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Being Fast or Slow at Naming Depends on Recency of Experience

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Abstract

The speed with which we produce words (e.g., dog) changes depending on whether a word named in the past is from the same semantic category (e.g., cat) or not (e.g., vase). Strikingly, whereas earlier studies find that producing semantically related words speeds up subsequent naming, recent studies report that it slows down future naming. It is unclear why the same experience results in opposite effects and whether both effects originate within the language system. Using the same picture naming paradigm and materials, we manipulated the interval between two naming events, while reducing the influence of expectation. We observed facilitation when semantically related pictures were presented adjacently. By contrast, when semantically related pictures were separated by two unrelated pictures, interference was observed. The results suggest that both facilitation and interference effects emerge within the language system where changes are critically based on the interval between naming, rather than solely due to peripheral processes associated with task demands.

Keywords

naming; lexical access; priming

Introduction

What we experience in the past positively and negatively affects how we process information in the future when recognizing words (e.g., Neely, 1991), retrieving memories (e.g., Anderson, Bjork, & Bjork, 1994), and attending to events (Hunter & Ames, 1988; Posner & Cohen, 1984). For example, the same previously viewed stimuli change an infant's preference for future stimuli depending on how long they were viewed (e.g., Hunter & Ames, 1988). Remembering previous words impairs future attempts to remember related words (Anderson et al., 1994). Seeing a semantically related word (e.g., "cat") facilitates subsequent word reading (e.g., "dog"), compared to an unrelated word (e.g., "vase"; e.g.,

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Neely, 1991), whereas naming a picture (e.g., dog) is hampered by previously naming semantically related words (e.g., “cat”) (e.g., Brown, 1981). In this study, we examined whether similar to other cognitive domains, the same past experience produces different effects during speech production. By reconciling previous findings, we demonstrate how experience shapes the language system. We consider how these phenomena in the language system reflect the way other cognitive domains use the same experience to positively and negatively influence future action.

The speed with which we name a picture (e.g., dog) changes depending on whether a picture named in the past is from the same semantic category (e.g., cat) or not (e.g., vase). It has been well demonstrated that future speech production is hampered by semantically related naming experience (e.g., Belke, 2013; Brown, 1981; Damian et al., 2001; Howard et al., 2006; Schnur et al., 2006; Vitkovitch, Cooper-Pye, & Leadbetter, 2006; Vitkovitch, Rutter, & Read, 2001; Wheeldon & Monsell, 1994). This phenomenon, termed semantic interference, inspired several computational models of speech production (e.g., Howard et al., 2006; Oppenheim, Dell, & Schwartz, 2010; Roelofs, 2018). However, early studies report that speech production is *facilitated* by naming semantically related pictures in the past (i.e., semantic facilitation; e.g., Biggs & Marmurek, 1990; Huttenlocher & Kubicek, 1983; Lupker, 1988; Sperber et al., 1979) as similarly observed in other language-related tasks, e.g., during reading (e.g., Meyer, Schvaneveldt, & Ruddy, 1975) and semantic classification (Belke, 2013; Riley, McMahon, and de Zubicaray, 2015). However, computational models of speech production have not addressed semantic facilitation during naming (Dell, 1986; Roelofs, 1992; Howard et al., 2006; Oppenheim, Dell, & Schwartz, 2010; Roelofs, 2018). This was in part because it is unclear whether facilitation reflects changes within the language system (e.g., Navarrete, Del Prato, & Mahon, 2012) or outside the language system because of peripheral processes associated with task demands (e.g., working memory, Belke, 2008; or participants’ strategy, Belke, Shao, & Meyer, 2017; Oppenheim et al., 2010; Roelofs, 2018). The theoretical question we posed was whether the same naming experience induces opposite effects on subsequent naming as a result of changes within the language system as opposed to processes which occur outside of the language system.

