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The locus of interference in Picture-Word Interference and Stroop effects: an eye-tracking study

In word production literature, the functional locus of the semantic interference effect is under debate. The effect, consisting of longer naming latencies in presence of semantically related materials, receives different explanations from different models, placing the locus of the effect either at the response selection or at the response articulation stage of processing. The aim of the present study is to test interference effects in lexical production using the Stroop and the Picture-Word Interference paradigm in order to clarify if the interference effect takes place at an early phase (response selection) or later (response articulation). To this aim, an experiment based on a dual-task procedure was realized. Behavioral measures (response times) and visual behavior data (gaze duration) were collected. The analysis evidenced the presence of the interference effect in both the tasks. In addition, some evidence suggests an early origin of the effect.

Keywords: Stroop paradigm, picture-word interference paradigm, interference effect, eye-tracking, psychological refractory period

Nella letteratura sulla produzione di parole, il luogo funzionale dell'effetto di interferenza semantica è tema di dibattito tra gli

studiosi. L'effetto, costituito da latenze di denominazione più lunghe in presenza di materiali semanticamente correlati, riceve spiegazioni diverse da modelli diversi, collocando il luogo dell'effetto nella selezione della risposta o nella fase di elaborazione dell'articolazione della risposta. Lo scopo del presente studio è di testare gli effetti di interferenza nella produzione lessicale utilizzando il paradigma di Stroop e il paradigma di interferenza figura-parola al fine di chiarire se l'effetto di interferenza si verifica in una fase iniziale (selezione della risposta) o successiva (articolazione della risposta). A tale fine è stato realizzato un esperimento basato sulla procedura del doppio compito. Sono state raccolte misure comportamentali (tempi di risposta) e dati sul comportamento visivo (durata dello sguardo). L'analisi ha evidenziato la presenza dell'effetto di interferenza in entrambi i compiti. Inoltre, alcune prove suggeriscono un'origine precoce dell'effetto.

Parole chiave: *Paradigma di Stroop, paradigma di interferenza parola-figura, effetto di interferenza, eye-tracking, periodo refrattario psicologico*

Introduction

One of the most important and debated paradigms for the study of the cognitive functions is the Stroop[1]. In its original version the task consisted in a naming: participants were asked to name the ink color of a color word or a non-word[2]. Since its introduction, the paradigm has been submitted to different changes and has generated different

[1] C.M. Macleod, *Half a century of research on the Stroop effect: An integrative review*, in «Psychological Bulletin», CIX (2) (1991), pp. 163-203.

[2] J.R. Stroop, *Studies of interference in serial verbal reactions*, in «Journal of experimental psychology», XVIII (6) (1935), pp. 643.

variants called "Stroop like tasks"; among the others the Picture-Word Interference task (hereafter PWI)[3]. Both the paradigms are based on a word production task where participants were presented with a target stimulus, accompanied with a distractor. In both the paradigms they were instructed to name the targets ignoring the distractors; the difference between the two paradigms is in the nature of the target, a color in the Stroop task and a picture in the PWI task.

For a long time the interference mechanisms obtained by the PWI has been considered synergistic to those of the Stroop. However, this issue has been questioned in a work by Dell'Acqua, Job, Peressotti and Pascali[4]. Authors used a Psychological Refractory Period (PRP) paradigm. In the paradigm two different stimuli are presented in succession and both require a fast response. The time between the presentation of the two stimuli (SOA) acts as independent variable whereas the reaction time (RT) to the second stimulus acts as dependent variable. The PRP is the period of time during which the RT to a second stimulus is slowed because the first stimulus is still processed. Dell'Acqua *et al.* (2007) tested participants in a dual task: each trial was made by two stimuli presented sequentially and separated by different Stimulus Onset Asynchrony (SOA). The first stimulus was a tone on which participants had to perform a manual discrimination task; the second stimulus was a picture to be named. A semantic effect (longer naming latencies) was found

[3] R.R. Rosinski, *Picture-word interference is semantically based*, in «Child Development», (1977), p. 6. S.J. Lupker, *The semantic nature of response competition in the picture-word interference task*, in «Memory and Cognition», VII (6) (1979), 485-495, 43-647.

