of wave for participants who studied the same items, $F(1,79) = 27.13$, $p < .001$, *partial* $\eta^2 = .26$, $BF_{10} > 10{,}000$, but not for participants who studied different items, $F(1,79) = 1.33$, $p = .252$, *partial* $\eta^2 = .02$, $BF_{01} = 4.34$.

False Memory Effect

Materials and Methods

Participants were randomly assigned to one of four versions of the task. Upon return they were assigned to either the same version with the same assignment of items or a different version with completely different items. Thirty-six lists from Stadler, Roediger, and McDermott (1999) were divided into four sets of nine lists each such that mean false recognition rates of the lures (as reported by Stadler et al.) were similar between sets. Each of the lists consisted of 15 items that were all related to a non-presented lure (e.g., cold: hot, snow, warm, winter, ice, wet, frigid, chilly, heat, weather, freeze, air, shiver, Arctic, frost). In each of the four versions of the experiment one set of lists was studied. Another set was not studied, but the lure and three list items from each of those lists were presented on the recognition test. The other two sets were not used. Across the four versions, each set was used once in the studied condition and once in the unrelated lure condition. For the recognition test, the critical lures and the list items from positions 1, 8, and 10 were presented.

Participants were instructed to study the nine lists of 15 words carefully for a memory test. The nine lists were presented in random order, but the words within each list were presented in the fixed order that was also used by Stadler et al. (1999) based on associative strength with the strongest associates first. Before each new list, the word LIST plus its number (e.g., LIST 1) was presented slightly above the center of the screen for 1500 ms, followed by a 1000 ms blank screen. Each list item was presented in the center of the screen for 1000 ms, followed by a 500 ms blank screen. After the entire list was presented a 1000 ms blank screen was presented before the next list was announced. After all nine lists were presented, participants read the instructions for the recognition test. They were instructed to press the /-key for studied words and the Z-key for non-studied words. The recognition test consisted of 72 words; the critical lure and three items from each of the nine studied lists and the nine nonstudied lists. The items were presented in random order. Each item was presented until the participant responded, and followed by a 500 ms blank screen. During the recognition test a reminder of the response assignment was presented at the bottom of the screen. Additional exclusion criteria for this task: Participants with hits-false alarms(unrelated lures) = 0 (or lower).

Results

In total 185 participants completed both waves (.63 return rate). We selected the data of the first 20 participants in each counterbalanced version so that the total number of participants included in the analyses was 160 (90 females, mean age = 37.7 (range 19-71)).

The mean proportions of ‘old’ responses per condition are shown in Table S5. A 2 (lure relatedness) 2 (wave) by 2 (similarity) mixed factor ANOVA showed a false memory effect; participants falsely recognized more related lures than unrelated lures, $F(1,158) = 236.26$, $p < .001$, *partial* $\eta^2 = .60$, $BF_{10} > 10{,}000$. The false memory effect was not affected by wave, $F(1,158) = 0.14$, $p = .705$, *partial* $\eta^2 = .00$, $BF_{01} = 11.06$, or by similarity, $F(1,158) = 2.18$, $p = .142$, *partial* $\eta^2 = .01$, $BF_{01} = 1.04$, nor was the effect affected by the wave by similarity interaction, $F(1,158) = 0.22$, $p = .643$, *partial* $\eta^2 = .00$, $BF_{01} = 5.82$. Overall, the number of old response to lures was not affected by wave, $F(1,158) = 0.42$, $p = .517$, *partial* $\eta^2 = .00$, $BF_{01} = 88.21$, by similarity, $F(1,158) = 0.24$, $p = .629$, *partial* $\eta^2 = .00$, $BF_{01} = 10.13$, nor by the wave by similarity interaction, $F(1,158) = 1.32$, $p = .252$, *partial* $\eta^2 = .01$, $BF_{01} = 5.82$.

We estimated false memory strength by calculating *d*-primes from ‘hits’ (old response to related lures) and ‘false alarms’ (old responses to unrelated lures) (Zeelenberg, Boot, & Pecher, 2005). A 2 (wave) by 2 (similarity) ANOVA showed no significant effects of wave, $F(1,158) =$

0.16, p = .692, *partial* η^2 = .00, BF_{01} = 7.70, similarity, F(1,158) = 2.08, p = .152, *partial* η^2 = .01, BF_{01} = 1.89, nor an interaction, F(1,158) = 0.25, p = .621, *partial* η^2 = .00, BF_{01} = 5.86.

Data for list items are shown in Table 6. A 2 (wave) by 2 (similarity) ANOVA on the d-*primes* for list items showed no significant effects of wave, F(1,158) = 1.06, p = .304, *partial* η^2 = .01, BF_{01} = 4.94, similarity, F(1,158) = 0.12, p = .735, *partial* η^2 = .00, BF_{01} = 1.74, nor a wave by similarity interaction, F(1,158) = 0.12, p = .735, *partial* η^2 = .00, BF_{01} = 5.80.