We hypothesized that the polarity of the naming effect depends on the interval between two naming events because facilitation is short-lived and interference is long-lasting (e.g., Damian & Als, 2005; Wheeldon & Monsell, 1994). Consistent with this hypothesis, the time interval between prime and target onsets is shorter in studies demonstrating facilitation (< 2 sec., Biggs & Marmurek, 1990; Huttenlocher & Kubicek, 1983; Lupker 1988; Sperber et al., 1979) compared to those demonstrating interference (> 4 sec., Vitkovitch et al., 2001; 2006; Wheeldon & Monsell, 1994). However, to allow for this conclusion, another explanation needs to be ruled out. Semantic interference also occurs when all the pictures (prime and target) are presented at a consistent rate (Vitkovitch et al., 2001; 2006; Wheeldon & Monsell, 1994), while semantic facilitation occurs when the response-stimulus interval (RSI) between the prime and target is much shorter (< 1sec.) than the RSI between the target and next prime (3–10 sec.) (Biggs & Marmurek, 1990; Huttenlocher & Kubicek, 1983; Lupker 1988; Sperber et al., 1979). Compared with the first case, in the second case participants may be more likely to notice the prime-target pairs and thus rely on the semantic

relationship to predict the target response, resulting in facilitation. Indeed, Huttenlocher and Kubicek (1983) manipulated the probability of related pairs (87.5% vs. 12.5%) and found a larger facilitation effect (175 ms vs. 59 ms) in the high vs. low expectancy condition. Thus, the expectation of a relationship between trial pairs impacts the degree of facilitation in naming.

To uncover how speech production is affected by past naming experience, we conducted two sets of experiments testing whether facilitation and interference effects in naming are caused by different time courses while reducing the influence of expectation.

Experiment 1

We performed the following manipulations to assess whether semantic facilitation and interference occur within the language system due to the same naming experience. First, to detect short-lived facilitation in naming, we presented the prime and target adjacently and the time interval between onset of prime and target was fixed to 2 sec. (lag0). Second, to directly test whether opposite effects caused by semantically related naming experience depend on different intervals between naming trials, we included a lag2 condition, where the prime and target were separated by two unrelated intervening pictures (i.e., fillers). In this lag2 condition, the time interval between the onset of the prime and target was 6 sec., similar to previous studies reporting semantic interference (e.g., Wheeldon & Monsell, 1994). Third, to make the primetarget pairs less obvious to participants, we followed Wheeldon and Monsell (1994) and Vitkovitch et al. (2001, 2006), presenting pictures at a consistent rate (2 sec.).

If opposite effects of naming experience on speech production occur within the language system due to different intervals between naming occurrences, we predicted a facilitation effect when the prime and target are presented adjacently to each other with a short time interval (2 sec., lag0) and an interference effect when the prime and target are separated by two intervening trials with a longer time interval (6 sec., lag2). Alternatively, if facilitation is the result of processes peripheral to the language system because of the obvious grouping of primes and targets, the consistent presentation rate in the current study predicts no facilitation in either the lag0 or lag2 condition.

Method

Participants—Ninety-Six Rice University undergraduates participated in Experiment 1 for course credit, 40 of whom participated in rating the materials (see Materials). All participants were native English speakers who provided written informed consent in accordance with the Institutional Review Board at Rice University.

Materials and Design.—The stimuli were 320 color photographs (80 targets, 80 primes, and 160 fillers) from the Bank of Standardized Stimuli (Brodeur, Guérard, & Bouras, 2014) scaled to 300 × 300 pixels. We chose the target pictures from several semantic categories and paired each target with a semantically related prime from the same category to form the related prime-target pairs (the related condition). Unrelated prime-target pairs were created by re-pairing the semantically related prime and target pictures into unrelated pairs (see

Supplemental Materials). Using a 5point scale, another group of 40 participants rated the degree of semantic similarity between the prime and target in the related and unrelated pairs. The related pairs (mean: 4.52; range: 3.555.00) were rated more similar than the unrelated pairs (mean: 1.13, range: 1.00–1.40; $t_1(39) = 58.35$, $p < .001$; $t_2(79) = 56.79$, $p < .001$).

To control for possible diminution of effects due to repetition, participants named the same pictures once during the experiment. To this end, we performed the following manipulations. First, we divided the 80 related prime-target picture pairs into two lists of 40 pairs each (lists A and B) and created the unrelated prime-target pairs within a list. Half of the participants saw targets in list A with related primes and list B with unrelated primes, while the other participants saw the reverse. Second, we manipulated the condition of lag between-subject but within-item. Specifically, we paired each target picture with an additional two pictures (unrelated to the target and the target's paired semantically related and unrelated primes) to serve as fillers. The two unrelated fillers were interleaved between the prime and target (i.e., prime, filler, filler, target) in the lag2 condition. In the lag0 condition, we presented the two unrelated fillers before the prime-target pair (i.e., filler, filler, prime, target) to reduce the possibility of participants detecting the occasional semantic relationship between two sequential pictures. 56 participants were equally assigned between the lag0 and lag2 conditions.

