Fast Habituation to Semantic Interference Generated by Taboo Connotation in Reading Aloud

Simone Sulpizio[1,2], Michele Scaltritti[3], and Giacomo Spinelli[1]

[1]Dipartimento di Psicologia, Università degli Studi di Milano-Bicocca,

[2]Milan Center for Neuroscience (NeuroMI), University of Milano-Bicocca

[3]Dipartimento di Psicologia e Scienze Cognitive, Università degli Studi di Trento

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Author Note

Simone Sulpizio: https://orcid.org/0000-0002-4051-9494

Michele Scaltritti: https://orcid.org/0000-0002-3328-1748

Giacomo Spinelli: https://orcid.org/0000-0002-3913-8109

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Correspondence concerning the article should be addressed to: Simone Sulpizio, Department of Psychology, University of Milano-Bicocca, Piazza dell’Ateneo Nuovo, 1 – 20126 Milano, Italy, email: simone.sulpizio@unimib.it

Abstract

The recognition of taboo words – i.e., socially inappropriate words – has been repeatedly associated to semantic interference phenomena, with detrimental effects on the performance in the ongoing task. In the present study, we investigated taboo interference in the context of reading aloud, a task configuration which prompts the overt violation of conventional sociolinguistic norms by requiring the explicit utterance of taboo items. We assessed whether this form of semantic interference is handled by habituative or cognitive control processes. In addition to the reading aloud task, participants performed a vocal Stroop task featuring different conditions to dissociate semantic, task, and response conflict. Taboo words were read slower than non-taboo words, but this effect was subject to a quick habituation, with a decreasing interference over the course of trials, which allowed participants to selectively attend to goal-relevant information. In the Stroop task, only semantic conflict was significantly reduced by habituation. These findings suggest that semantic properties can be quickly and flexibly weighed on the basis of contextual appropriateness, thus characterizing semantic processing as a flexible and goal-directed component of reading aloud.

Keywords: taboo words; habituation; reading aloud; semantic control; semantic conflict; Stroop

The ultimate goal of reading is to extract meaning from visual symbols. Semantic access is extremely fast, as it occurs in a few hundred of milliseconds (Chen et al., 2015; Hauk et al., 2006; Sulpizio et al., 2022a). Once active, semantic information may modulate lexical processing, thus affecting word recognition and reading (e.g., Carreiras et al., 2014; Strijkers et al., 2015). A particularly interesting case of semantic effects in reading is represented by socially inappropriate words that are considered a linguistic taboo, as for example, insults, slurs, sexual referents, scatological referents, or physical and psychological deviations. Taboo words have been consistently reported to interfere with visual word recognition, showing slower response latencies in comparison to non-taboo ones (Carretié et al., 2008; Geer & Bellard, 1996; Madan et al., 2017; Scaltritti et al., 2021; Sulpizio et al., 2019; 2022b). This detrimental effect has been related to attentional-capture phenomena triggered by the salience of the taboo connotation (e.g., MacKay et al., 2004; White et al., 2017), which would operate as a prepotent stimulus feature and draw attention away from the ongoing task (e.g., Scaltritti et al. 2021; Sulpizio et al., 2022b).

The taboo interference involves at least two theoretically relevant and related facts. First, the taboo interference is a genuine example of semantic interference, as the taboo connotation itself can become available only through semantic access. The observation of semantic interference phenomena during visual word recognition is not trivial, given the ancillary role that most models of reading traditionally attribute to semantic processing (e.g., Coltheart et al., 2001; Perry et al., 2007; Snell et al., 2018), often envisaged as a representational stage that is accessed only after the termination of orthographical-lexical processing (e.g., Balota & Yap, 2006). Second, at least in recognition tasks, the interference triggered by the prepotent, yet task-irrelevant taboo connotation seems to be counteracted by cognitive control processes (e.g., Scaltritti et al., 2021; Sulpizio et al., 2022b; see below for further discussion). Taboo connotation thus offers a window on the interplay between the reading system and attentional / executive factors that have been traditionally eschewed in leading theoretical approaches to visual word recognition (Besner et al., 2016).

Despite the growing interest for taboo words in psycholinguistic research, the impact of taboo connotation on reading aloud is still underinvestigated. Previous studies have focused on either the recognition (as in the lexical decision task, e.g., Carretié et al., 2008; Scaltritti et al., 2021; Sulpizio et al., 2019) or the implicit processing of taboo words (as in the picture-word interference task, e.g., Dhooge & Hartsuiker, 2001). In contrast, reading aloud requires the explicit production of these stimuli. By prompting the production of taboo words and thus an overt violation of conventional sociolinguistic norms, reading may uniquely capture the dimension of social inappropriateness that characterizes this type of words. In turn, this task may provide novel insight with respect to the issue of the interplay between reading and cognitive control, compared to recognition tasks in which the dimension of social inappropriateness remains implicit. In the current study, we conducted a reading aloud experiment in which participants were presented with taboo and non-taboo words and were asked to read them aloud in a fast and accurate way. The main research question concerns how the reading system handles this interfering semantic information to achieve the goal of an optimal performance.

One possibility is that the taboo interference is counteracted by control mechanisms supporting a goal-oriented weighing of semantic information (Davey et al., 2016; Lambon Ralph et al., 2017), including selective inhibition of the taboo connotation, in line with the notion that semantic access is a dynamic process relying on control mechanisms that match semantic information with task- and context-relevant goals (Lambon Ralph et al., 2017; for recent empirical evidence, see, e.g., Montefinese et al., 2020; Scaltritti et al., 2021; Sulpizio et al., 2022b). In the case of taboo words, this may occur via the implementation of a selective suppression mechanism recruited to dampen the interference generated by prepotent yet task-irrelevant information (van den Wildenberg et al., 2010). Evidence for this mechanism is highlighted by the analysis of the distributional profile of the interference effect, with a significant reduction (or reversal) of interfering phenomena in the slower responses (i.e., in the last quantiles of the Reaction Times [RTs] distribution), where the selective suppression process has sufficient time to fully accrue. Although selective suppression has been traditionally investigated in relation to the Simon effect (van den Wildenberg et al., 2010), recent evidence has shown that this mechanism is also involved in dampening taboo interference surfacing in the lexical decision task (Scaltritti et al., 2021; Sulpizio et al., 2022b). Selective suppression might thus be implemented also during reading aloud. According to this control hypothesis, we should expect that taboo interference is significantly reduced (or eliminated) in the slowest responses (e.g., in a delta-plot analysis, the responses in the slowest quantiles), in which there is enough time to implement selective suppression (Scaltritti et al., 2021; Sulpizio et al., 2022b; van den Wildenberg et al., 2010).

Alternatively, or in addition to this possibility, the interfering taboo connotation may be subject to habituation processes. The literature on the processing of taboo words has widely documented habituation effects across different tasks (e.g., Bertels & Kolinsky, 2016; Harris & Pashler, 2004; MacKay et al., 2004, 2015; Sulpizio et al., 2022b), with a reduction of the taboo interference over the course of the trials. In these contexts, habituation has been tentatively linked to the reduction of the emotional reaction due to a repeated exposure (MacKay et al., 2004). Following the habituation hypothesis, we should thus expect a decrease of taboo interference with the progress of the experiment, which should involve the whole RTs distribution in a rather homogeneous way, i.e., the reduction of the effect should be similar across all quantiles.

To summarize our predictions, by addressing both the evolution of the taboo interference as a function of trial progression and its distributional features, we should be able to disentangle whether taboo interference in reading aloud is subject to control mechanisms, habituation, or both. Control mechanisms would be detected by a reduction or a reversal of the interference effect in the slowest responses. Notably, this unique pattern may surface across the whole experiment, or as a function of trial progression (e.g., Sulpizio et al., 2022b). Differently, habituation phenomena would be tracked by a reduction of the taboo interference during the progression of the experiment and in a homogeneous way across the whole RT distribution, including the fastest responses. The joint presence of control mechanisms and habituation mechanisms would show a mixture of the two profiles described above.

