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## How to cite

FARGIER, Raphaël, LAGANARO, Marina. Spatio-temporal dynamics of referential and inferential naming: different brain and cognitive operations to lexical selection. In: Brain topography, 2017, vol. 30, n° 2, p. 182–197. doi: 10.1007/s10548-016-0504-4

This publication URL: https://archive-ouverte.unige.ch/unige:94895
Publication DOI: 10.1007/s10548-016-0504-4

*Final draft:* Fargier, R., Laganaro M. (2017). Spatio-temporal dynamics of referential and inferential naming: different brain and cognitive operations to lexical selection. *Brain Topography, 30(2)*, 182-197.

# Spatio-temporal dynamics of referential and inferential naming: different brain and cognitive operations to lexical selection

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Acknowledgments

This research was supported by Swiss National Science Foundation grant no 105319_146113.

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## Abstract

Picture naming tasks are largely used to elicit the production of specific words and sentences in psycholinguistic and neuroimaging research. However, the generation of lexical concepts from a visual input is clearly not the exclusive way speech production is triggered. In inferential speech encoding, the concept is not provided from a visual input, but is elaborated though semantic and/or episodic associations. It is therefore likely that the cognitive operations leading to lexical selection and word encoding are different in inferential and referential expressive language. In particular, in picture naming lexical selection might ensue from a simple association between a perceptual visual representation and a word with minimal semantic processes, whereas richer semantic associations are involved in lexical retrieval in inferential situations. Here we address this hypothesis by analyzing ERP correlates during word production in a referential and an inferential task. The participants produced the same words elicited from pictures or from short written definitions. The two tasks displayed similar electrophysiological patterns only in the time-period preceding the verbal response. In the stimulus-locked ERPs waveform amplitudes and periods of stable global electrophysiological patterns differed across tasks after the P100 component and until 400-500ms, suggesting the involvement of different, task-specific neural networks. Based on the analysis of the time-windows affected by specific semantic and lexical variables in each task, we conclude that lexical selection is underpinned by a different set of conceptual and brain processes, with semantic processes clearly preceding word retrieval in naming from definition whereas the semantic information is enriched in parallel with word retrieval in picture naming.

Keywords: referential naming; inferential naming; ERPs; spatio-temporal segmentation; lexical selection; word form encoding.

## Introduction

Language production is very often elicited using picture naming tasks in psycholinguistic and neuroimaging research as well as in clinical settings. The main reason for the use of such tasks is related to the control pictures allow on the content of words and sentences speakers are asked to produce. Much of what we know about how speakers encode words and sentences, about the cognitive processes and brain areas involved in the transformation of a concept into an articulated message is therefore based on picture naming paradigms. The main advantage of the use of pictures to elicit concepts in experimental tasks is related to the fact that they allow elicitation of the same sentences (and exactly those sentences the experimenter wishes to study) from many participants. There are however also some downsides in the use of picture naming tasks. First of all, only words corresponding to depictable objects and actions can be elicited with picture naming tasks. Second, although a visual input often triggers speech production in daily referential communication ("he wears a red tie today"; "look, it is snowing outside"; "there is a big bird on the tree"…), the generation of lexical concepts from a visual input is clearly not the exclusive way speech production is triggered. In inferential speech encoding, the concept is not provided *per se* from the visual input, but is elaborated though semantic and/or episodic associations. Whereas the processes underlying speech production have been particularly investigated using visual referential situations, it is very likely that the processes underlying conceptual to lexical encoding differ in inferential verbal production (e.g. in response to a verbal question) relative to referential production.

### *Word production from pictures and from definition*

In picture naming (PN) paradigms the speaker transforms a concept corresponding to a depicted object or action into articulated words or sentences through a series of cognitive processing stages. These include at least visual perception and object recognition, the activation of a word corresponding to the concept triggered by the pictorial representation (lexical-semantic encoding) and the encoding of the word surface form (lexical-phonological encoding) leading to the preparation of the motor programs for speech articulation (Glaser 1992). Most models of word production agree on this basic set of word planning processes preceding articulation (Dell 1986; Levelt et al. 1999), despite different theoretical views on the exact content of abstract word representations (eg. Levelt et al. 1999 versus Caramazza and Miozzo 1997), the mechanisms underlying lexical selection (e.g. Dhooge & Hartsuiker 2010) and the way activation flows during word encoding.