[4] R.Dell'Acqua, R. Job, F. Peressotti, A. Pascali, *The picture-word interference effect is not a Stroop effect*, in «Psychonomic bulletin and review», XIV (4) (2007), pp. 717-722.

at long SOA in the picture naming, but not at short SOA. The underadditive interaction between SOA and semantic relatedness suggested that the locus of the PWI is functionally earlier than the PRP effect locus. On the contrary, the Stroop effects have been shown to be additive with SOA effects in PRP design, suggesting a different functional origins of the interference effect in the two paradigms. In a recent study, Starreveld and La Heij[5] pointed out how the larger conceptual network activated by pictures and picture names compared to colors and colors name and the characteristics of the distractors in terms of response-set membership, the task relevance, semantic relatedness and lexicality can contribute to explain the different results between the two paradigms and that there is no a priori reason to assume that the Stroop and the PWI differ in their underlying processes.

To understand the debate concerning the Stroop tasks and the PWI and if the locus of the effect is placed at an earlier stage of processing or if it is a postperceptual has important implications also in lexical production studies and in the mechanisms responsible for lexical retrieval in language production models[6,7]. The two main hypotheses can be referred to the lexical competition hypothesis (hereafter LCH)[6] and the response exclusion hypothesis (hereafter REH)[7]. According with the two hypothesis the locus of interference is placed earlier during lexical access for the first account[6] and later, during articulation in the

[5] P.A. Starreveld and W. La Heij, *Picture-word interference is a Stroop effect: A theoretical analysis and new empirical findings*, in «Psychonomic bulletin and review», XXIV (3) (2017), pp. 721-733.

[6] W.J. Levelt, A. Roelofs and A.S. Meyer, *A theory of lexical access in speech production*, in «Behavioral and brain sciences», XXII (1) (1999), pp. 1-38. A. Roelofs, *WEAVER++ and other computational models of lemma retrieval and word-form encoding*, in «Psychology Press», (2000), pp. 71-114.

latter account[7]. A crucial difference between the LCH and the REH concerns the trend of the effect of interference over time. While for the LCH the interference emerges during the planning phase, for the REH the interference is determined afterward, at the level of the articulatory buffer. As reported in Roelofs[8] (2011), lemma retrieval begins about 200 ms after the presentation of the target stimulus, whereas the phonetic coding begins about 145 ms before articulation[9]. Access to motor programs takes some time and therefore the articulatory buffer is reached shortly after the beginning of the phonetic coding, that is after 145 ms before the articulation. Therefore, for the REH the interference emerges when the articulatory buffer is reached whereas for the LCH the

A. Roelofs, V. Piai, H. Schriefers, *Context effects and selective attention in picture naming and word reading: Competition versus response exclusion*, in «Language and Cognitive Processes», XXVIII (5) (2013), pp. 655-671. A. Roelofs, *Tracking eye movements to localize Stroop interference in naming: Word planning versus articulatory buffering*, in «Journal of Experimental Psychology: Learning, Memory, and Cognition», XL (2014) (5), pp. 1332.

7 A. Caramazza, *How many levels of processing are there in lexical access?*, in «Cognitive neuropsychology», XIV (1) (1997), pp. 177-208. M. Finkbeiner and A. Caramazza, *Now you see it, now you don't: On turning semantic interference into facilitation in a Stroop-like task*, in «Cortex», XLII (6) (2006), pp. 790-796. Janssen, N., Schirm, W., Mahon, B.Z., Caramazza, A. (2008). *Semantic interference in a delayed naming task: evidence for the response exclusion hypothesis.* Journal of Experimental Psychology: Learning, Memory, and Cognition, 34(1), 249. B.Z. Mahon, A. Costa, R. Peterson K.A. Vargas, and A. Caramazza, *Lexical selection is not by competition: a reinterpretation of semantic interference and facilitation effects in the picture-word interference paradigm*, in «Journal of Experimental Psychology: Learning, Memory, and Cognition», XXXIII (3) (2007), 503.