Finally, to further address the relation between cognitive control and semantic processing in the context of reading, the present study also included a Stroop task (Stroop, 1935). In the Stroop task, participants are presented with colored written stimuli and are asked to name the color while ignoring the written stimulus. While in typical Stroop tasks several types of conflict (i.e., task, semantic, and response conflict) jointly influence the performance, our Stroop configuration was designed to tease apart the different sources of conflict (cf. Parris et al., 2022; see Methods section for details on how this measurement was conducted). By measuring the different types of conflicts involved in the Stroop task, and by isolating the semantic conflict in particular, we were able to tackle the potential specificity of the control mechanisms acting on semantic information (Lambon Ralph et al., 2017) across different task configurations. The same analytic approach adopted for the reading aloud task was thus also adopted for the Stroop task, and potential associations between the two were explored by assessing the a) selectivity of the habituative / control processes with respect to the semantic domain, b) the qualitative similarity in the pattern of results across effects and task configurations, and c) correlations between the two tasks. Together, these analyses allowed us to examine whether taboo interference in the reading aloud task was selectively associated with semantic conflict in the Stroop task while having little or no association with the other types of conflict (i.e., response and task conflict). This pattern would support the notion of semantic-specific mechanisms.

Method

Participants

Thirty-six students of the University of Milano-Bicocca took part in the experiment (30 females, mean age = 20.75; SD = 2.85) and received course credits for their participation. They were all Italian native speakers and reported normal or corrected-to-normal vision and no history of learning disabilities. The study was approved by the Ethical Committee of the University of Milano-Bicocca (protocol nr.: RM-20-237).

The sample size was decided on the basis of recent recommendations in the field (Brysbaert, 2019), and was in line with our previous in-lab experiment on taboo words (Scaltritti et al., 2021; Sulpizio et al., 2021). Data are fully available at https://osf.io/p5wes/.

Stimuli

One-hundred and eight taboo words and 108 nontaboo words were selected for the reading aloud task. Taboo words were socially inappropriate words belonging to the domains of sexuality, insults, and scatology/disgust (e.g., cazzo '*dick*'), and were selected from ITABOO (Sulpizio et al., 2020), a database of Italian taboo words. Nontaboo words were socially appropriate words that belonged to different semantic domains such as objects, plants, and others (e.g., carro '*cart*'), and were selected from the Italian adaptation of the Affective Norms for English Words database (Montefinese et al., 2014). The two categories of stimuli (taboo vs nontaboo) were matched 1-to-1 in terms of initial phoneme. Taboo and nontaboo words were also comparable in several psycholinguistic variables while differing in valence (see Table 1), with taboo words showing lower valence than nontaboo words.

For the Stroop task, we used 9 colors (red [RGB 255,0,0], green [RGB 0,192,0], white [RGB 255,255,255], black [RGB 0,0,0], purple [RGB 128,0,192], orange [RGB 255,168,0], brown [RGB 128,64,0], yellow [RGB 255,255,0], and blue [RGB 0,0,255]) and 3 different types of written stimuli: letter strings (XXXXX, JJJJJ, and KKKKK), color-neutral words (SANTO '*saint*', CIVILE '*civil*', and DEGNO '*worthy*'), and color words (ROSSO '*red*', VERDE '*green*', BIANCO '*white*', NERO '*black*', VIOLA '*purple*', ARANCIONE '*orange*', MARRONE '*brown*', GIALLO '*yellow*', and BLU '*blue*'). The letter strings were created selecting among the least frequent letters in Italian and using a similar length (5.33 letters on average) as that of the color words (5.56). The color-neutral words were selected so that they would not share the initial letter or phoneme with any of the color words while being similar to the color words in dominant part of speech (i.e., adjective), length (5.33 letters on average), log frequency (7.86 on average – for the colors words, 7.92) and Orthographic Levenshtein Distance (OLD) 20 (1.28 on average – for the colors words, 1.26; this information was extracted from Crepaldi et al., 2013).

There were three versions of the experiment with 6 of the 9 colors being used and 3 not being used in each version, on rotation (see Table 2 for the frequencies of the color-word combinations used in one of the versions of the experiment). In each version, the 6 colors used were combined with the written stimuli to form five types of stimuli: letter-string neutral (e.g., KKKKK in yellow), word neutral (e.g., DEGNO '*worthy*' in yellow), congruent color word (e.g., GIALLO '*yellow*' in yellow), incongruent color word with the word belonging to the response set (e.g., MARRONE '*brown*' in yellow, with brown being one of the colors used in that version of the experiment), and incongruent color word with the word not belonging to the response set (e.g., BLU 'blue' in yellow, with blue not being one of the colors used in that version of the experiment).

Note that, to both have an equal number of stimuli for each type of condition and to avoid introducing contingencies between words and color responses in the design (Schmidt & Besner, 2008), only a subset of the possible color-word combinations was used. Specifically, the stimuli were divided into 3 non-overlapping sets, created such that the colors within each set would be perceptibly distinct, the corresponding color words would not share the initial letter or phoneme, and the letter strings and the neutral words would have similar characteristics as those of the color words within that set. A first set was thus composed of the written stimuli XXXXX, SANTO, ROSSO, VERDE, and BIANCO, which could only appear in the colors red, green, and white; a second set was formed by the written stimuli JJJJJJ, CIVILE, NERO, VIOLA, and ARANCIONE, which could only appear in the colors black, purple, and orange; and a third set was formed by the written stimuli KKKKK, DEGNO, MARRONE, GIALLO, and BLU, which could only appear in the colors brown, yellow, and blue. In each version of the experiment, 2 of the 3 colors within each set were used and the other color was not used whereas all the 5 written stimuli in that set were used. As a result, in each version of the experiment, each set involved 10 color-word combinations and the whole experiment 30. Each color-word combination occurred 12 times in the experiment, meaning that each color was presented 72 times, each written stimulus 24, each stimulus type (i.e., letter string neutral, word neutral, congruent, response-set incongruent, and non-response-set incongruent) 72, and the total number of stimuli was 360.

As noted, this design allowed us to measure task, semantic, and response conflict separately from one another. Following Parris et al. (2022), we reasoned that the response-set incongruent condition (e.g., MARRONE in yellow) would involve all three types of conflict, the non-response-set incongruent condition (e.g., BLU in yellow) would involve task and semantic conflict but not response conflict, the word neutral condition (e.g., DEGNO in yellow) would involve only task conflict, and the letter-string neutral condition (e.g., KKKKK in yellow) would involve no conflict at all. Different contrasts between conditions would thus measure three types of conflict. Specifically, a) the contrast between the response-set incongruent condition and the non-response-set incongruent condition would produce a measure of response conflict, b) the contrast between the non-response-set incongruent condition and the word neutral condition would produce a measure of semantic conflict, and c) the contrast between the word neutral condition and the letter-string neutral condition would produce a measure of task conflict.[1]

Table 1

Psycholinguistic variables of the stimuli used in the reading aloud experiment.

Variables	Taboo	Nontaboo	*p* value
Frequency (log)	5.79	5.91	.61
Familiarity	5.82	7.90	.16
Imageability	6.17	8.10	.25
Concreteness	6.30	6.04	.17
Valence	4.05	5.28	<.001
Arousal	5.07	5.15	.37
N. of Letters	7.52	7.57	.85
N. of Syllables	3.17	3.22	.68
OLD20	1.79	1.74	.44
Prop. dom. stress	0.87	0.87	.83

Note. OLD = orthographic Levenshtein distance and Frequency values (log-transformed) were taken from the SUBTLEX-IT database (Crepaldi et al., 2013). Concreteness, familiarity, imageability, valence, and arousal scores were taken from ITABOO (Sulpizio et al., 2020) and the Italian adaptation (Montefinese et al., 2014) of the Affective Norms for English Words database (Bradley & Lang, 1999) for taboo and nontaboo words, respectively. Prop. dom. stress = proportion of words bearing the dominant stress pattern.