Serial Position Effect

Materials and Methods

Participants were randomly assigned to one of two versions of the task. Upon return they were assigned to either the same version or a different version with completely different items. Two sets of 160 high frequency words (M = 106.5 per million, range = 32.6 – 866.0 in SUBTLEX-US, Brysbaert & New, 2009) were used. All words were singular nouns between 4 and 7 letters. Each version of the task comprised one of the sets of words. For each participant the words were randomly distributed over the eight lists.

Participants were instructed to study eight lists of 20 words each and to free recall the words from each list in any order. They started presentation of a list by pressing the space bar. The 20 words were presented in random order. Each word was presented in the center of the screen for 1000 ms, followed by a 500 ms blank screen. After all 20 words were presented, three asterisks were presented for 500 ms as a signal that the recall phase had started. Participants could type the words they recalled for 60 s. After the recall phase they were instructed to press space again for the next list.

Results

In total 240 participants completed both waves (.63 return rate). Data from 3 participants were removed because accuracy was below 10%, and data from 1 participant were incomplete for unknown technical reasons. From the remaining 236 participants we selected the data of the first 20 participants in each counterbalanced version so that the total number of participants included in the analyses was 160 (96 females, 1 other, mean age = 37.1 (range 18-71)).

The proportions of correctly recalled items (including misspellings) are shown in Figures S1 and S2. The recall data were analyzed in a 20 (position) by 2 (wave) by 2 (similarity) mixed factor ANOVA. Serial position affected proportion correct recall, F(19,3002) = 100.05, $p < .001$, *partial* η^2 = .39, $BF_{10} > 10{,}000$. The items in the first part and the items in the last part of the list were recalled at a higher rate than the items in the middle of the list. Recall was slightly higher overall on the second wave than the first wave, F(1,158) = 3.63, p = .059, *partial* η^2 = .02, but the Bayesian analysis indicated that there was more evidence for the null hypothesis of no difference, BF_{01} = 5.24. The interaction between wave and similarity, F(1,158) = 5.30, p = .023, *partial* η^2 = .03, BF_{10} = 72.94, indicated that this effect of wave was present for participants who studied the same items, F(1,79) = 8.96, p = .004, *partial* η^2 = .10, BF_{10} = 5.09, but not for those who studied different items, F(1,79) = 0.08, p = .781, *partial* η^2 = .00, BF_{01} = 24.24.The serial position effect was affected by wave, F(19,3002) = 1.80, p = .018, *partial* η^2 = .01, although the Bayesian analysis indicated that there was more evidence for no difference, $BF_{01} > 10{,}000$, but not by similarity, F(19,158) = 0.98, p = .490, *partial* η^2 = .01, $BF_{01} > 10{,}000$; the interaction was significant, F(19,3002) = 1.80, p = .02, *partial* η^2 = .01, but the Bayesian analysis indicated sttrong evidence for no difference, BF_{01} = 8638.58. Visual inspection of the curves (Fig. S1 and

Fig. S2) suggests that the recall advantage for items at the beginning of the list (primacy effect) was larger on the second wave than on the first.

To estimate effect sizes separately for primacy and recency effects, we compared the mean recall rates for items on the first 4 positions to that of items for the middle 4 position to calculate primacy effect, and those of the last 4 positions to the middle 4 positions to calculate the recency effect. The mean effect sizes are shown in Table S7.

Associative Priming

Materials and Methods

Participants were randomly assigned to one of four versions of the experiment. Upon return they were randomly assigned to the exact same version or another version with completely different materials.

We selected 120 strongly associated word pairs from Nelson, McEvoy, and Schreiber (1998). The mean forward associative strength was .65 (range .39 -.94) and the mean backward associative strength was .47 (range .21 - .78). This set was divided into four sets of 30 pairs such that the sets were matched on average strengths. To create unrelated pairs the primes were rearranged within each set. Sets were counterbalanced across versions such that each set was used once in the related condition and once in the unrelated condition. Additional sets were created of 120 unrelated word-word pairs, 240 word-nonword pairs, and 16 practice pairs with the same proportions of related, unrelated, and word-nonword pairs. Nonwords were created using Wuggy (Keuleers & Brysbaert, 2010) or by changing one or two letters in existing words. All nonwords were pronounceable. All filler and practice sets were split in two for use in the different versions of the experiment.

Procedure. Participants were instructed that on each trial they would see two letter strings in quick succession. They were to read the first letter string but not respond to it, and make a lexical decision on the second letter string as accurately and quickly as possible. A trial consisted of a fixation (* * * * * * *) in the center of the screen for 450 ms, a blank screen of 50 ms, the prime word in the center of the screen for 300 ms, a blank screen for 50 ms, and the target letter string in the center of the screen which remained visible until the participant responded by pressing the /-key for word or the Z-key for nonword. If the response was incorrect, feedback ("Incorrect") was given for 1000 ms. If the response was slower than 1500 ms, feedback ("Response too slow. Please respond faster. Press space to continue.") was given for at least 2000 ms plus the time to hit the space bar. The experiment started with eight practice trials, followed by 240 experimental trials. The order of pairs was randomized for each participant. After 120 trials there was a self-paced break.