8 A. Roelofs, *Attention, exposure duration, and gaze shifting in naming performance*, in «Journal of Experimental Psychology: Human Perception and Performance», XXXVII (2011), pp. 860-873.

9 P. Indefrey and W.J. Levelt, *The spatial and temporal signatures of word production components*, in «Cognition», XCII (1-2) (2004), pp. 101-144. P. Indefrey, *The spatial and temporal signatures of word production components: a critical update*, in «Frontiers in psychology», II (2011), pp. 255.

interference originates much earlier, about 200 ms after the presentation of the stimulus (i.e. in the phase of lemma retrieval). The two accounts differ in the description of the time course of interference effect. According to Roelofs[10], the functional locus of an experimental effect could be detected by collecting multiple measures during word planning and articulation phases. In Roelofs[11] eye tracking measures were collected in dual-task experiments with color-word Stroop stimuli accompanied with spatially separated stimuli (left or right-pointing arrows) and he found an interference effect in behavioral and in visual behavior measures. The author claimed that the data pattern was compatible with the LCH which predicts interference for all the measures. According to the author, the data were not compatible with the REH which predicts interference in the incongruent condition in naming, but facilitation in gaze shift latencies. The two different accounts also differ in the expectation of interference effect as a function of SOA (Stimulus Onset Asynchrony) manipulation: the LCH predicts that interference effect should be present at short SOA and reduced or absent at long post-exposure SOA; following the REH, interference effect should be observed at long post-exposure SOA.

In a study by Janssen, Schirm, Mahon, and Caramazza[12] the time course of interference effect has been

[10] A. Roelofs, *Tracking eye movements to localize Stroop interference in naming: Word planning versus articulatory buffering*, cit.

[11] A. Roelofs, and V. Piai, *Attention demands of spoken word planning: A review*, in «Frontiers in psychology», II (2011), p. 307. Roelofs, *Tracking eye movements to localize Stroop interference in naming: Word planning versus articulatory buffering*, cit.

[12] N. Janssen, W. Schirm, B.Z. Mahon, and A. Caramazza, *Semantic interference in a delayed naming task: evidence for the response exclusion hypothesis*, in «Journal of Experimental Psychology: Learning, Memory, and Cognition», 34(1) (2008), p. 249.

explored. In two picture-word interference experiments, the SOA was manipulated in two different naming conditions: in the immediate condition (SOA 0), targets and distractors appeared on the screen simultaneously and participants named the pictures immediately; in the delayed condition (SOA +1000), participants had to wait the onset of distractors on the screen to name pictures. The authors observed semantic interference effects in both the immediate and delayed naming conditions. According to the authors, these data indicate that semantic interference can be observed when target picture naming latencies do not reflect the bottleneck at the level of lexical selection. The authors interpret these data as supporting the view that the semantic interference effect arises at a post-lexical level of processing. The conclusions reached by Janssen and colleagues were questioned by Mädebach, Oppermann, Hantsch, Curda and Jescheniak[13] who failed to replicate the effect in the delayed naming condition leaving the debate still open.

In this study the earlier or late origin of the interference effect has been investigated comparing the performances in the PWI and in the Stroop. Similar to the procedure used by Roelofs (2008; 2011) in order to control the trend of the interference effect over time distractor SOA was manipulated, a dual-task procedure, as suggested by was used, and eye tracking data were collected. The same participants were tested on both tasks. In order to balance the response set across conditions three colors were used as targets for the

[13] A. Mädebach, F. Oppermann, A. Hantsch, C. Curda and J.D. Jescheniak, *Is there semantic interference in delayed naming?*, in «Journal of Experimental Psychology: Learning, Memory, and Cognition», XXXVII (2011), pp. 522-538.

Stroop test and three figures, from the same semantic category, were selected for the PWI task.