[1] Note that the congruent condition was not involved in these contrasts. The congruent condition is assumed to involve task conflict, and the contrast between this condition and the letter-string neutral condition (which involves no conflicts) would produce another measure of task conflict (Goldfarb & Henik, 2007). However, such contrast is assumed to produce evidence for task conflict only under special circumstances (Kalanthroff et al., 2018). Because the present experiment is not one of those circumstances, the inclusion of the congruent condition allowed us to determine whether that assumption was correct (for contrasting evidence, see Spinelli & Lupker, 2023). However, because that issue is not within the scope of the present research, that contrast, and the congruent condition in general, will be ignored in the analyses.

Table 2

Frequency of color-word combinations in one of the versions of the Stroop task

	Written stimulus														
Color	XXXXX	SANTO	ROSSO	VERDE	BIANCO	JJJJJJ	CIVILE	NERO	VIOLA	ARANCIONE	KKKKK	DEGNO	MARRONE	GIALLO	BLU
Red	12	12	12	12	12										
Green	12	12	12	12	12										
White															
Black						12	12	12	12	12					
Purple						12	12	12	12	12					
Orange															
Brown											12	12	12	12	12
Yellow											12	12	12	12	12
Blue															

Note. SANTO ‘*saint’*; ROSSO ‘red’; VERDE ‘*green*’; BIANCO ‘*white*’; CIVILE ‘*civil*’; NERO ‘*black*’; ARANCIONE ‘*orange*’; DEGNO ‘worthy’; MARRONE ‘*brown*’; GIALLO ‘*yellow*’; BLU ‘*blue*’.

Apparatus and Procedure

Experimental procedures and data acquisition were controlled via DMDX software (Forster & Forster, 2003). Participants completed the study individually, seated 60 cm away from the computer screen in front of a condenser microphone mounted on a desktop stand, and completed first the reading aloud task, then the Stroop task. For each participant, before the reading aloud task, the experimenter calibrated DMDX's digital voice key threshold by having the participant say the word "prova" ('*test*') in their normal voice and manually adjusting the threshold so that it matched the participant's voice volume. Participants were invited to maintain that voice volume and that distance from the microphone throughout the session. For all participants, the microphone volume was set at 100% with a +20 dB boost in Windows settings. Single vocal responses were recorded in .wav files.

The reading aloud task was composed of a single block of 216 trials. Each trial started with a fixation cross (+) presented for 250 ms followed by the word presented for 2000 ms or until the voice key was triggered by the participant's vocal response (barring issues, see the "Statistical analyses" section), after which the stimulus disappeared from the screen. Stimuli were presented one at the time at the center of the screen. Stimuli appeared in black (RGB 0,0,0) against a white (RGB 255,255,255) background. The order of the stimuli was randomized for each participant. Participants were instructed to read the word as quickly and as accurately as possible. The experiment was preceded by a practice session including 8 words, 4 taboo and 4 non-taboo words not included in the main experiment.

The Stroop task was composed of 2 blocks of 180 trials each. The trial procedure was the same as in the reading aloud task, i.e., a fixation cross (+) presented for 250 ms followed by the stimulus presented for 2000 ms or until the voice key was triggered by the participant's vocal response (again, barring the issues described in the "Statistical analyses" section), after which the stimulus disappeared from the screen. Stimuli were presented one at the time at the center of the screen in their designated color against a medium grey (RGB 128,128,128) background. The order of the stimuli for each of the 12 iterations of the 30 color-word combinations used in each version of the experiment was randomized for each participant. The assignment of participants to the 3 versions of the experiment was counterbalanced. Participants were instructed to name the color as quickly and as accurately as possible and ignore the word. The experiment was preceded by a practice session including 18 neutral trials in which a hashtag string (#####) was presented in each of the 6 colors used in that version of the experiment 3 times.

For both procedures, the experimenter explained the instructions of the task to the participant, remained in the room during the practice sessions and left afterwards (i.e., the participant completed the experiments alone in the room, and responses were not scored live but afterwards based on the recordings). The whole study lasted about 45 minutes.

Statistical Analyses

Waveforms of all responses were manually inspected with CheckVocal (Protopapas, 2007) to determine response accuracy and the correct placement of timing marks.

In both tasks, RTs were analyzed via linear mixed effects models and response accuracy via generalized linear mixed effects models, using the lme4 library (version 4_1.1-21; Bates et al., 2015) in R (version 4.2.2, R Core Team, 2022). Participants and items were included as random intercepts. Fixed effects were assessed via likelihood ratio tests, by comparing the model in which the fixed effect under examination was present vs. absent. We started by testing the most complex model. Fixed terms were retained only if their inclusion determined a significant increase in explained variance. In case any interaction resulted significant, all the involved lower-order terms were retained.

RTs were measured from stimulus onset until the beginning of the participant's vocal response. Five trials in the reading aloud task (0.06% of all observations in that task) and 30 trials in the Stroop task (0.23%) were excluded from all the analyses because of improper triggering of the voice key during the experiment (e.g., involuntarily produced noises such as a smack of the lips before responding), which caused an early termination of the stimulus. Four trials in the reading aloud task (0.05%) and 26 trials in the Stroop task (0.20%) were excluded because no response was given. No response was excluded due to being too fast (i.e., there was no response below 200 ms). For 112 trials in the reading aloud task (1.44%) and 228 trials in the Stroop task (1.76%), the voice key was not triggered even though the participant did respond. However, we did not exclude those trials, as the experimental procedure was not affected in these trials. RTs analyses were conducted on correct responses only. Accuracy analyses were conducted on the whole dataset (excluding trials removed for improper activation of the voice key). Response accuracy was modeled as a binomial variable within generalized linear mixed effects models.

For the reading task, in a first step we assessed variations in the overall effect of taboo connotation as a function of trial progression. The RTs analysis thus included word category (taboo vs. non-taboo), trial number and their interaction as fixed terms. In contrast, the analysis of response accuracy only included word category as fixed term, because of the very high accuracy.

In a second step, we focused on delta-plot analysis (e.g., De Jong et al., 1994) and considered the variation of the taboo effect as a function of response latency. Specifically, within each participant and within each condition, RTs were partitioned into five quantiles. The first quantile included the fastest 20% of responses, the second quantile the next fastest 20%, and so on, until the fifth quantile, which included the slowest 20% of the responses. The variable quantiles, treated as a continuous predictor, word category (taboo vs. non-taboo), and their interaction were then considered as fixed effects in the analysis. Potential non-linear effects in modeling the quantile variable were assessed by using orthogonal quadratic polynomials. The quadratic term, however, was retained (and explicitly noted in the reported analyses) only when involved in the interaction with the condition of interest (i.e., word category).

The analyses of the Stroop task paralleled those of the reading aloud task except that the analyses were conducted for each of the 3 types of conflicts separately. That is, in the first step, we examined the observations relevant to semantic conflict (i.e., the non-response-set incongruent words, e.g., BLU 'blue' in yellow, and the neutral words, e.g., DEGNO 'worthy' in yellow). The model included word-color association (non-response-set incongruent vs. neutral word), trial number, and their interaction, as fixed effects. The same analysis was also run for response conflict (involving a contrast between response-set incongruent words, e.g., MARRONE 'brown' in yellow, and non-response-set words, e.g., BLU 'blue' in yellow) and task conflict (involving a contrast between neutral words, e.g., DEGNO 'worthy' in yellow, and neutral letter strings, e.g., KKKKK in yellow) to investigate whether effects of trial progression occur for all types of conflict or for some conflicts in particular.