Results

In total 170 participants completed both waves (.68 return rate). Data from one participant were removed because accuracy was below 80%. From the remaining 169 participants we selected the data of the first 20 participants in each counterbalanced version so that the total number of participants included in the analyses was 160 (85 females, 1 other, mean age = 39.6 (range 20-70)).

Mean reaction times for correct responses that fell within three standard deviations of the participant's mean for that wave were included in the analyses (2.78% errors, 1.72% outliers). Mean reaction times per condition are shown in Table S8. A 2 (relatedness) by 2 (wave) by 2 (similarity) mixed factor ANOVA showed a priming effect, participants responded faster to related than to unrelated targets, $F(1,158) = 200.87$, $p < .001$, *partial* $\eta^2 = .56$, $BF_{10} > 10,000$. Participants were faster on wave 2 than wave 1, $F(1,158) = 10.00$, $p = .002$, *partial* $\eta^2 = .06$, $BF_{10} = 273.85$. The size of the priming effect was not affected by wave, $F(1,158) = 1.65$, $p = .202$, *partial* $\eta^2 = .01$, $BF_{01} = 6.20$, nor by similarity, $F(1,158) = 0.21$, $p = .647$, *partial* $\eta^2 = .00$, $BF_{01} = 8.76$, nor by the interaction, $F(1,158) = 1.78$, $p = .184$, *partial* $\eta^2 = .01$, $BF_{01} = 3.92$.

Repetition Priming and Word Frequency

Materials and Methods

A set of 104 low frequency words, a set of 104 high frequency words, and a set of 208 nonwords were selected from Wagenmakers, Zeelenberg, Steyvers, Shiffrin, & Raaijmakers (2004) and SUBTLEX-US. The mean SUBTLEX-US frequency per million was 1.22 (range 0.04 – 4.61) for the low frequency set and 248.48 (range 70.20 – 926.45) for the high frequency set. Four lists were created of 24 high frequency words, 24 low frequency words, and 48 nonwords. In each version of the experiment one list was presented twice and another list was presented once. Across versions each list was presented once in the repeated condition and once in the nonrepeated condition. Two lists of 16 items with the same proportions of high frequency, low frequency and nonwords served as practice items.

Participants were instructed that on each trial they would see a letter string and make a lexical decision on it as accurately and quickly as possible. A trial consisted of a fixation (* * * * * * *) in the center of the screen for 450 ms, a blank screen of 50 ms, and the target letter string in the center of the screen which remained visible until the participant responded by pressing the / key for word or the Z key for nonword. If the response was incorrect, feedback (“Incorrect”) was given for 1000 ms. If the response was slower than 1500 ms, feedback (“Response too slow. Please respond faster. Press space to continue.”) was given for at least 2000 ms plus the time to press the space bar. The experiment started with 16 practice trials, followed by 288 experimental trials. The first block of 96 trials consisted of items that would be repeated. The next block of 192 items consisted of 96 repeated and 96 nonrepeated items. The order of items was randomized for each participant. After 96 and 192 trials there was a self-paced break.

Results

In total 171 participants completed both waves (.75 return rate). Data from 2 participants were removed because of low accuracy. From the remaining 169 participants we selected the data of the first 20 participants in each counterbalanced version so that the total number of participants included in the analyses was 160 (83 females, mean age = 39.4 (range 18-69)).