In naming from definition (ND) paradigms, the speaker has to find and produce a word corresponding to a given definition. The information contained in the definition must be combined in order to retrieve the target word. Naming from definition tasks have been only marginally used in the framework of theoretical studies on word production, mainly in the investigation of tip of the tongue states (Yaniv & Meyer 1987; Brown 1991; Burke et al. 1991). By contrast naming from definition has repeatedly been used to assess lexical and semantic competence in clinical settings (Sartori & Lombardi 2004) and in clinical research (e.g. in the investigation of temporal lobe epilepsy: Bell et al. 2003; Hamberger and Seidel 2003; Trebuchon et al. 2009). The cognitive operations involved in naming from definition have been much less described than those involved in picture naming and often the two tasks have been combined to identify brain areas associated with amodal word retrieval processes, i.e. areas common to picture naming and to naming from definition. For instance, Trebuchon et al. (2009) clustered together the anomic states from the two tasks in patients with temporal lobe epilepsy to investigate brain regions involved in word finding difficulties, and reported task-independent correlation between rates of word finding difficulties and PET metabolism in left inferior and left superior temporal regions. Race et al. (2013) analyzed the correlation between word finding performance in a referential (picture naming) and an inferential task (responding to questions) and atrophied brain areas in progressive aphasia. The authors observed a common region showing an association between atrophy and performance in both naming tasks in the left middle inferior temporal gyrus and concluded that this region is involved in amodal lexical retrieval. Hence, in these investigations combining picture naming and naming from definition the authors have explicitly (e.g. Trebuchon et al. 2009) or implicitly (e.g. Race et al. 2013) considered that the two tasks involve the same brain processes. Only a very few investigations have specifically compared word production in picture naming and in naming from definition. Marconi et al. (2013) used fMRI to compare the networks activated during two referential tasks, a picture naming and a word to picture matching task, with those activated during two inferential tasks, a naming from written definition and a word to word matching task. The result from the direct comparison across tasks by Marconi et al. (2013) suggests largely common but also some task-specific brain processes in the middle temporal gyrus for the inferential tasks and right frontal activations for the referential tasks. More specifically, inferential production may involve different semantic knowledge about the objects compared to referential naming. The latter task triggers mainly visual features, whereas naming from definitions can involve other semantic modalities and larger semantic encyclopedic knowledge associated to the objects. For instance, one may be able to produce the word “seahorse” when presented with a picture of the corresponding object, without being able to identify it from a richer semantic description such as “a fish that swims vertically and with males carrying the eggs”.

The idea of a minimal semantic involvement in picture naming, where a simple association between a perceptual visual representation and a word may be sufficient to perform the task, has been suggested previously (Kremin 1988). The fact that picture naming may be achieved with minimal semantic processes is also supported by the neuropsychological observations of cases with preserved picture naming despite impaired semantic knowledge (e.g. naming without comprehension, Brennen et al. 1996; Heilman et al. 1976; Kremin 1986; Silveri & Colosimo 1995).

In sum, considering the nature of the tasks, the dissociations observed in neuropsychological studies and the task-specific activations in the neuroimaging results, we might infer that different processes lead to lexical selection in referential and inferential naming, whereas the same processes are involved once the word has been selected, i.e. for lexical-phonological and phonetic encoding. Here we test this prediction by using neuroimaging techniques with high temporal resolution (EEG) coupled with spatio-temporal analyses. We reason that referential (PN) and inferential (ND) word production should involve different processes from visuo-conceptual activation to lexical selection. As a consequence, different ERP correlates should be observed in the time period preceding lexical selection but ERPs should converge in time-periods corresponding to word form encoding and articulation planning. This was addressed by combining stimulus-aligned and response-aligned ERP analyses. Following the minimal semantic involvement hypothesis, the strength or duration of semantic processes before lexical selection should be minimal in PN relative to ND. Note though one should also take into account that any definition already contains some semantic information. At least, we can hypothesize a different set of cognitive operations between tasks, reflecting that referential naming is a confrontation task whereas in inferential naming information from parts of the definition have to be combined in order to retrieve the target word (Marconi, 1997).

To this aim and given that precise cognitive models exist for picture naming (Indefrey and Levelt 2004; Indefrey 2011; see Strijkers & Costa 2016) but not for naming from definition, we examined the effects of specific psycholinguistic variables on the ERPs in order to be able to compare the two tasks in relation to specific cognitive processes. As the participants had to produce the same words in picture naming and naming from definition, two categorical variables animacy (living vs. non-living items) and word age-of-acquisition (AoA) (early vs. late acquired) were used to index respectively semantic and phonological processes in both tasks. Other continuous variables related to the target words or specifically to the definitions (ND task) or to the pictures (PN task) were included in the analyses to fully characterize each task.

## Method

### Participants

The participants were 24 undergraduate students (mean age 24.9 years, 6 men) who received course credits for participation to the study. They were all right-handed and French speaking with no reported neurological disease. 18 participants were retained after elimination of those with bad EEG/ERP signal and insufficient ERP epochs in each task (see below).