In a second step, delta-plot analyses were conducted for the semantic conflict effect (delta-plot analyses for task and response conflict are reported in the Supplementary Information), following the same steps and criteria outlined for the reading task.

Finally, two complementary analyses were conducted to assess the potential relation between the taboo interference and the semantic conflict. Details on these analyses are postponed to the Results section as some of them are conditional on the results of the previous analyses.

Results

Reading Aloud Task

Overall Analysis

The mean RTs and response accuracy for each condition are presented in Table 3.

The analysis of RTs showed a significant interaction between word category and trial number (χ^2 [1] = 5.12, *p* = .02), with the difference between taboo and non-taboo words (i.e., slower reading times for taboo than non-taboo words) decreasing over the course of the experiment. The pattern is represented in Figure 1a. Parameters of the final model are reported in Table 4. To further investigate the interaction, we separately tested the presence of the effect of trial number for taboo and non-taboo words (single slope significance was tested with the *emtrends* function in the *emmeans* package, version 1.8.6). The results showed that trial number was significant for taboo words (b = -0.072, SE = 0.02, t = -3.06, *p* = .002), but not for non-taboo words (b = 0.003, SE = 0.02, t =.15, *p* = .878).

Errors were few and therefore, as noted, trial number was not included in the analysis. The analysis of response accuracy did not show any effect of word category (χ^2 [1] = 0.89, *p* = .34).

Table 3

Mean response latencies (RTs in ms) and proportion of accurate responses in the reading aloud task.

	RTs		Accuracy	
Condition	M	SE	M	SE
Taboo	595	23	.98	.01
Non-taboo	591	23	.98	.01
Difference	4		0	

Note. M = mean; SE = standard error of the mean.

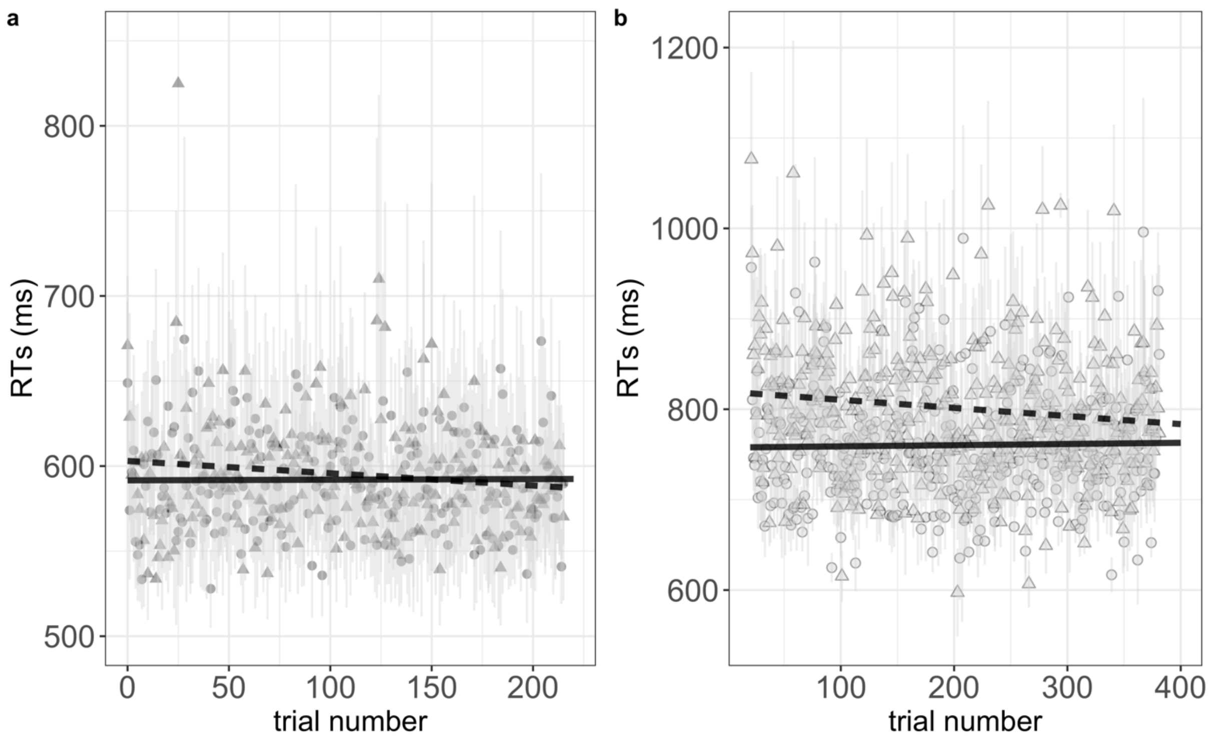
Table 4

Parameters of the model for the reading aloud task.

Random effects	Variance	SD	
Participant	10253	101.26	
Item	1837	42.86	
Residual	8160	90.33	
Fixed Effects	b	SE	t
Intercept	591.63	17.62	33.57
Word type (taboo)	11.37	7.16	1.58
Trial number	0.003	0.02	0.15
Word type x Trial number	-0.07	0.03	-2.26

Note. SD = standard deviation; SE = standard error.

Figure 1.