Mean reaction times for correct responses that fell within three standard deviations of the participant’s mean for that wave were included in the analyses (7.96% errors, 1.23% outliers). Mean reaction times per condition are shown in Table S9. A 2 (repetition) by 2 (frequency) by 2 (wave) by 2 (similarity) mixed factor ANOVA showed a repetition priming effect, participants responded faster to repeated than to new targets, $F(1,158) = 379.20$, $p < .001$, *partial* $\eta^2 = .71$, $BF_{10} > 10,000$. Participants responded faster to high frequency than low frequency words, $F(1,158) = 1155.87$, $p < .001$, *partial* $\eta^2 = .88$, $BF_{10} > 10,000$. The interaction between repetition and frequency showed that repetition had a larger effect on low frequency than high frequency words, $F(1,158) = 143.66$, $p < .001$, *partial* $\eta^2 = .48$, $BF_{10} > 10,000$. Participants were faster on wave 2 than wave 1, $F(1,158) = 3.98$, $p = .048$, *partial* $\eta^2 = .03$, although the Bayesian analysis indicated that there was slightly more evidence for no difference, BF_{01} = 2.08. The size of the repetition priming effect was not affected by wave, F(1,158) = 1.76, p = .187, *partial* η^2 = .01, BF_{01} = 6.20, nor by similarity, F(1,158) = 0.85, p = .359, *partial* η^2 = .00, BF_{01} = 13.45, nor by the interaction, F(1,158) = 1.97, p = .163, *partial* η^2 = .01, BF_{01} = 5.74. The size of the frequency effect was affected by wave, the frequency effect was slightly larger on the first wave (92 ms) than on the second wave (87 ms), F(1,158) = 4.27, p = .041, *partial* η^2 = .03, although the Bayesian analysis indicated that there was slightly more evidence for no difference, BF_{01} = 2.41, not by similarity, F(1,158) = 2.31, p = .130, *partial* η^2 = .010, BF_{01} = 1.88, and was affected by the interaction, which showed that the reduction of the frequency effect was larger for similar than for different stimuli, F(1,158) = 4.61, p = .033, *partial* η^2 = .03, although the Bayesian analysis indicated that there was more evidence for no difference, BF_{01} = 6.60. Finally, the interaction between frequency and repetition was marginally affected by wave, F(1,158) = 3.68, p = .057, *partial* η^2 = .02, although the Bayesian analysis indicated that there was more evidence for no difference, BF_{01} = 4.18, but not by similarity, F(1,158) = 1.01, p = .317, *partial* η^2 = .01, BF_{01} = 5.59, nor the interaction, F(1,158) = 0.09, p = .762, *partial* η^2 = .00, BF_{01} = 3.66.

Shape Simulation

Materials and Methods

Stimuli were 120 sentences and 120 pictures. Fifty-two sentences were taken from (*28*). The other 68 sentences were new. The sentences described 60 objects, in two different implied shapes. The pictures represented the same 60 objects, with one picture showing one of the implied shapes and the other showing the other implied shape. All pictures were grayscale photographs showing the object on a white background. Two sets were created with 30 objects each for the two waves of the experiment. Order of the two sets was counterbalanced. For each set, four versions were created with 30 sentence-picture pairs each, such that the shape shown in the picture matched that implied by the sentence for half of the pairs, and mismatched for the other half. Across the four versions, all items were used equally often in the match and mismatch condition. Because all experimental items required a “yes” response, two sets of 30 additional sentence-picture pairs were used as fillers. The filler sentences were similar to the experimental sentences in length and position of object nouns, but were followed by an unrelated picture, thus requiring a “no” response.

Each trial started with a fixation (+), vertically centered and left justified, for 1000 ms, immediately followed by the sentence. The sentence was also left justified so that the first letter appeared at the same location as the fixation. Participants pressed the P key when they had read and understood the sentence. Then a fixation (+) was presented in the center of the screen for 500 ms, immediately followed by the picture. Participants responded by pressing the /-key if the picture presented an object that was named in the sentence, or the Z-key if the object was not named in the sentence. An incorrect response was followed by feedback (“Incorrect”) for 500 ms. Half of the filler trials was followed by a yes/no comprehension question. Each trial was followed by an interval of 1000 ms before the next trial started.

Results

In total 180 participants completed both waves (.56 return rate). Data from 1 participant were removed because accuracy was below 80%. From the remaining 179 participants we selected the data of the first 10 participants in each counterbalanced version so that the total number of participants included in the analyses was 160 (86 females, 1 other, mean age = 40.0 (range 18-69)).

Mean reaction times for correct responses that fell within three standard deviations of the participant's mean for that wave were included in the analyses (3.86% errors, 1.65% outliers). Mean reaction times per condition are shown in Table S10. A 2 (match) by 2 (wave) by 2 (similarity) mixed factor ANOVA showed a match effect, participants responded faster to pictures that matched the shape implied by the sentence than to pictures that mismatched the shape, $F(1,158) = 32.89$, $p < .001$, *partial* $\eta^2 = .17$, $BF_{10} > 10{,}000$. Participants were faster on wave 2 than wave 1, $F(1,158) = 152.94$, $p < .001$, *partial* $\eta^2 = .49$, $BF_{10} > 10{,}000$. The match effect was not different between waves, $F(1,158) = 1.26$, $p = .263$, *partial* $\eta^2 = .01$, $BF_{01} = 6.68$, nor was it affected by similarity, $F(1,158) = 1.29$, $p = .257$, *partial* $\eta^2 = .01$, $BF_{01} = 5.49$. The size of the match effect was affected, however, by the interaction between wave and similarity, $F(1,158) = 10.70$, $p = .001$, *partial* $\eta^2 = .06$, although the Bayesian analysis indicated ambiguous evidence, $BF_{01} = 1.02$. The match effect was larger on wave 2 than wave 1 when the items were different, $F(1,79) = 9.94$, $p = .002$, *partial* $\eta^2 = .11$, although the Bayesian analysis indicated ambiguous evidence, $BF_{01} = 1.31$, but not when the items were the same, $F(1,79) = 2.24$, $p = .138$, *partial* $\eta^2 = .03$, $BF_{01} = 3.99$.