To control the functional locus of the interference effect a dual-task procedure was used[14]. Participants were presented at the same time with two stimuli: on the left side of a computer screen Stroop type stimuli or picture-word stimuli appeared, while on the right side appeared arrows pointing to the right or to the left (flanked by two pairs of 'X', e.g. XX <XX). Participants were instructed to perform first the naming task and then the manual task, by pressing a button to indicate the direction of the arrow. The right task was inserted to cause eye movements in participants. Also, the distractor SOA (Stimulus Onset Asynchrony) was manipulated: in Stroop and PWI task, targets and distractors could appear simultaneously on the screen (SOA 0) or the distractors could appear 500 ms after targets (SOA 500). Participants had to wait the onset of the distractors on the screen to name the pictures; in this way, we obtained two conditions, an immediate and a delayed naming condition. A long post-exposure SOA was chosen as LCH and REH differ in the expectations about the presence or absence of an effect. +500 ms SOA was used because it is at this time that the processes near the articulation phase occur. In addition, a +500 SOA would avoid repetition strategies of the target name already processed. The accuracy and speed of verbal and manual responses were collected. Vocal responses were recorded. Furthermore, the eye movements were traced to determine the time of the gaze shifting from the first (color or figure) to the second stimulus

[14] A. Roelofs, V. Piai, *Attention demands of spoken word planning: A review*, in «Frontiers in psychology», II (2011), pp. 307. Roelofs, *Tracking eye movements to localize Stroop interference in naming: Word planning versus articulatory buffering*, cit.

(arrow). Gaze shift onset was measured by means of Time to First Fixation (TFF) metric. TFF is a Region Of Interest (ROI) based metric which indicates the time between stimulus onset and the first time the eye passes on the stimulus region. The exact time when eyes moved from naming task (left portion of the screen) to manual task (right portion of the screen) was computed comparing naming response times with TFF on the right region.

2. *Experiment*

PARTICIPANTS

Sixteen students, eight females and eight males, volunteered in the experiment. Participants were students at the University of Naples Suor Orsola Benincasa. The age range was between 18 and 29. All participants had normal or corrected to normal vision. None of the participants received money or course credits for participation.

MATERIALS

Materials were adapted from Piai and Schriefers[15]. Stroop stimuli consisted of 6x3 (WxH) cm colored patches. Red, green and blue rectangles were accompanied with the words "BLUE", "GREEN" and "RED" in function of distractors. A row of five X was used in the neutral condition. The distractors appeared in the center of the rectangles, superimposed on them.

[15] V. Piai, A. Roelofs, H. Schriefers, *Locus of semantic interference in picture naming: Evidence from dual-task performance*, in «Journal of Experimental Psychology: Learning, Memory, and Cognition», XL (1) (2014), pp. 147.

Stroop stimuli were presented in three conditions: congruent, incongruent and neutral. The congruent condition, in which the color of the rectangle and the distractor word corresponded (e.g. "RED" word on red rectangle) was inserted to increase the magnitude of the interference effect. In the incongruent condition, the rectangles appeared together with names of mismatched colors (e.g. "RED" word on green rectangle). Three pairs of stimuli were inserted in the incongruent condition. Similarly, three pairs were obtained for the neutral condition (XXXXX on red, green or blue rectangle).

PWI stimuli consisted of 6 x 3 cm black and white drawings of three parts of the body: arm, finger and leg. Distractors were the words corresponding to the figures: "ARM", "FINGER" and "LEG". Also, in this case three conditions have been created. In the congruent condition, the three figures appeared with the corresponding words overlapped (e.g. "LEG" word superimposed on a leg design). The incongruent condition was built by coupling the figures with words belonging to the same semantic class (e.g. "LEG" word on arm figure). Three pairs of incongruent stimuli were created. In the neutral condition, the three figures were presented together with a series of five "X". The entire list of material is reported in Tables 1 and 2.