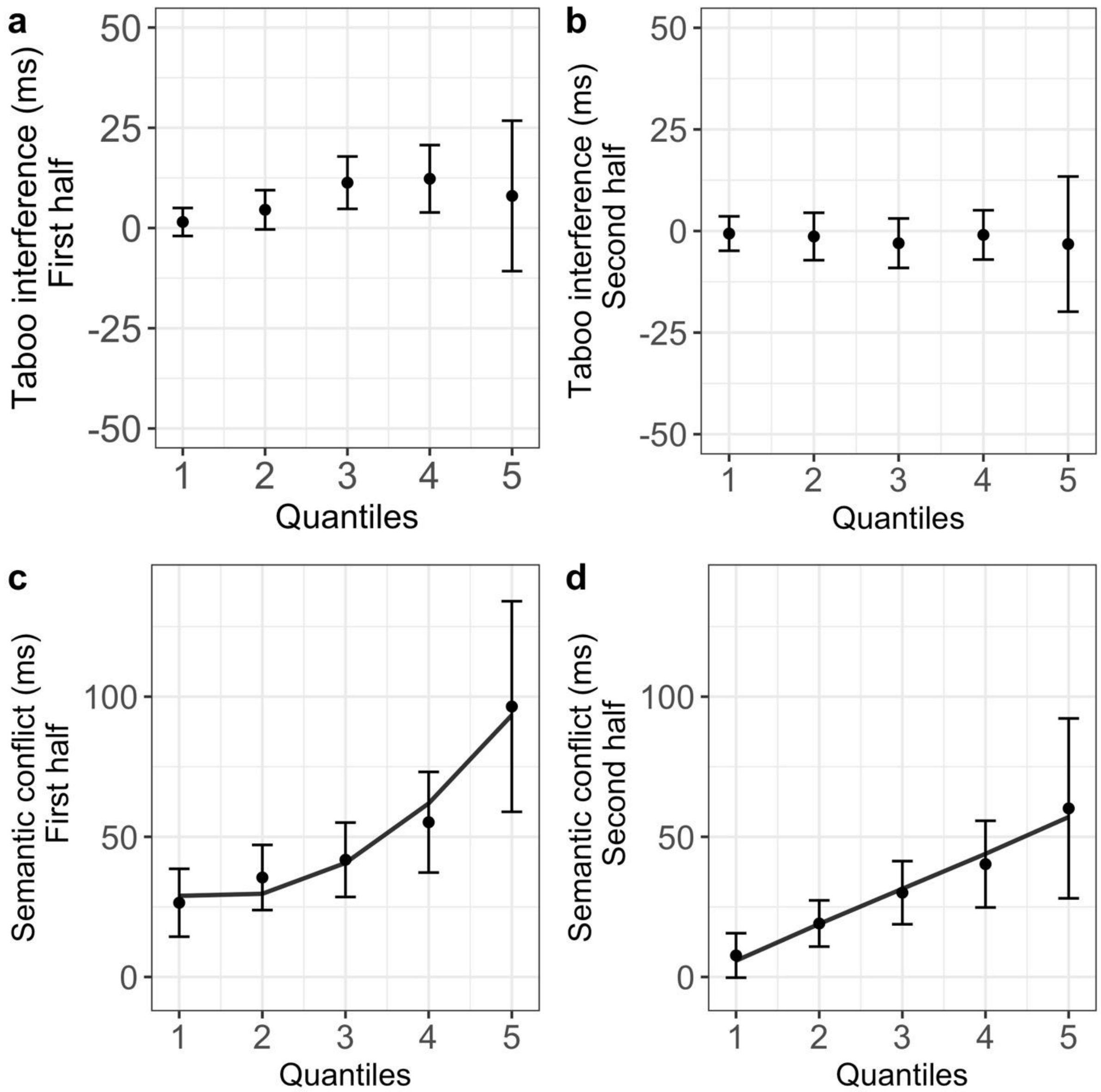


Note. Mean RTs as a function of experimental conditions for the two tasks. (a) Reading aloud task: taboo words are represented by triangles and the dashed line and non-taboo words by circles and the solid line. (b) Stroop task, semantic conflict: incongruent words are represented by triangles and the dashed line and control words by circles and the solid line. In both panels, trial number is represented on the *x*-axis, circles and triangles represent mean RTs and error bars reflects corresponding 95% confidence interval for each trial. Lines represent the effect of trial number predicted by the statistical model for each condition.

Delta-Plot Analyses

Because of the clear evidence for the word category by trial number interaction, quantiles were separately computed in the first vs the second half of the experiment (for the same approach, see Sulpizio et al., 2022b). The analysis of the first half showed effects of quantile (χ^2 [1] = 2564.1, p < .001), indicating longer RTs for slower quantiles, and of word category (χ^2 [1] = 5.6, p = .01), indicating longer RTs for taboo than non-taboo words (see also Fig. 2a). The interaction was not significant (χ^2 [1] = 2.18, p = .13). In contrast, in the analysis of the second half, there was an effect of quantile (χ^2 [1] = 2491.12, p < .001), indicating again longer RTs for slower quantiles, but there was no effect of word category (χ^2 [1] = 0.47, p = .49), and no significant interaction (χ^2 [1] = 0.08, p = .77, see also Figure 2b). Parameters of the final models for the analyses of both halves are reported in Table 5. Results are represented in Figure 2a,b.

Figure 2.



Note. Results of the delta-plot analyses. The upper part shows plots for the reading task, with mean taboo interference effect (taboo words – non-taboo words; *y*-axis) as a function of quantile (*x*-axis) for the first (a) and the second half (b) of the experiment. The lower part shows plots for the Stroop task, with mean semantic conflict effect (word-color incongruent – control, *y*-axis) as a function of quantile (*x*-axis) for the first (c) and the second half (d) of the experiment. In all panels, points represent empirical means, and error bars reflect corresponding 95% confidence intervals, whereas the black lines represent means predicted by the statistical model.

Table 5.

Parameters of the model for the delta-plot analysis of the reading task.

Random effects	Variance	SD	
	First half		
Participant	10559.8	102.76	
Item	208.9	14.45	
Residual	4311.9	65.67	
	Second Half		
Participant	10493.5	102.44	
Item	120.4	10.97	
Residual	4438.7	66.62	
Fixed Effects	b	SE	t
	First half		
Intercept	440.26	17.41	25.27
Word category (taboo)	6.91	2.90	2.37
Quantile	50.67	0.80	63.33
	Second half		
Intercept	447.15	17.33	25.80
Word category	-1.79	2.63	-0.68
Quantile	48.37	0.78	61.79

Stroop Task

Overall Analyses

The mean RTs and response accuracy for each condition for the three types of conflict are presented in Table 6.

For the semantic conflict the interaction between word-color association and trial number was significant (χ^2 [1] = 4.94, *p* = .02), with a reduction of semantic interference over trials (*b* = -0.10, *SE* = 0.04, *t* = -2.22). The pattern is reported in Figure 1b. Parameters of the final model are reported in Table 7. The further investigation of the interaction, by means of single slope significance tests, showed that trial number was significant for the non-response-set incongruent condition (b = -0.089, SE = 0.03, $t = -2.84$, $p = .004$), but not for the word neutral condition (b = 0.013, SE = 0.03, $t = .38$, $p = .699$). Accuracy was not analyzed as the means indicated no difference between conditions.

For response conflict, the analysis showed effects of word-color association (χ^2 [1] = 22.27, $p < .001$), with response-set incongruent words producing slower latencies than non-response-set incongruent words (*b* = 25.07, *SE* = 5.26, t = 4.76), and trial number (χ^2 [1] = 19.21, $p = .39$), with RTs decreasing with the progress of the experiment (*b* = -0.11, *SE* = 0.02, t = -4.42). The interaction was not significant (χ^2 [1] = 0.73, $p = .39$). In the analysis of response accuracy, trial number was not included as the errors were few. The analysis showed a significant effect of word-color association (χ^2 [1] = 17.22, $p < .001$), with response-set-incongruent words being less accurate than non-response-set incongruent words (*b* = -0.83, *SE* = 0.20, z = -4.07).

Finally, with respect to task conflict, the effect of word-color association was significant (χ^2 [1] = 37.29, $p < .001$), with neutral words producing slower latencies than letter strings (*b* = 30.09, *SE* = 4.80, t = 6.25). No further effect reached significance (trial number: χ^2 [1] = 0.79, $p = .37$; word-color association x trial number: χ^2 [1] = 2.49, $p = .11$). Accuracy was not analyzed because there was no hint of a difference between conditions.

Table 6
Mean response latencies (RTs in ms) and proportion of accurate responses in the Stroop task.

	Conflict type			RTs		Accuracy	
Condition/effect	Task	Semantic	Response	M	SE	M	SE
Letter string neutral	–	–	–	730	25	.98	.01
Word neutral	+	–	–	759	27	.98	.01
Non-response-set incongruent	+	+	–	800	30	.98	.02
Response-set incongruent	+	+	+	826	33	.96	.03
Task conflict effect (word – letter string neutral)				29		0	
Semantic conflict effect (non-response-set incongruent – word neutral)				41		0	
Response conflict effect (non-response-set – response-set incongruent)				26		-.02	

Note. M = mean; SE = standard error of the mean.

Table 7

Parameters of the model for the analysis of the Semantic conflict (in the Stroop task) including trial number.

Random effects	Variance	SD	
Participant	10209.5	101.04	
Item	632.9	25.16	
Residual	19804.9	140.73	
Fixed Effects	b	SE	t
Intercept	757.65	18.50	40.94
Word-color association (incongruent)	61.70	10.47	5.88
Trial number	0.01	0.03	0.38
Word-color association x Trial number	-0.10	0.04	-2.22

Note. SD = standard deviation; SE = standard error.