Financial Compensation of Participants

Participants received the equivalent of approximately US$6 per hour. Specified by experiment (per wave) this amounted to: Simon Task: $0.50; Flanker Task: $0.70;Motor Priming: $0.70; Spacing Effect: $0.90; False Memory Effect: $0.70; Serial Position Effect: $0.90; Associative Priming: $1.00; Repetition Priming and Word Frequency: $1.00; Shape Simulation $0.50.

Raw Data

The raw data and files used in the analyses for each experiment can be found at: https://osf.io/ghv6m/.

Response accuracy

We calculated the accuracy rates when the main analysis was performed on the reaction times. In general, the accuracy rates showed the same patterns as the reaction times – when reaction times were faster, accuracy was higher – indicating no speed-accuracy trade-off. Given that our predictions focused on reaction times, we only report descriptive statistics for the accuracy data for the Simon task (S11), the flanker task (S12), motor priming (S13), associative priming (S14), repetition priming (S15), and shape simulation (S16).

Demographics

At the end of wave 1 of each experimental task participants provided demographic information and answered questions concerning their environment and self-perceived performance. These data are summarized in Table S17.

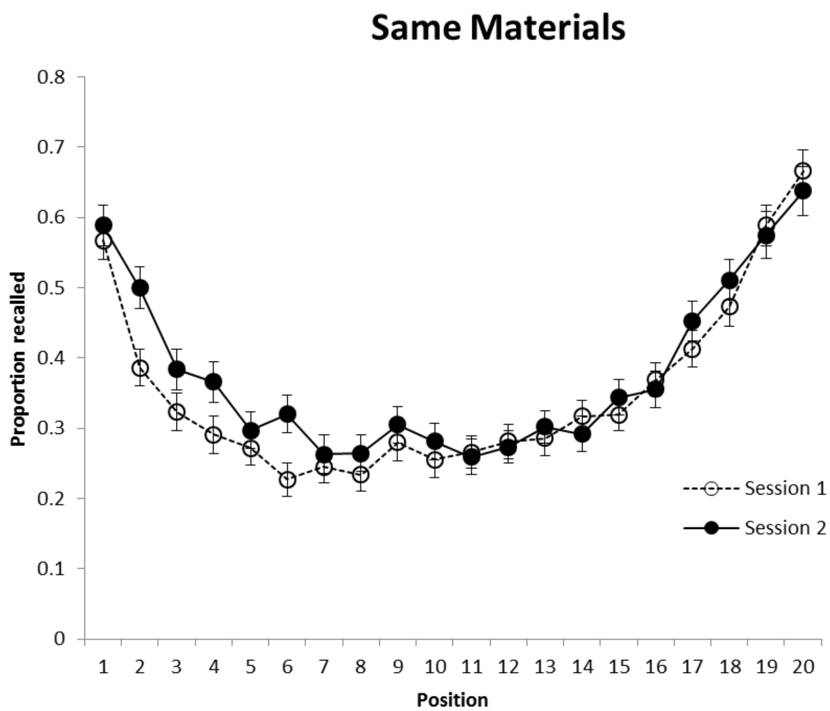

Fig. S1.

Proportion correct recall for each study position with same materials being used across the two waves. Error bars are SE of the mean.

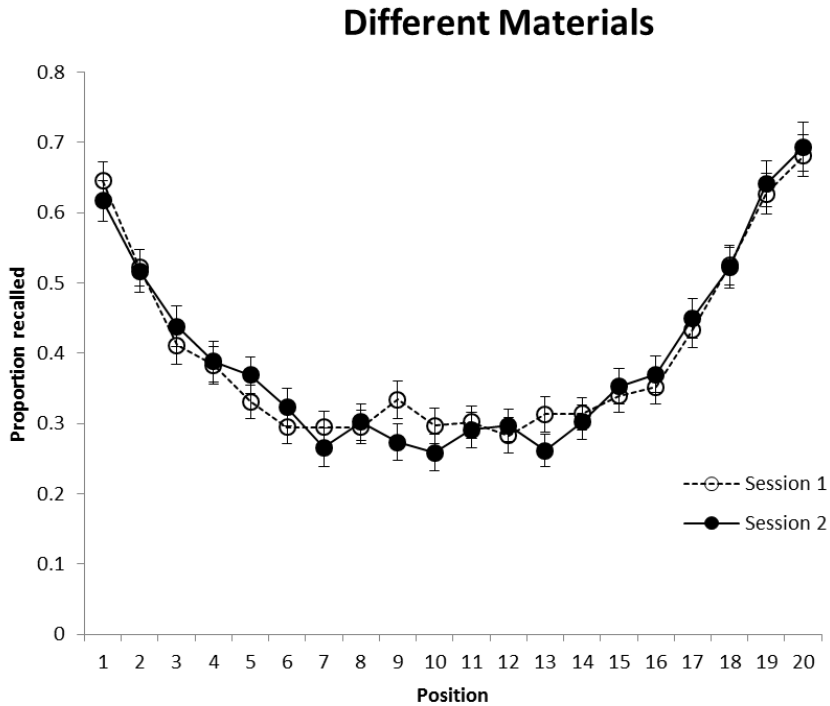

Fig. S2

Proportion correct recall for each study position with different materials being used across the two waves. Error bars are SE of the mean.