Apparatus.—DMDX software (Forster & Forster, 2003) was used to run the experiment and record verbal responses. A microphone headset triggered a voice key to collect naming response times (RTs) to the nearest millisecond (ms).

Procedure.—First, participants were familiarized with all picture stimuli used in this experiment. The experimenter corrected participants when a wrong name or no response was provided. Immediately after the familiarization phase, the experiment began with ten practice items presented in the same way as experimental items. Each item began with a cross (+) in the center of the screen for 500 ms, followed by a single picture. Participants named pictures as quickly and accurately as possible. Pictures remained on the screen for 1000 ms followed by a 500 ms blank screen. The experiment lasted ~20 minutes.

Results

Five participants were excluded due to equipment/experimenter errors. Incorrect responses and omissions were coded as analyzable errors (2.5%) in the error analyses. Trials with analyzable errors, voice key/microphone errors and RTs beyond 2.5 standard deviations from the mean were removed from the RT analyses (7.8%). Figure 1 (left) shows Experiment 1a mean naming latencies in different conditions with 95% confidence intervals (CI). To test how naming was affected by semantic relatedness, the following analyses were conducted in the R software environment (Version 3.4.4; R Core Team, 2018) using lme4 (Version 1.1–15; Bates, Maechler, Bolker, & Walker, 2015) and lmerTest (Version 2.0–36; Kuznetsova, Brockhoff & Christensen, 2017). Specifically, we modeled the logRTs/errors using Relatedness (Related vs. Unrelated), Lag (Lag0 vs. 2) and the interaction as fixed-effect variables. The random-effect variables were determined by choosing the maximal random-effect structure that converged (Barr, Levy, Scheepers, & Tily, 2013) and removing

random slopes if they were perfectly correlated among each other or with the random intercept (Baayen, Davidson, & Bates, 2008).

The final mixed-effect models and statistical details of the logRT and error analyses are listed in Table 1 and Table 2 respectively. All correlations between fixed-effect variables were less than .12, suggesting collinearity was not an issue. The logRT analysis revealed no main effect of relatedness ($p = .08$) nor lag ($p = .33$), but a significant interaction between relatedness and lag ($p < .001$), suggesting that semantically related naming experience (related vs. unrelated prime) had different effects on naming, depending on the number of intervening trials (0 vs. 2) between the prime and target. Specifically, in lag0, participants were 34 ms faster to name targets preceded by semantically related vs. unrelated primes ($p < .001$). In contrast, when the prime and target were separated by two unrelated intervening trials, participants were 18 ms slower to name targets after semantically related vs. unrelated primes ($p = .03$). The error analysis was not significant (no significant relatedness/lag main effects or interaction between them; all p 's $> .27$).

Experiment 2

The aim of Experiment 2 was to confirm that the reversal from facilitation to interference in Experiment 1 was indeed due to the manipulation of number of intervening trials, as opposed to variability between different groups of participants in the lag0 and lag2 conditions. Thus, Experiment 2 manipulated the number of intervening trials (lag0 vs. lag2) as a within-subject instead of a between-subject variable. The semantic facilitation effect in Experiment 2a was marginally significant, so we performed a replication in Experiment 2b. In addition, to further verify whether semantic effects in Experiment 1 depended on awareness of prime/target relations, during debriefing of Experiment 2b we directly asked participants if they noticed any relationship between two successive stimuli.

Method

Participants.—One hundred and ten Beijing Normal University (BNU) undergraduates participated in Experiment 2 as paid volunteers: 40 participated in rating the materials (see Materials), 28 in Experiment 2a and 32 in Experiment 2b. All participants were native Mandarin Chinese speakers who provided written informed consent in accordance with the Institutional Review Board of BNU.