Delta-Plot Analysis

Only trials relevant to the semantic conflict were considered. Again, given the interaction between word-color association and trial number, quantiles were separately computed in the first vs the second half of the experiment. In the analysis of the first half, the interaction between word-color association and the quadratic term of quantile was significant (χ^2 [1] = 45.24, $p < .001$), indicating that the semantic conflict increased across quantiles, especially in the slowest ones (see Figure 2c). In the analysis of the second half, word-color association and quantile again interacted, however, only the linear term of quantile was involved (χ^2 [1] = 29.41, $p < .001$), indicating that the semantic conflict increased linearly across quantiles (see Figure 2d). Parameters of the final models for the analyses of both halves are reported in Table 8.

Table 8.

Parameters of the model for the delta-plot analysis of the semantic conflict in the Stroop task.

Random effects	Variance	SD	
	First half[2]		
Participant	11298	106.29	
Residual	6538	80.86	
	Second Half		
Participant	10146.92	100.73	
Item	57.03	7.55	
Residual	6915.12	83.15	
Fixed Effects	b	SE	t
	First half		
Intercept	760.88	18.11	42.01
Word-color (incongruent)	50.69	3.25	15.55
Quantile (linear)	5046.19	113.93	44.29
Quantile (quadratic)	1047.71	113.96	9.19
Quantile (linear) x Word-color (incongruent)	1132.47	161.73	7.00
Quantile (quadratic) x Word-color (incongruent)	426.49	161.73	2.63
	Second half		
Intercept	540.28	17.91	30.16
Word-color (incongruent)	-6.98	7.83	-0.89
Quantile (linear)	74.39	1.66	44.71
Quantile (linear) x word-color (incongruent)	12.79	2.35	5.43

[2] The by-item random intercept was dropped from this analysis because of 0 variance explained.

Investigating the Relation between the Decrease in the Taboo Interference and in the Semantic Conflict

Two complementary analyses were conducted to investigate whether the processing dynamics underlying the reduction of the taboo interference over the unfolding of the reading task was associated with the similar pattern highlighted for the semantic conflict in the context of the Stroop task.

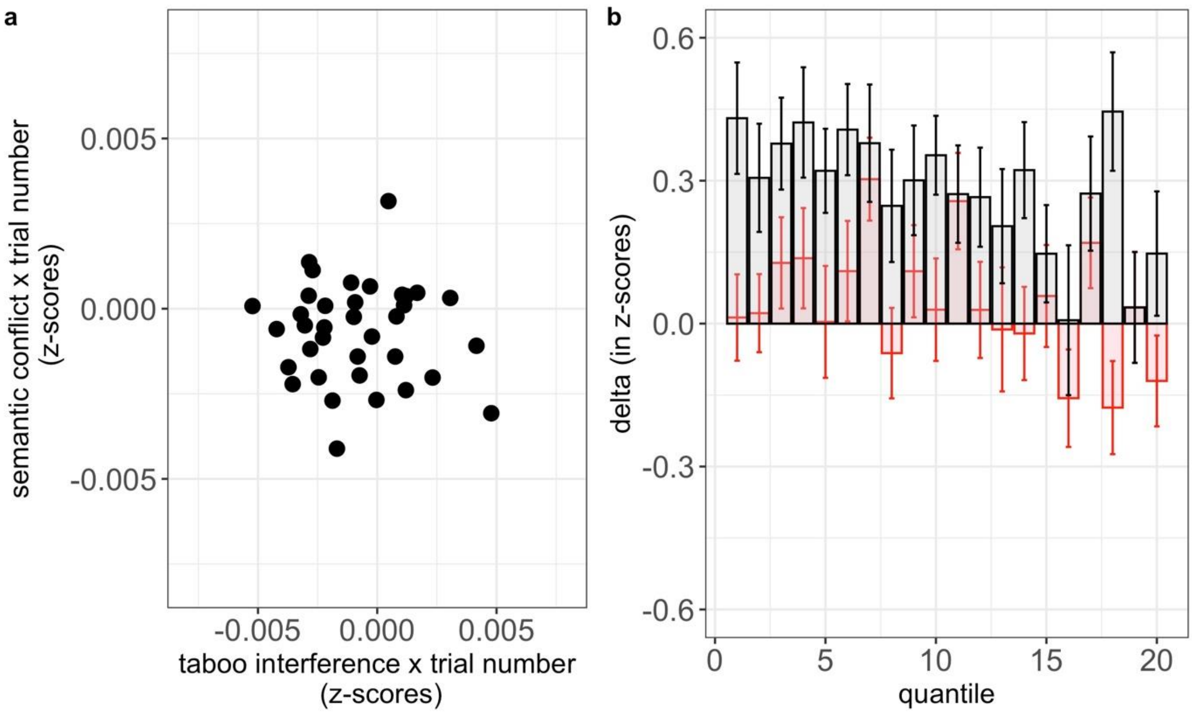
Correlational Analysis

In the first analysis, we first transformed RTs into within-participants and within-task z-scores (Faust et al., 1999), to control for overall differences between participants in terms of response speed. Then, for each participant, we ran a linear model with word category, trial number, and their interaction as fixed factors for the reading aloud task, and word-color association, trial number, and their interaction as fixed factors for the Stroop task. For the latter, we considered the trials relevant to semantic conflict only (response and task conflict were not examined as they did not show any conflict X trial number interaction in the main analysis). Lastly, we focused on the coefficients for the interactions separately estimated via linear models for each participant in each task and assessed the between-task correlation (Pearson). The correlation was not significant (r = -.07, p =.68, see also Figure 3a).

Combined-Task Analysis

In the second analysis, trial number was partitioned – within each task, participant, and condition – into 20 quantiles. The first quantile included the first 5% of trials, the second quantile the next 5% and so on until the 20^{th} quantile that included the last 5% of trials. In this way, each quantile contained an average RT of the items falling in that quantile, thus accounting for idiosyncratic differences in the trial number due to stimuli randomizations (for the variable trial number, the item corresponding to, e.g., position 1 could represent different experimental conditions across different participants). Then, RTs were transformed into within-participants and within-task z-scores (Faust et al., 1999). Finally, using the z-scores, we calculated, for each experiment and within each quantile, delta scores for the taboo connotation effect (taboo words – non-taboo words) and for the semantic conflict effect (non-response-set incongruent – word neutral) (see also Figure 3b). We ran a linear model with the delta scores as dependent variable, task (reading aloud vs. Stroop), quantile (as a continuous variable), and their interaction as predictors. The analysis showed no evidence for an interaction (F [1] = 0.74, p = .38). However, the effect of task was significant (F [1] = 49.09, p < .001), indicating the semantic conflict was larger than the taboo interference (b = 0.24, SE = 0.03, t = 7.07). More interestingly, also the effect of quantile was significant (F [1] = 12.69, p < .001), indicating that both effects decreased across the experiment (b = -0.01, SE = 0.002, t = -3.56), showing a similar trend.

Figure 3



Note. Plots of the analyses investigating the relation between the decrease in the taboo interference and in the semantic conflict. (a) scatter plot of the correlation between the coefficients of the interaction between trial number, on one hand, and taboo interference (x-axis) and semantic conflict (y-axis) on the other hand. (b) Delta scores of the taboo interference (in red, taboo words – non-taboo words) and of the semantic conflict (in black, word-color incongruent – incongruent) as a function of quantile.

Discussion

The main goal of the present study was to investigate how the reading system handles interfering semantic information. We used taboo words to trigger semantic interference, and asked participants to read taboo and non-taboo words aloud. The same participants also performed a Stroop task, and the interference component selectively associated with semantic conflict was used to assess the specificity of control mechanisms acting on semantic information.