Target	Congruent distractor	Incongruent distractor
BLU (BLUE)	Blu	Verde
ROSSO (RED)	Rosso	Blu
VERDE (GREEN)	Verde	Rosso

Table 1
Materials used in the Stroop task

Target	Congruent distractor	Incongruent distractor
BRACCIO (ARM)	Braccio	Gamba
DITO (FINGER)	Dito	Braccio
GAMBA (LEG)	Gamba	Dito

Table 2
Materials used in the picture-word interference task

For the manual task, arrow-like stimuli consisted of "<" or ">" signs flanked by two "Xs" on each side

(e.g. XX>XX). The side Xs are inserted to induce foveal vision and to reduce the possibility that the subjects use peripheral vision to identify the direction of the arrows[16].

White stimuli were presented on a black background. The character of the distractors and the stimuli used in the manual task was Arial, font size 36.

SOA was manipulated. The distractor words appeared at the same time as the target stimuli (SOA 0) or 500 ms after (SOA 500).

PROCEDURE

Participants were tested individually in a quiet room. They were invited to carefully read the instructions on the computer screen in presence of the experimenter. Participants were informed that data would have been collected in an

[16] M.J. Lamers and A. Roelofs, *Attentional control adjustments in Eriksen and Stroop task performance can be independent of response conflict*, in «Quarterly Journal of Experimental Psychology», LXIV (6) (2011), pp. 1056-1081. A. Roelofs, *Attention and gaze control in picture naming, word reading, and word categorizing*, in «Journal of Memory and Language», LVII (2007), pp. 232-251. A. Roelofs, *Tracing attention and the activation flow in spoken word planning using eye movements*, in «Journal of Experimental Psychology: Learning, Memory, and Cognition», XXXIV (2) (2008), pp. 353. A. Roelofs and V. Piai, *Attention demands of spoken word planning: A review*, in «Frontiers in psychology», II (2011), p. 307.

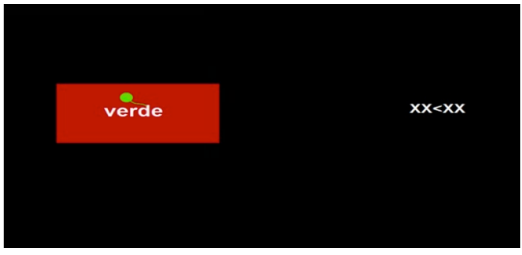
anonymous manner and not identifiable. Once the oral and informed consents were acquired from participants, the experimental procedure could start.

Participants were asked to perform first the naming task and later the manual task. For the first task participants were asked to name the target aloud in a microphone, ignoring the distractor. For the second task participants were requested to press the arrows on the keyboard. Each naming task appeared on the left of the screen and was accompanied by the manual task, on the right of the same screen (fig. 1). The second task was inserted to induce saccades, rapid eye movements from a portion to another portion of the space in order to avoid . The procedure has been adapted from Roelofs[17].

Figure 1:

Before the experiment proper, participants were introduced in a learning phase in which they performed 18 trials. No feedback was given to participants about their performances. They were not familiarized with experimental materials before the experiment[18].

In the experiment the order of presentation of the trials was randomized. Each of the 9 pairs of stimuli for



[17] A. Roelofs, *Tracking eye movements to localize Stroop interference in naming: Word planning versus articulatory buffering*, cit.

[18] S. Collina, P. Tabossi, F. De Simone, *Word Production and the Picture-Word Interference paradigm: the role of learning*, in «Journal of psycholinguistic research», XLII (5) (2013), pp. 461-473.

Stroop and PWI task was presented for both distractors SOA (0 and 500 ms) and for both directions of the arrow (right and left), for a total of 72 trials. The set of the 72 trials constituted an experimental session. Each subject was engaged in 3 sessions of 72 trials (216 in total). Between two consecutive trials a 1.5 second blank screen was inserted. A trial remained on the screen until responses were collected or for a maximum time of 3 seconds.

Experiment running and data collection were controlled by E-Prime experimental software.

To control the attentional demand (Roelofs, 2011), the visual behavior of participants was monitored by FaceLab eye tracker and EyeWorks software. To detect the visual behavior in each trial a trigger was sent from E-Prime to EyeWorks software every time a new trial began. Before the experiment, the eye-tracker was calibrated on each participant. The experiment started when the eye-tracker reached a level of accuracy higher than 90%.