Materials and Design.—Experiment 2 used a 2 (relatedness) by 2 (lag) within-subject and within-item design. In the lag0 condition, the prime was immediately followed by the target (prime, target), while in the lag2 condition, the prime and target were separated by two unrelated fillers (prime, filler, filler, target). See Supplemental Materials for semantically related and unrelated pairs. The stimuli consisted of 168 color photographs (Brodeur et al., 2014; 56 primes, 56 targets and 56 fillers). As in Experiment 1, 40 participants rated the degree of semantic relatedness in the related and unrelated pairs on a 5-point scale. The related pairs (mean: 4.20; range: 3.50–4.80) were rated as having a stronger semantic relationship than the unrelated pairs (mean: 1.09, range: 1.00–1.35; $t_1(39) = 43.22$, $p < .001$; $t_2(55) = 70.83$, $p < .001$).

During the naming experiment, each participant named all pictures four times, once in each of the four conditions (related/unrelated by lag0/lag2). The resulting 672 trials were equally divided into four blocks, so that within a block participants saw the same number of trials from each condition but did not see the same pictures twice. The order of blocks was counterbalanced across participants. Experiment 2 lasted 30 minutes and was similar in all other respects to Experiment 1. The only difference between Experiment 2a and 2b is that at the end of Experiment 2, we asked participants if they noticed any relationship between two adjacent stimuli to evaluate participants' awareness of semantic relatedness.

Apparatus and Procedure.

Results

Following the same criteria as Experiment 1, 7.4% and 9.3% of the data points were removed in the RT analyses and 3.5% and 6.5% of the data points were coded as analyzable errors in the error analyses of Experiments 2a and 2b respectively. Figure 1 (middle and right) shows Experiment 2 mean naming latencies and 95% CI across the relatedness by lag conditions. Table 1 and Table 2 show the final mixed-models and statistical details of logRT and accuracy analyses respectively. All correlations between fixed-effect variables were less than .19, suggesting collinearity was not an issue. The logRT analysis showed no main effect of relatedness ($p = .59$ in Experiment 2a, and $p = .16$ in Experiment 2b), but revealed a main effect of lag ($p = .003$ in Experiment 2a, and $p = .005$ in Experiment 2b) and an interaction between relatedness and lag ($p < .001$ in both Experiment 2a and 2b). As in Experiment 1, we observed facilitation effects (magnitude = 9 ms, $p = .09$ in Experiment 2a; magnitude = 9 ms, $p = .04$ in Experiment 2b) when two semantically related vs. unrelated pictures were named adjacently, and interference effects (magnitude = 17 ms, $p = .007$ in Experiment 2a; magnitude = 12 ms, $p = .002$ in Experiment 2b) when semantically related vs. unrelated pictures were separated by two unrelated pictures. The Experiment 2a error analysis did not produce significant relatedness/lag main effects or an interaction between them (all p 's $> .34$). The Experiment 2b error analysis revealed a significant interaction between relatedness and lag ($p = .03$). Planned analyses further show that participants were more accurate to name the target after a semantically related (94.7%) vs. unrelated prime (92.9%, $p = .01$) in lag0 condition, while naming accuracy in the lag2 condition was not affected by semantic relatedness ($p = .53$).

During the debriefing period in Experiment 2b, 10 out of 32 participants mentioned that they noticed some semantically related objects appeared adjacently. To test whether participants' awareness of semantic relationship affected the effects we observed, we further coded awareness as a binomial variable (aware as 1 and unaware as -1) and included its interaction with relatedness in the separate lag 0 and lag 2 mixed models. The results did not show a significant interaction between awareness and relatedness in either the lag0 (logRTs: $p = .47$; accuracy: $p = .50$) or lag2 condition (logRTs: $p = .20$; accuracy: $p = .61$), suggesting that both facilitation and interference effects were independent of participants' awareness.

General Discussion

We demonstrated for the first time within the same paradigm, using the same materials, and replicating across different subject groups that depending on the interval between two naming occurrences, past naming experience has opposite effects on future naming. When a prime and target picture were named adjacently, the semantically related naming experience facilitated subsequent naming (Biggs & Marmurek, 1990; Huttenlocher & Kubicek, 1983; Lupker, 1988; Sperber et al., 1979). In contrast, when a prime and target picture were separated by two unrelated pictures, naming performance was hampered by semantically related naming experience. This interference is consistent with semantic interference found across various speech production paradigms (e.g., semantically-blocked-naming, Damian et al., 2001; continuous naming, Howard et al., 2006; priming naming, Vitkovitch et al., 2001). We argue that our demonstration of the change from facilitation to interference in naming reflects changes within the language system as opposed to peripheral processing (conscious awareness of the relationship between stimuli) which occurs outside the language system.