### Material

The same 80 words were used for the picture naming (PN) and for naming from definition (ND) tasks. The words and the corresponding pictures were selected from a picture database used in picture naming tasks (Alario and Ferrand, 1999). For definition, simple sentences with only the last word disambiguating the defined concept were created (eg. “outil qui sert à couper le *pain*“ – objects used to cut *bread*-; “outil qui sert à couper le bois“ - objects used to cut *wood* - ; “animal qui *miaule*“ –animal which *miaows*; “animal qui *aboit*“ – animal which *barks*-). The definitions were the same for at least two target items up to the last word/phrase. To ensure that all definitions had at least two alternative solutions before the last word 15 fillers were added.

Given our hypothesis on different conceptual and lexical-semantic processes and common lexical-phonological encoding processes we manipulated one variable supposed to modulate semantic processes (animacy of the target object) and a second variable known to affect lexical-phonological processes (age of acquisition of the target word). Age of acquisition (AoA) effects have been repeatedly reported in picture naming studies and have been associated with lexical-phonological processes in ERP studies (Perret et al. 2014; Valente et al. 2014). The manipulation of object animacy is well suited to index semantic processes. Living and non-living objects are thought to be associated to different semantic domains (respectively sensory and motor domains, Warrington and Shallice 1984, Cree & McRae, 2003). They also involve different brain regions (Damasio et al. 1996; Martin & Chao 2001), and different ERP waveforms have been reported for living and non-living items in semantic tasks (Kiefer 2001; Paz-Caballero et al. 2006).

The 80 words corresponded to 40 early-acquired and 40 late-acquired nouns (on a 5-points scale; early-acquired 1.8 and late-acquired 2.6; $p<0.001$) and to 40 living and 40 non-living objects. Early and late acquired words and living and non-living objects were balanced on a set of pertinent lexical and semantic properties of the target word (from the French database Lexique, New et al. 2004) and on the properties of the stimuli used to elicit word production in the two tasks, namely on those associated with the pictures for the picture naming task (name agreement, image agreement, from Alario and Ferrand 1999; image complexity, defined as the perimeter of line drawings assessed through Canny perimeter-detection calculation) and on the properties of the last word used in the definitions (frequency, length, orthographic neighborhood density) (see supplementary material S1). It was virtually impossible to disentangle animacy from familiarity, as participants from urban regions are bound to be less familiar with living than with manufactured objects. For most of our analyses we therefore applied a multiple regression approach (see analyses).

### Procedure

All participants underwent the picture naming task and the definition task in a counterbalanced order and without familiarization to the stimuli. For each task, stimuli were presented twice in pseudo-random order in two blocks with a short break in between. A longer break was taken between tasks, which started with the new instructions and five practice trials in presence of the examiner.

Participants sat in a sound-proof dimly lit room approximately 70 cm in front of a PC screen. The presentation of the trials was controlled by the E-Prime software (E-Studio). For picture naming the participants were asked to produce the word corresponding to the picture as fast and accurate as possible. A trial started with a fixation cross presented for 500ms, a 200ms black screen, then a picture (245 x 245 on a grey screen) appeared on the screen and remained for 1800 ms. A blank screen lasting 2000ms was displayed before the next trial. For the definition task, the definition sentence was divided into three phrases which were displayed in white on a gray screen (Courier New, 18, bold). The first phrase appeared 200 ms after the fixation cross and the second phrase appeared 100 ms after the first one. 200 ms afterwards, the last word/phrase was displayed. The duration of the first phrase was 600 ms while it depended on phrase length for the second (from 600 to 1750 ms). The last word/phrase was presented in yellow and remained for 3000 ms on the screen. The participants were asked to produce the word corresponding to the definition ending with the yellow phrase as fast and accurate as possible. The following trial started after 2000 ms.

### *Behavioral analyses*

The digitized responses were systematically checked with a speech analysis software (CheckVocal 2.2.6, Protopapas 2007) to identify correct responses and production latencies (the time separating the onset of the picture or of the last word in definition and the articulation onset). No-responses, wrong responses (i.e. the participant produced a different name than the one expected), hesitations and/or auto-corrections during articulation were considered errors.

Production latencies (RTs) were analyzed by means of mixed-effects regression models (e.g., Baayen, Davidson, & Bates 2008; Goldstein 1987, 1995), conducted with the statistical software R version 3.2.4. (R Development Core Team, 2007) and the packages lme4 and lmerTest (Bates et al. 2014). The Step function was used to perform backward elimination of all fixed and random effects of the linear mixed effect models. The model started with the most complex, i.e. with the entire set of psycholinguistic variables as well as task, task order and item repetition as fixed effects and with participants and items as crossed random effects. For the set of psycholinguistic variables, at first step we checked the linear relation of each predictor with RTs. Then all the significant variables were entered in the same model provided they were not correlated (Pearson correlation <.3). Familiarity and animacy, which were correlated (r=-0.471) were orthogonalised using a residualisation approach. The residuals of the linear model of familiarity~animacy, was highly correlated with familiarity (r=.88) whereas it was no longer correlated with animacy (r=-.004). On the other hand, the residualised animacy measure was still hightly correlated with the original animacy (r=.932), but no longer with familiarity (r=-.123). When animacy and familiarity were both significant in isolation, the residualised measure of familiarity was entered in the model. Other correlated variables (e.g. word length and phonological neighborhood density) were entered in alternation in the model if both were significant in isolation.