Table S1.

Mean Reaction Times on Congruent and Incongruent Trials in the Simon Task (SE in Parentheses; Effect Size in Cohen's *d*)

	Congruent	Incongruent	Simon effect	Effect size
Same stimuli				
Wave 1	422 (8.0)	462 (8.0)	39 (3.4)	1.30
Wave 2	428 (10.0)	461 (9.9)	33 (3.2)	1.16
Different stimuli				
Wave 1	424 (8.0)	457 (8.0)	32 (3.4)	1.07
Wave 2	436 (10.0)	469 (9.9)	33 (2.7)	1.40

Table S2.

Mean Reaction Times to Targets as a Function of Congruency in the Flanker Task (SE in Parentheses; Effect Size in Cohen's *d*)

	Stimulus Congruent	Response Congruent	Response Incongruent	Response Congruency Effect	Effect size
Same stimuli					
Wave 1	587 (18.5)	604 (19.6)	648 (20.7)	44 (7.5)	0.67
Wave 2	572 (18.9)	583 (19.6)	623 (19.9)	39 (6.8)	0.65
Different stimuli					
Wave 1	560 (18.5)	587 (19.6)	622 (20.7)	34 (4.8)	0.80
Wave 2	571 (18.9)	596 (19.6)	626 (19.9)	30 (8.1)	0.41

Table S3.
Mean Reaction Times to Targets with Compatible and Incompatible Masked and Unmasked Primes in the Motor Priming Experiment (SE in Parentheses; Effect Size in Cohen's *d*)

	Compatible	Incompatible	Compatibility effect	Effect size
Same stimuli				
Masked				
Wave 1	423 (7.2)	397 (6.4)	-27 (4.7)	-0.63
Wave 2	419 (5.3)	394 (5.5)	-26 (2.3)	-1.22
Unmasked				
Wave 1	374 (6.7)	443 (6.5)	69 (5.4)	1.44
Wave 2	359 (5.3)	430 (5.9)	71 (3.3)	2.42
Different stimuli				
Masked				
Wave 1	432 (7.2)	409 (6.4)	-23 (2.3)	-1.11
Wave 2	422 (5.3)	399 (5.5)	-23 (2.2)	-1.13
Unmasked				
Wave 1	374 (6.7)	452 (6.5)	79 (3.9)	2.27
Wave 2	360 (5.3)	440 (5.9)	80 (3.6)	2.45

Table S4.
Mean Proportion Correctly Recalled Target Words in the Spacing Experiment (SE in Parentheses; Effect Size in Cohen's *d*)

	Massed	Spaced	Spacing effect	Effect size
Same stimuli				
Wave 1	.13 (.011)	.24 (.013)	.11 (.015)	0.86
Wave 2	.19 (.014)	.32 (.014)	.13 (.014)	1.02
Different stimuli				
Wave 1	.14 (.011)	.25 (.013)	.11 (.013)	0.89
Wave 2	.16 (.014)	.25 (.014)	.09 (.011)	0.83

Table S5.
Mean Proportion 'Old' Responses to Related and Unrelated Critical Lures in the False Memory Experiment (SE in Parentheses; Effect Size in Cohen's *d*)

	Related lure	Unrelated lure	False memory effect	D-prime	Effect size
Same stimuli					
Wave 1	.76 (.028)	.27 (.031)	.49 (.049)	1.51 (0.16)	1.11
Wave 2	.77 (.027)	.28 (.031)	.49 (.047)	1.50 (0.14)	1.17
Different stimuli					
Wave 1	.74 (.028)	.34 (.031)	.39 (.053)	1.20 (0.16)	0.83
Wave 2	.73 (.027)	.31 (.031)	.42 (.040)	1.29 (0.14)	1.20

Note. Effect size estimates are based on the difference of the number of 'old' responses to related lures and unrelated lures.

Table S6.
Mean Proportion of Hits and False Alarms to List Items in the False Memory Experiment (SE in Parentheses)

	Hits	False alarms	D-prime
Same stimuli			
Wave 1	.76 (.027)	.29 (.019)	1.54 (0.14)
Wave 2	.76 (.024)	.26 (.022)	1.67 (0.14)
Different stimuli			
Wave 1	.71 (.032)	.29 (.021)	1.32 (0.16)
Wave 2	.75 (.026)	.31 (.019)	1.38 (0.14)

Table S7.