That we observed facilitation with a consistent presentation rate between stimuli suggests that the facilitation effect in previous studies was not solely due to subjects being aware of prime and target groupings. First, when the probability of a picture being categorically related to the next presented picture was relatively low (12.25% in Exp. 1 and 8.33% in Exp. 2), rendering a participant's strategy of predicting the next picture's name from category membership unlikely, we still observed significant facilitation. Second, although 10/32 participants in Exp. 2 reported that they noticed some semantically related pictures were presented adjacently, this awareness did not change the magnitude of the facilitation effect. Third, if semantic facilitation was due to participants' awareness of prime-target relationships, we should observe that the facilitation effect increases when participants become more aware of prime-target relationships as the experiment progresses (cf. Meyer, 1991). In post-hoc analyses, we tested whether the facilitation or interference was different between the first vs. second half of the experiments (Experiment Half). No experiment showed such a difference, as revealed by non-significant interactions between Relatedness and Experiment Half as analyzed within Lag0 and Lag2 conditions respectively (p 's > .21). In sum, our results suggest that facilitation effects in naming emerge because of changes in the language system rather than solely due to participants' expectation.

To our knowledge, we demonstrated for the first time that manipulating the number of intervening trials between semantically related naming occurrences reverses the effect of naming experience from facilitation to interference. Why did previous studies not find this reversal (e.g., Damian & Als, 2005; Wheeldon & Monsell, 1994; Vitkovitch et al., 2001)? First, compared to studies with similar prime-target presentation (Wheeldon & Monsell, 1994; Vitkovitch et al. 2001), we used a shorter interval between primes and targets, which we hypothesize more likely captured the short-lived facilitation effect. The longer intervals between primes and targets for the lag 0 conditions in these studies may account for the absence of semantic facilitation. Second, the lack of semantic facilitation in other naming paradigms (e.g., Damian et al., 2001) may be due to the experimental design. Specifically, in semantically-blocked naming, people are slower to name successively presented pictures in a semantically related block (cat, dog, rabbit, monkey) vs. unrelated block (apple, bus, table,

monkey). Assuming the facilitation effect is short-lived, it should not accumulate across trials. In contrast, if the interference effect is longlasting, it will build up across trials. In this way, the interference effect is more likely to overwhelm facilitation when the response times are averaged across trials within a block and thus only interference is observed. Taken together, we conclude that the semantic relatedness paradox demonstrated here is due to short-lived facilitation and long-lasting interference, both due to changes within the language system, not due to peripheral processes occurring outside of the language system.

The opposite semantic relatedness effects due to naming experience suggests that the language system is dynamic where changes are critically based on the interval between naming experiences (short vs. long intervals), which has implications for similar phenomena across different cognitive domains. First, in naming, both semantic facilitation and interference are associated with language processing, so a successful speech production model should be able to explain both effects. Semantic interference has been simulated via different mechanisms in recent speech production models (lateral inhibition in Howard et al., 2006 and weakened connection weights in Oppenheim et al., 2010). Future studies should consider implementing a relevant mechanism(s) (e.g., residual activation) into existing models and test whether and how these models can account for both semantic facilitation and interference (also see Scaltritti, Peressotti, & Navarrete, 2017). Second, a similar reversal from facilitation to interference is observed in visual attention (see Klein, 2000 for a review). When visually attending to stimuli, participants are faster to detect the location of cued vs. un-cued targets (facilitation) when the interval between onset of the cue and target is shorter than 200–300ms, while they are slower (inhibition of return) when the interval between onset of the cue and target is longer than 200–300ms (e.g., Posner & Cohen, 1984). Similar to our interpretation of the opposite effects in speech production, the facilitation effect in visual attention is attributed to residual activity by the cue/prime (e.g., Bell, Fecteau, & Munoz, 2004; Lupiáñez, 2010), while inhibition of return is explained as the attended location in the preceding trial being gradually suppressed by an inhibitory mechanism (Itti & Koch, 2001). Together, these results show that experience changes the cognitive system in a similar way across different domains where the dynamics of different cognitive systems may be governed by the same mechanisms.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Fig. 1. Mean response times for naming target pictures in different conditions (Relatedness: (Related/Unrelated) by Lag (Lag0/Lag2)) in Experiments 1 and 2. The error bars represent 95% confidence intervals in within-subject designs (Cousineau, 2005).