The entire procedure lasted about 30 minutes.

RESULTS

Four independent variables were identified: Task (Stroop or PWI), Condition (congruent, incongruent and neutral), SOA (0 or 500) and Practice (learning effect across the sessions). The dependent variables measured were the naming latencies, manual responses and gaze duration.

Trials with manual RTs shorter than 100 ms and trials in which the voice key was triggered by a sound that was not the participant's response or with vocal RTs shorter than 200 ms were discarded. Trials with incorrect manual responses were labeled as errors and subsequently excluded from the RT analyses. Additionally, vocal responses that contained a

dysfluency, a wrong pronunciation of the word, or a wrong response word were also classified as errors by the experimenter and subsequently discarded from further analysis. The percentage of errors was 12,9% in Stroop task (168) and 11,4% in PWI task (190). Errors were equally distributed between conditions: a X-square analysis did not evidence any significant difference between errors in different tasks and conditions (X-square: 5.4613; p-value: .14).

Means and standard deviation of correct naming latencies (Table 3), correct manual responses (Table 4) and gaze duration (Table 5) per Task, Condition and SOA are reported below.

For the analysis of experimental data SPSS statistical software was used to construct a multivariate generalized linear model (GLM). We opted for the GLM model to avoid separate multivariate analyses. In the analysis, subjects and items were independent random effects factors. Task, Condition, SOA and Practice were included as fixed factors.

The significance of fixed effects was evaluated by means of the usual F-test. The GLM highlighted the effects of Task and Condition on all the dependent variables. SOA had an effect just on Manual Responses. The Practice had an effect on Verbal and Manual responses but not on Gaze Duration. No interaction effects were detected. The synthesis of the results is reported in Table 6.

The analysis of naming latencies in picture-word interference and Stroop task confirmed a semantic interference effect in both the tasks: participants were slower to name targets in presence of incongruent distractors compared to congruent and neutral distractors. Participants were faster to perform the naming task in presence of Stroop Stimuli compared to PWI Stimuli. However Task, Condition, SOA

Table 3: Correct Verbal Responses per Task, Condition and SOA

TASK	PWI	PWI	PWI	PWI	PWI	PWI	STROOP	STROOP	STROOP	STROOP	STROOP	STROOP
Condition	C	C	I	I	N	N	C	C	I	I	N	N
SOA	0	500	0	500	0	500	0	500	0	500	0	500
Mean	842,94	833,87	933,64	932,22	851,15	837,48	817,19	820,69	910,15	905,09	805,28	807,93
nStDev	26,97	40,09	40,89	49,4	53,6	43,66	34,27	62,38	44,77	46,07	41,43	43,56