In the reading aloud task, we found that taboo words were read more slowly than non-taboo ones. The effect was overall small, despite the task context being particularly suitable to induce a taboo interference, as participants were explicitly required to violate a general social norm by producing words deemed inappropriate in most contexts. Notably, taboo interference decreased over the course of the experiment and vanished toward its end. This pattern accounts for the overall small effect and nicely reproduces in reading aloud the same pattern highlighted across different paradigms involving taboo words (Stroop: Bertels & Kolinsky, 2016; MacKay et al., 2004, 2015; digit parity task, with digits presented at the sides of taboo (and neutral) words: Harris & Pashler, 2004; memory recall: MacKay et al., 2004), including visual word recognition (Scaltritti et al., 2021; Sulpizio et al., 2022b). The consistency of the taboo interference across this heterogeneous set of paradigms indirectly points toward a semantic origin of taboo interference, as the involvement of semantic information seems to represent the only pivotal element shared across such different experimental contexts (cf. Scaltritti et al., 2021). In fact, the interference caused by the activation of the taboo connotation is consistently reported in all experiments using taboo stimuli, suggesting that, at least at a general level, such interference is not sensitive to task-specific properties. Interestingly, the consistency of taboo interference is in opposition to the variability of the effects associated with emotional (non-taboo) words, for which both facilitation (e.g., e.g., Kousta et al., 2009) and interference (e.g., Estes & Adelman, 2008) effects have been reported. This difference suggests that the taboo dimension is not reducible to affective factors, such as valence and arousal. Although a certain degree of overlap among such dimensions indeed exists (Janschewitz, 2008), they are likely best considered as distinct semantic properties.

The decrease of taboo interference over the course of the experiment supports the habituation hypothesis, that is a reduction in the response to a repeatedly occurring interfering information. Interestingly, in the Stroop task, a similar habituation surfaced selectively for semantic conflict, but not for task or response conflict, which remained constant throughout the experiment. More specifically, no effect of trial number surfaced for the conditions involved in the task conflict contrast (i.e., neutral letter strings and neutral words) whereas trial progression modulated *both* the conditions involved in the response set contrast (i.e., non-response-set incongruent and response-set incongruent). Because neither of the conditions in the first contrast involved semantic conflict, whereas both the conditions of the second comparison did (see the semantic conflict column in Table 6), these results suggest that habituation occurred selectively for conditions involving semantic conflict.

This selectivity supports two interpretations of the phenomenon. First, the effects of trial number are not to be ascribed to a mere increase in familiarity with the task. This type of general practice effect should in fact be observed consistently across all conditions. Second, the habituation effects that we report are specific for some cases of interference, which in our experiments are triggered by semantic information. The similarity between how participants habituate to taboo interference and semantic conflict is also suggested by the combined-task analysis, which highlighted a similar pattern.

Habituation may thus act as a filter allowing participants to selectively attend to what is relevant for their current goals while ignoring what is not (e.g., Cowan, 1999). Regarding the reading aloud task, the high probability of encountering a taboo word would weaken (or delete) their taboo status (i.e., being forbidden). Over the course of the experiment, participants' attention would be less captured by taboo stimuli, as their repeated exposure would make them indistinguishable from non-taboo ones: Both types of words are equally frequent in the context of the experiment and the recognition of this fact would make both types of words equally appropriate in that context. Concerning the Stroop task, although non-response-set incongruent words reliably trigger semantic interference, over the course of the experiment the system may become aware that these specific semantic representations are not involved in to-be-produced responses. In turn, this may mitigate their impact and/or facilitate their filtering. The same may not occur, however, for task conflict – as the impact of the process of reading may not be reduced over the course of a typical experiment (see, e.g., MacLeod, 1998) –, and for response conflict – as colors activated by the response-set-incongruent words are part of the response options (cf. Roelofs, 2003), and hence more difficult to ignore.

If the habituation-as-an-attentional filter explanation is correct, one may wonder why no correlation emerged between the habituation to taboo interference and the one related to the Stroop semantic conflict. One possibility is that habituation is weighed on the amount of interference experienced by the participants. The smaller taboo interference and the larger semantic conflict might thus require a different adjustment of the filter, which would thus not necessarily correlate. Note, however, that the absence of correlation might also be due to task-specific differences, as reading the printed stimulus aloud is the main task of reading aloud, and the to-be-avoided prepotent behavior in the Stroop context. Moreover, although the difference between non-response-set incongruent words and neutral words is likely the most suitable to isolate semantic conflict (Parris et al., 2022), this might still contain a residual of response conflict, as the non-response set incongruent words might indirectly activate, through semantic connections, response-set colors (Roelofs, 2003).

Concerning the type of semantic information that undergoes habituation during reading aloud, according to MacKay et al. (2004), the decrease of response latencies to taboo words associated with their repeated exposure would be linked to the dampening of the participants' emotional reaction, which would be similar to what happens with emotional stimuli in general (e.g., Plichta et al., 2014; Wright et al., 2001). However, an alternative possibility is that habituation operates on the *tabooness* of the stimuli – i.e., the semantic property specifying that in certain contexts these words are forbidden (on the relation between emotional properties and tabooness, see, e.g., Janschewitz, 2008; Madan et al., 2017). In particular, as the experiment advances, participants are exposed to (and produce) more and more taboo words. As noted above, this repeated exposure makes, by definition, taboo words increasingly acceptable in the experimental context, thus reducing or even eliminating their tabooness. In fact, participants could quickly habituate to the production of taboo words in the lab, as this verbal behavior was allowed and even requested multiple times in this context, without any negative outcome or consequence. This explanation of a context-related habituation for taboo stimuli resonates with the one proposed by Christianson et al. (2017) for their silent reading experiments featuring taboo (and non-taboo) words inserted in sentences. In these experiments, they manipulated the speakers' likelihood to use taboo words and the situation appropriateness for using these words (e.g., during a sermon vs alone in a prison). The authors found that the effects of taboo words could be largely ascribed to both the participants' attitude toward taboo words and (more relevant for the present investigation) the context in which these stimuli are used.

Although our data do not allow us to adjudicate between habituation in terms of a dampening of emotional reaction vs (contextual) tabooness, we believe the second hypothesis to be more likely considering that 1) our taboo and non-taboo stimuli were comparable in terms of arousal, and 2) although they were not comparable in terms of valence, the effect of the words' valence has produced inconsistent results – it has been associated with both detrimental (e.g., Estes & Adelman, 2008) and facilitatory effects (e.g., Kousta et al., 2009). Therefore, emotionality seems unlikely to be the sole determinant of the taboo interference effect.

The results of the delta-plot analyses show a constant taboo interference across the whole RTs distribution in the first half of the experiment, and no taboo interference at all in the second half. This pattern is in line with the habituation hypothesis, according to which a general reduction of the taboo interference is expected irrespectively of response latency. Habituation seems also compatible with the results of the delta-plot analyses for the Stroop semantic conflict. Here, in the first half of the experiment the semantic conflict is substantial across all quantiles and displays a steep increase in the slowest tail of the distribution (for a similar pattern, see, e.g., Pratte et al., 2010). In the second half of the experiment, instead, semantic interference is negligible in the fastest responses and displays a more moderate increase across quantiles. The reduction of the semantic interference effect thus appears rather homogenously across the RTs distribution, involving fast, modal and slow trials.

More importantly, the distributional pattern of the taboo interference allows us to discard the control hypothesis: Had selective suppression been involved in dampening taboo information, we would have seen a selective reduction (or a reversal) of taboo interference in the slower responses (van den Wildenberg et al., 2010), at least in the second half of the experiment (cf., e.g., Sulpizio et al., 2022b). However, no trace of such a pattern surfaced.