Mean Recall Rates and Primacy and Recency Effects in the Serial Position Experiment (SE in Parentheses; Effect Size in Cohen's *d*)

	Position 1-4	Position 9-12	Position 17-20	Primacy effect	Primacy Effect size	Recency effect	Recency Effect size
Same stimuli							
Wave 1	.39 (.022)	.27 (.018)	.54 (.022)	.12 (.021)	0.63	.26 (.028)	1.06
Wave 2	.46 (.023)	.28 (.020)	.54 (.026)	.18 (.023)	0.86	.26 (.031)	0.95
Different stimuli							
Wave 1	.49 (.021)	.30 (.022)	.57 (.025)	.19 (.021)	0.99	.26 (.026)	1.13
Wave 2	.49 (.026)	.28 (.022)	.58 (.027)	.21 (.029)	0.81	.30 (.027)	1.22

Table S8.
Mean Reaction Times to Related and Unrelated Targets in the Associative Priming Experiment (SE in Parentheses; Effect Size in Cohen's *d*)

	Related	Unrelated	Priming effect	Effect size
Same stimuli				
Wave 1	532 (7.8)	555 (8.1)	23 (3.0)	0.85
Wave 2	524 (7.4)	547 (7.4)	23 (2.7)	0.95
Different stimuli				
Wave 1	527 (7.8)	557 (8.1)	30 (4.2)	0.80
Wave 2	517 (7.4)	540 (7.4)	23 (2.7)	0.93

Table S9.
Mean Reaction Times to Repeated and Nonrepeated High and Low Frequency Targets in the Repetition Priming Experiment (SE in Parentheses; Effect Size in Cohen's *d*)

	Nonrepeated	Repeated	Priming effect	Effect size
Same stimuli				
Low Frequency				
Wave 1	635 (9.2)	589 (8.4)	46 (4.6)	1.11
Wave 2	625 (8.8)	575 (7.5)	50 (4.7)	1.18
High Frequency				
Wave 1	528 (7.6)	516 (7.1)	12 (3.0)	0.44
Wave 2	523 (6.8)	515 (6.7)	8 (2.8)	0.31
Different stimuli				
Low Frequency				
Wave 1	631 (9.2)	594 (8.4)	36 (4.9)	0.82
Wave 2	630 (8.8)	582 (7.5)	49 (4.0)	1.34
High Frequency				
Wave 1	523 (7.6)	514 (7.1)	9 (2.9)	0.36
Wave 2	517 (6.8)	506 (6.7)	11 (2.7)	0.46

Table S10.
Mean Reaction Times to Matching and Nonmatching Target pictures in the Shape Simulation Experiment (SE in Parentheses; Effect Size in Cohen's *d*)

	Match	Nonmatch	Match effect	Effect size
Same stimuli				
Wave 1	873 (34.3)	925 (36.9)	51 (18.0)	0.32
Wave 2	664 (26.0)	690 (30.1)	25 (9.1)	0.31
Different stimuli				
Wave 1	898 (34.3)	928 (36.9)	30 (15.6)	0.22
Wave 2	722 (26.0)	806 (30.1)	84 (14.1)	0.66

Table S11.

Mean Accuracy on Congruent and Incongruent Trials in the Simon Task (SE in Parentheses)

	Congruent	Incongruent	Simon effect
Same stimuli			
Wave 1	.975 (.003)	.946 (.006)	.029 (.006)
Wave 2	.983 (.003)	.945 (.005)	.038 (.005)
Different stimuli			
Wave 1	.98 (.003)	.94 (.006)	.041 (.006)
Wave 2	.98 (.003)	.95 (.005)	.025 (.005)

Table S12.
Mean Accuracy to Targets as a Function of Congruency in the Flanker Task (SE in Parentheses)

	Stimulus Congruent	Response Congruent	Response Incongruent	Response Congruency Effect
Same stimuli				
Wave 1	.971 (.004)	.975 (.004)	.934 (.008)	.041 (.008)
Wave 2	.973 (.004)	.982 (.004)	.941 (.007)	.040 (.006)
Different stimuli				
Wave 1	.973 (.004)	.980 (.004)	.947 (.008)	.033 (.005)
Wave 2	.973 (.004)	.978 (.004)	.939 (.007)	.039 (.007)

Table S13.
Mean Accuracy to Targets with Compatible and Incompatible Masked and Unmasked Primes in the Motor Priming Experiment (SD in Parentheses)

	Compatible	Incompatible	Compatibility effect
Same stimuli			
Masked			
Wave 1	.953 (.005)	.974 (.004)	-.021 (.005)
Wave 2	.948 (.006)	.981 (.003)	-.033 (.006)
Unmasked			
Wave 1	.986 (.004)	.922 (.007)	.064 (.006)
Wave 2	.987 (.003)	.922 (.008)	.065 (.007)
Different stimuli			
Masked			
Wave 1	.944 (.005)	.969 (.004)	-.025 (.004)
Wave 2	.946 (.006)	.976 (.003)	-.030 (.004)
Unmasked			
Wave 1	.980 (.004)	.905 (.007)	.075 (.007)
Wave 2	.984 (.003)	.899 (.008)	.084 (.009)