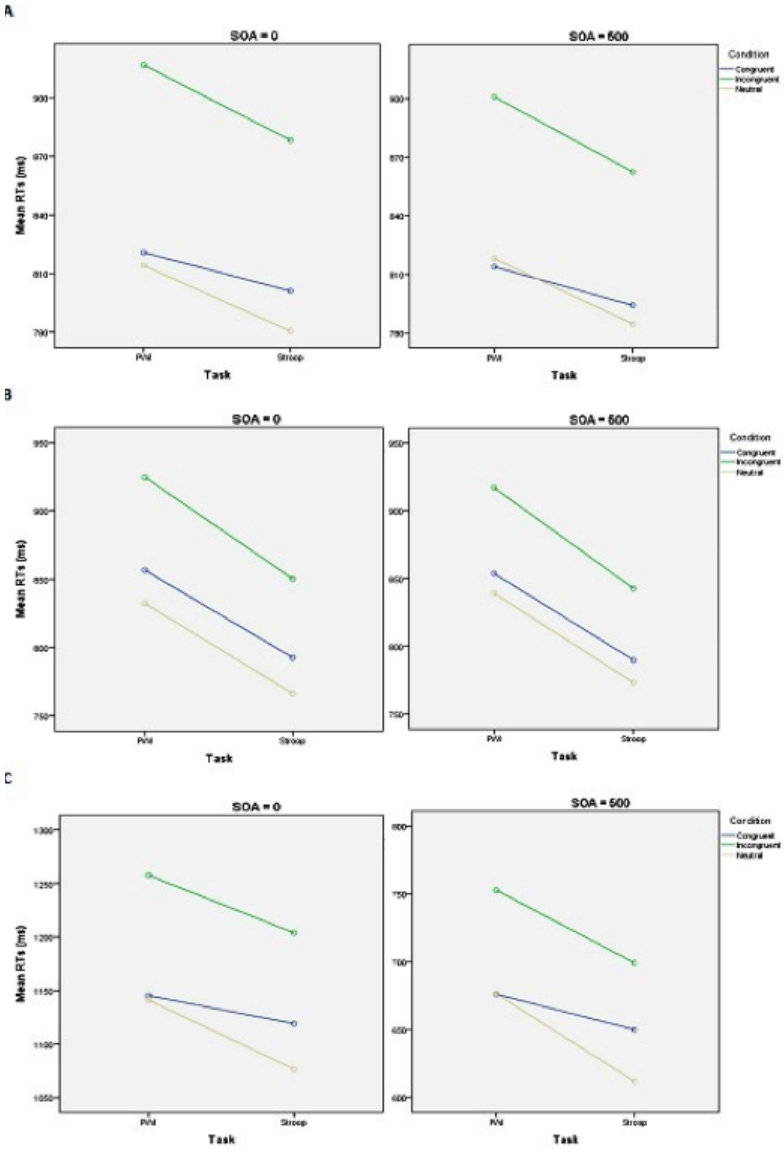
Table 4: Correct Manual Responses per Task, Condition and SOA

Task	PWI	PWI	PWI	PWI	PWI	PWI	STROOP	STROOP	STROOP	STROOP	STROOP	STROOP
Condition	C	C	I	I	N	N	C	C	I	I	N	N
SOA	0	500	0	500	0	500	0	500	0	500	0	500
Mean	1153,5	678,1	1294	824,1	1160,9	720,1	1095,97	649,94	1226,5	747,7	1094,75	613
nStDev	74,51	57,4	87,2	110,2	53,6	53,27	71,9	87,02	83,07	103,59	60,36	48,77

Table 5: Gaze Duration per Task, Condition and SOA

Task	PWI	PWI	PWI	PWI	PWI	PWI	STROOP	STROOP	STROOP	STROOP	STROOP	STROOP
Condition	C	C	I	I	N	N	C	C	I	I	N	N
SOA	0	500	0	500	0	500	0	500	0	500	0	500
Mean	846,12	841,33	913,09	897,84	811,02	836,76	769,31	765,27	823,38	836,21	760,52	756,52
nStDev	44,73	55,6	56,64	49,49	36,05	48,46	56,9	51,89	53,77	51,65	36,31	46,53

and Practice did not interact: Vocal Responses analysis highlighted that the semantic interference effect has the same magnitude (longer naming responses in incongruent



condition compared to congruent and neutral conditions) in presence of Stroop and PWI Task for both SOA in all the three sessions (no effect of Practice).

It is important to note that the interference effect also reflected not only on Manual Responses but also on Gaze Duration regardless of Task, SOA and Practice. As stated below, Gaze Duration is a reliable measure of the cognitive workload.

The interference effect is evident in means for naming latencies (figure 2, A), gaze duration (figure 2, B) and manual responses (figure 2, C).

Figure 2:

In order to verify the impact of sample size on the results, a post hoc power analysis was conducted using the software package, GPower[19]. The sample size of 16 was used for the statistical power analyses and a 2 predictors variable equation was used as a baseline. The recommended effect sizes used for this assessment were as follows: small (f 2 = .02), medium (f 2 = .15), and large (f 2 = .35) (see Cohen, 1977[20]). The alpha level used for this analysis was $p < .05$. The post hoc analyses revealed the statistical power for this study was .20 for detecting a moderate effect, whereas the power was .44 for the detection of large effect size. A total sample size of 31 was indicate as adequate to reach the actual power of .80.