Naming logRTs final linear mixed-effect models used to evaluate the effect of semantic relatedness in Exp. 1 & 2. We present analyses with all conditions (both Relatedness and Lag) and analyses within each lag separately (0 or 2). Asterisk denotes $p < 0.05$ and cross denotes $p < .10$.

Table 1.

Experiment	Conditions Included	Random Effects	Fixed Effects	b	SE	df	t	p
Exp. 1	All	(1 Subject) +	+Relatedness	-3.26E-03	1.84E-03	77	-1.77	0.08
		(1+Relatedness+Lag Item)	Lag	6.33E-03	6.42E-03	51	0.99	0.33
			*Relatedness × Lag	8.06E-03	1.44E-03	3500	5.60	<0.001
	Lag0	(1 Subject) + (1+Relatedness Item)	*Relatedness	-1.13E-02	2.54E-03	73.89	-4.43	<0.001
	Lag2	(1 Subject) + (1+Relatedness Item)	*Relatedness	4.79E-03	2.17E-03	76.52	2.21	0.03
Exp. 2a	All	(1 Subject) +	Relatedness	7.89E-04	1.45E-03	54	0.54	0.59
		(1+Relatedness+Lag Item)	*Lag	5.39E-03	1.70E-03	54	3.16	.003
			*Relatedness × Lag	4.31E-03	1.20E-03	5747	3.58	<0.001
	Lag0	(1 Subject) + (1+Relatedness Item)	+Relatedness	-4.29E-03	2.51E-03	53.82	-1.71	0.09
	Lag2	(1 Subject) + (1+Relatedness Item)	*Relatedness	5.29E-03	1.90E-03	54.29	2.78	0.007
Exp. 2b	All	(1 Subject) +	Relatedness	3.37E-03	2.35E-03	54	1.43	0.16
		(1+Relatedness+Lag Item)	*Lag	7.62E-03	2.57E-03	55	2.96	0.004
			*Relatedness × Lag	7.93E-03	1.65E-03	6310	4.81	<0.001
	Lag0	(1 Subject) + (1+Relatedness Item)	*Relatedness	-6.13E-03	2.87E-03	55.56	-2.14	0.04
	Lag2	(1 Subject) + (1+Relatedness Item)	*Relatedness	1.11E-02	3.35E-03	53.87	2.92	0.002

(1|Subject): random intercepts for subjects

(1+Relatedness|Item): random intercepts and slopes of the relatedness effect for items

(1+Relatedness+Lag|Item): random intercepts, slopes of the relatedness effect, and slopes of the lag effect for items

Naming accuracy final mixed-effect models used to evaluate the effect of semantic relatedness in Exp. 1 & 2. We present analyses with all conditions (both Relatedness and Lag) and analyses within each lag separately (0 or 2). Asterisk denotes $p < 0.05$.

Table 2.

Experiment	Conditions Included	Random Effects	Fixed Effects	b	SE	z	p
Exp. 1	All	(1 Subject) + (1 Item)	Relatedness	-0.03	0.10	-0.32	0.75
			Lag	-0.15	0.13	-1.11	0.27
			Relatedness $\times$ Lag	0.07	0.10	0.66	0.51
Exp. 2a	All	(1 Subject) + (1 Item)	Relatedness	-0.05	0.06	-0.95	0.34
			Lag	-0.004	0.06	-0.08	0.93
			Relatedness $\times$ Lag	-0.05	0.06	-0.83	0.41
Exp. 2b	All	(1 Subject) + (1 Item)	Relatedness	-0.06	0.05	-1.33	0.18
			Lag	0.07	0.05	1.42	0.16
			*Relatedness $\times$ Lag	0.11	0.05	2.19	0.03
	Lag0	(1 Subject) + (1 Item)	*Relatedness	-0.18	0.07	-2.56	0.01
	Lag2	(1 Subject) + (1 Item)	Relatedness	0.04	0.07	0.63	0.53

(1|Subject): random intercepts for subjects
(1|Item): random intercepts for items