Table S14.
Mean Accuracy to Related and Unrelated Targets in the Associative Priming Experiment (SD in Parentheses)

	Related	Unrelated	Priming effect
Same stimuli			
Wave 1	.983 (.004)	.963 (.004)	.019 (.004)
Wave 2	.977 (.003)	.974 (.005)	.003 (.006)
Different stimuli			
Wave 1	.973 (.004)	.969 (.004)	.003 (.006)
Wave 2	.983 (.003)	.969 (.005)	.014 (.005)

Table S15.
Mean Accuracy to Repeated and Nonrepeated High and Low Frequency Targets in the Repetition Priming Experiment (SD in Parentheses)

	Nonrepeated	Repeated	Priming effect
Same stimuli			
Low Frequency			
Wave 1	.782 (.014)	.903 (.009)	.121 (.012)
Wave 2	.822 (.013)	.936 (.008)	.114 (.010)
High Frequency			
Wave 1	.980 (.004)	.988 (.003)	.008 (.004)
Wave 2	.986 (.003)	.990 (.003)	.004 (.004)
Different stimuli			
Low Frequency			
Wave 1	.786 (.014)	.910 (.009)	.123 (.013)
Wave 2	.788 (.013)	.911 (.008)	.123 (.012)
High Frequency			
Wave 1	.984 (.004)	.988 (.003)	.003 (.005)
Wave 2	.987 (.003)	.991 (.003)	.004 (.003)

Table S16.
Mean Accuracy to Matching and Nonmatching Target pictures in the Shape Simulation Experiment (SD in Parentheses)

	Match	Nonmatch	Match effect
Same stimuli			
Wave 1	.963 (.006)	.939 (.009)	.024 (.012)
Wave 2	.983 (.005)	.973 (.006)	.011 (.007)
Different stimuli			
Wave 1	.968 (.006)	.943 (.009)	.025 (.009)
Wave 2	.971 (.005)	.953 (.006)	.018 (.008)

Table S17.
Proportion Responses to Exit Questions for Each Experiment.

	Experiment								
	1	2	3	4	5	6	7	8	9
Education									
High school	.12	.13	.09	.13	.11	.09	.13	.11	.13
College, no degree	.27	.31	.24	.19	.23	.19	.29	.22	.21
Associate's degree	.11	.09	.08	.09	.09	.12	.08	.10	.11
Bachelor's degree	.36	.28	.43	.41	.43	.38	.36	.37	.36
Graduate degree	.15	.19	.16	.18	.14	.22	.14	.20	.20
Noisy environment									
Not at all	.91	.91	.88	.92	.90	.89	.93	.94	.92
Somewhat	.09	.09	.11	.08	.09	.10	.07	.06	.07
Very much	.00	.00	.01	.00	.01	.00	.01	.00	.01
Many distractions									
Not at all	.93	.93	.91	.92	.93	.87	.94	.94	.94
Somewhat	.07	.07	.08	.08	.07	.13	.06	.06	.06
Very much	.00	.00	.00	.00	.00	.00	.00	.00	.01
Busy environment									
Not at all	.97	.97	.95	.95	.95	.96	.98	.99	.96
Somewhat	.03	.03	.05	.05	.05	.04	.02	.01	.03
Very much	.00	.00	.00	.00	.00	.00	.00	.00	.00
Clear instruction									
Not at all	.00	.00	.01	.01	.01	.00	.00	.00	.01
Somewhat	.01	.02	.05	.07	.03	.04	.07	.03	.12
Very much	.99	.98	.94	.93	.96	.96	.93	.97	.88
Interesting task									
Not at all	.12	.14	.21	.02	.02	.05	.09	.09	.03
Somewhat	.56	.59	.47	.31	.48	.38	.44	.54	.50
Very much	.32	.28	.32	.67	.51	.56	.47	.37	.48
Followed instruction									
Not at all	.00	.00	.00	.00	.00	.00	.00	.00	.00
Somewhat	.02	.01	.03	.03	.03	.04	.01	.01	.02
Very much	.98	.99	.97	.98	.98	.96	.99	.99	.98
Difficult									
Not at all	.64	.69	.47	.27	.23	.11	.48	.43	.55
Somewhat	.35	.30	.49	.65	.58	.45	.50	.54	.43
Very much	.01	.01	.04	.08	.19	.44	.03	.03	.02
Did my best									
Not at all	.00	.01	.01	.00	.00	.00	.00	.00	.00
Somewhat	.02	.04	.03	.02	.04	.03	.03	.05	.02
Very much	.98	.95	.97	.98	.96	.97	.97	.95	.98
I was distracted									

Not at all	.93	.94	.90	.92	.95	.87	.94	.94	.95
Somewhat	.07	.06	.09	.08	.05	.13	.06	.06	.05
Very much	.00	.01	.01	.00	.00	.01	.00	.00	.00