However, sample size could be considered just a indication for further studies, as Roelofs (2011) found significant effects only with twelve participants.

[19] E. Erdfelder, F. Faul, A. Buchner, *GPOWER: A general power analysis program*, in «Behavior research methods, instruments, and computers», XXVIII (1) (1996), pp. 1-11.

[20] J. Cohen, *Statistical power analysis for the behavioral sciences*, New York 1977 (Rev. ed.) Academic.

3. *Conclusion*

A dual-task experiment, based on Stroop and PWI tasks, has been realized following the procedure of Roelofs (2008) to test the origin of the semantic interference effect in lexical production and to clarify differences and similarities with the mechanisms involved in PWI and Stroop. Behavioral and eye-tracking measures have been collected, as the two main hypotheses about the origin of the effect predict different effects (interference effect in naming latencies in the incongruent condition and facilitation effect in eye-tracing measures). In addition, to detect the trend of the interference effect over time, distractor SOA in naming task has been manipulated in an immediate or delayed naming condition. The data evidenced similar patterns for the two paradigms, confirming the hypothesis that Stroop and PWI paradigms intercept the same mechanisms involved in word production.

The interference effect emerged regardless of SOA manipulation suggesting a late locus of the effect, placed near the articulation phase and close to the REH hypothesis[12]. However, the effect has been detected in all the three behavioural measures challenging the REH hypothesis. In a paper by Roelofs[21] the author states that eye gaze shifting from one stimulus to another occurs during spoken word planning and before reaching the articulatory buffer, suggesting that the locus of the semantic effect is placed late in the word production process but that its time course needs to be further investigated using multiple measures. Finally, no interaction between Practice and Condition has

[21] A. Roelofs, *Tracking eye movements to localize Stroop interference in naming: Word planning versus articulatory buffering*, cit.

been detected: this result suggests that the magnitude of the interference effect, in Vocal and Manual responses, is constant over repetitions and contrasts the hypothesis of Van Selst, Ruthruff and Johnston[22] that the dual-task effect rapidly decreased across the first few sessions. According to Klapp, Maslovat and Jacinsky[23], the dual-task effect is due to a late process that controls response initiation and is completed immediately prior to responding. The hypothesis that the bottleneck is caused by programming the time of the response initiation and the second response cannot be initiated until the completion of the first response implies that the dual-task effect can be reduced or even more eliminated by effect of practice that is supposed to facilitate motor streaming. This evidence is not supported by our data. The persistence of the interference effect in the delayed naming condition suggest that semantically related distractors affect the processing of pictures in more than one way captured only partially by the available evidences.

To conclude, the origin of the semantic interference effect in lexical production has been investigated by means of the Stroop task and the Picture-Word Interference paradigm in a dual-task experiment, in which a naming task was accompanied with a manual task. Behavioral and eye-tracking measures has been collected. Distractor SOA in naming task has been manipulated to the aim of detecting the evolution of the semantic interference effect over time.

[22] M. Van Selst, E. Ruthruff, J.C. Johnston, *Can practice eliminate the psychological refractory period effect?*, in «Journal of Experimental Psychology: Human Perception and Performance», XXV (5) (1999), p. 1268.

[23] S.T. Klapp, D. Maslovat, R.J. Jagacinski, *The bottleneck of the psychological refractory period effect involves timing of response initiation rather than response selection*, in «Psychonomic bulletin and review», XXVI (1) (2019), pp. 29-47.

The results obtained add a piece of evidence in a more than three decades of debate highlighting the complexity of the lexical production process.

Compliance with Ethical Standards

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The procedure has been submitted for review and has received approval from the Department of Educational, Psychological and Communication Sciences of the University.

Informed consent: Informed consent was obtained from all individual participants included in the study.

Conflict of interest: None of the authors have conflict of interest.

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