The distributional pattern we report here for reading aloud is partially different from the one previously reported in lexical decision experiments, where evidence for selective suppression has been found (Scaltritti et al., 2021; Sulpizio et al., 2022b). Thus, while taboo information similarly interferes with both reading aloud and lexical decision, it seems to be resolved only via habituation in reading aloud vs. by both habituation and selective suppression in lexical decision. A possible explanation for this difference may refer to processing differences between the two tasks. In lexical decision, participants have to make a general decision on the stimulus lexicality. Albeit this decision, in principle, may rely just on orthographic and lexical information, to optimally reach the goal the system may make use of information coming from all the available sources (orthography, phonology, and semantics). In other words, the decision mechanism may promiscuously use all the types of information that become available, even though the task may seemingly be carried out using on a single source of information (i.e., orthography) for their minimal performance (Mahon & Caramazza, 2007). Under these circumstances, semantic information, and the taboo connotation in particular, given its prepotent nature, are likely to influence the task by increasing response latencies (i.e., taboo interference). In response, the system may intervene by limiting the promiscuous use of all the sources of information, for example by actively dampening the interfering semantic dimension. Notably, the reversal of the taboo interference in the slowest lexical decision responses seems consistent with an increased reliance on purely orthographic information in an attempt to optimize task performance (Scaltritti et al., 2021). This perspective clearly echoes the notion of a flexible lexical processor (Balota & Yap, 2006) that adaptively weighs the emphasis on different information codes (e.g., orthographic, semantic, phonological) as a function of task constraints and demands.

The situation is different in reading aloud. Reading aloud involves mapping a single orthographic sequence onto its specific phonological code in order to articulate the appropriate response. The task may thus be less reliant on heterogeneous use of the different types of information available, and more closely focus on the most relevant ones, for example lexical representations (e.g., for Italian, e.g., Pagliuca et al., 2008), with the semantic information remaining in the background.

In conclusion, our results show that taboo information, which is indeed a semantic property of words, interferes with reading aloud. This interference, however, is short-lived, with the system quickly habituating to the repeated exposure to supposedly forbidden lexical units, and thus switching off tabooness for that specific context. This suggests that the semantic system is able to recalibrate a) the weight of semantic properties quickly and flexibly on the basis of contextual appropriateness, and b) the relation between specific semantic properties (e.g., *tabooness*) and general / semantic control mechanisms, in order to optimize their intervention on the basis of the context. Semantic processing thus appears to be a flexible and goal-directed component of reading aloud, whose activity is sensitive to several types of contextual factors, including social appropriateness.

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Supplemental Materials

Delta-plot analysis for task conflict

The relevant observations were divided into quantiles as described in the main text for the reading aloud task and the semantic conflict in the Stroop task. The variables quantile, word-color association (neutral words vs letter strings), and their interaction were then considered as fixed effects in a linear-mixed effects model including also by-participants random intercepts. The potential non-linear impact of the quantile variable was considered by using orthogonal quadratic polynomials. Non-linear terms were retained only when they interacted with the variable of interest (i.e., word-color association).

The results showed a significant interaction between word-color association and the quadratic term of quantile (χ^2 [1] = 5.51, p = .01), with the task conflict increasing across quantiles. The pattern replicates the typical finding reported for the Stroop task (e.g., Pratte et al., 2010). Parameters of the final model are reported in Table S1 (see also Figure S1a).

Table S1.
Parameters of the model

Random effects	Variance	SD	
Participant	9460	97.26	
Item	11	3.40	
Residual	6175	78.58	
Fixed Effects	b	SE	t
Intercept	521.91	16.61	31.41
Word color (incongruent)	18.30	5.13	3.56
Quantile	69.72	1.08	63.99
Quantile x Word-color (incongruent)	3.62	1.54	2.34

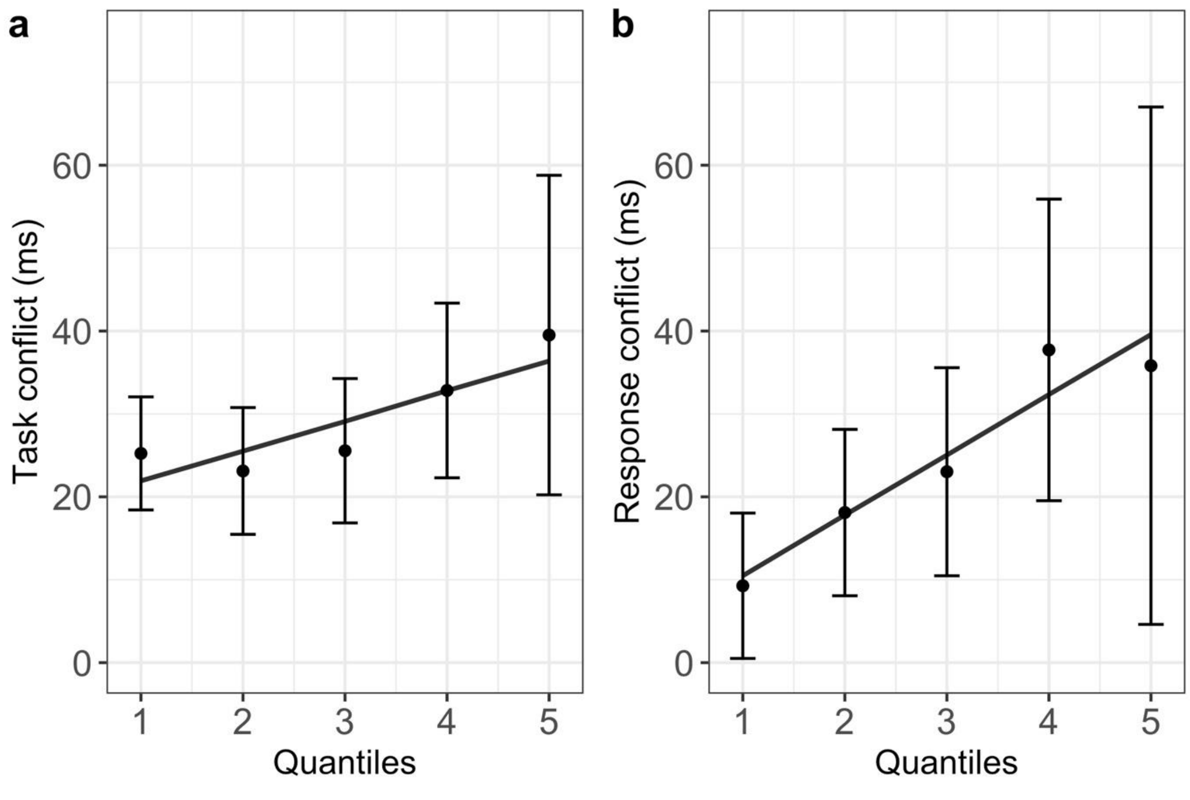
Delta-plot analysis for response conflict

The same analysis described above was conducted for response conflict, focusing on the contrast between response-set incongruent and non-response-set incongruent words. The results showed a significant interaction between word-color association and the quadratic term of quantile (χ^2 [1] = 16.75, p < .001), with response conflict increasing across quantiles. The pattern replicates the typical finding reported for the Stroop task (Pratte et al., 2010). Parameters of the final model are reported in Table S2 (see also Figure S1b).

Table S2.
Parameters of the model

Random effects	Variance	SD	
Participant	11059	105.16	
Item	26	5.16	
Residual	7988	89.37	
Fixed Effects	b	SE	t
Intercept	534.76	18.01	29.68
Word color (incongruent)	3.24	5.88	0.55
Quantile	89.06	1.25	71.22
Quantile x Word-color (incongruent)	7.26	1.77	4.09

Figure S1.



Note. Results of the delta-plot analyses. a) Plot of the task conflict effect (neutral words – letter strings) as a function of quantiles (x-axis); b) plot of the response conflict effect (response-set incongruent words – non-response-set incongruent words) as a function of quantiles (x-axis). In both panels, points represent empirical means, and error bars reflect corresponding 95% confidence intervals, whereas lines represent means predicted by the statistical model.