### *EEG acquisition and pre-processing*

EEG was recorded continuously using the Active-Two Biosemi EEG system (Biosemi V.O.F. Amsterdam, Netherlands) from 128 channels covering the entire scalp. Signals were sampled at 512 Hz (filters: DC to 104 Hz, 3 dB/octave slope). The custom online reference of the system is the common mode sense (CMS active electrode) – driven right leg (CMS-DRL) which drives the average potentials as close as possible to the amplifier zero (details of this setup can be found on the Biosemi website: http://www.biosemi.com). Offline, ERPs were band-pass filtered to 0.2–30Hz (2nd order acausal Butterworth filter with−12 dB/octave roll-off) and recalculated against the average reference.

Epochs of 600 ms for the picture naming task were extracted locked to the stimulus (-100 ms; +500 ms). 500 ms were extracted locked to 100ms before the vocal response (response-locked epochs: -600 ms; -100 ms). Given the longer RTs in the definition task, epochs of 700 ms locked to the stimulus (-100 ms; +600 ms) and epochs of 500 ms locked to 100 ms before the vocal response (-600 ms; -100 ms) were extracted. ERP epochs with amplitudes exceeding ±100µV were automatically rejected and each trial was visually inspected, and epochs contaminated by eye blinks, movements or other noise artifacts were rejected and excluded from averaging. Artifact electrodes were interpolated using 3-D splines interpolation (Perrin et al. 1987). Only trials with both response-aligned and its corresponding stimulus-aligned uncontaminated epochs were retained and six subjects with less than 70 uncontaminated ERP epochs per task were discarded.

Stimulus-aligned and response-aligned ERPs were averaged separately per participant per task and conditions (AoA and animacy).

### *ERP analyses*

The ERPs were first subjected to a sampling point-wise ERP waveform analysis to determine the time periods presenting local differences in ERP amplitudes between tasks and conditions. Then, a spatio-temporal segmentation was performed on the group-averaged ERPs to determine topographic differences across tasks and statistically validate them in the ERPs of single participants as described below.

Waveform analyses were carried out on evoked potential amplitudes by means of a cluster-based non-parametric analysis (Maris and Oostenveld, 2007) using the FieldTrip is the MATLAB software toolbox (Oostenveld et al.2011), . This allowed to compare each time point (every 2 ms) and channels between two conditions while correcting for multiple comparisons by taking into account spatial (four neighboring channels) and temporal (two successive time-points) adjacency: only clusters over a given significance level were kept. The level of significance was determined by building a distribution stemming from the data itself by successive random permutations (Monte Carlo ; 2000 randomizations) of the two experimental conditions being compared. Alpha-level was set at .05. The procedure was run to compare the picture naming (PN) task and the naming by definition (ND) task. The same procedure was then applied to Animacy and AoA conditions separately for each task on stimulus-aligned ERPs (of 250 and 350 time-frames for picture and definition naming respectively).

To disentangle whether the local differences on amplitudes observed across task are due to larger amplitudes in one task or to different underlying generators, we performed a global topographic analysis. The aim of this analysis is to identify periods of stable global electric fields, likely corresponding to particular periods in mental information processing (Changeux & Michel 2004; Koukkou & Lehmann 1987; Lehmann et al. 1998), and to compare them across tasks. The advantages of tracking global topographic configurations are related to their reference-independence and to their direct link to changes in the configuration of the intracranial sources (Michel et al. 2009, 2011). Thus, the analyses of global electrophysiological patters provide insights into how tasks differ in terms of likely underlying neurophysiological mechanisms (Murray et al. 2008; Michel & Murray 2012), in addition to the temporal information about ERP differences.

As a first step, we ran a topographic statistical analysis on each sampling point on stimulus- and backward response-aligned ERPs to identify periods of significant topographic modulation between tasks. This procedure is called TANOVA (although it is not an analysis of variance); it involves a non-parametric randomization test to the global dissimilarity between two electric fields. The global dissimilarity is a quantification of topographic differences between two electric fields independent of their strength ranging from 0 to 2 (Lehmann & Skrandies 1980, see an example of its computation in Murray et al. 2008). The permutation of the data is accomplished by re-assigning randomly the topographic maps of single subjects to the different conditions. The global dissimilarity of these random group-averaged ERPs is compared time-point by time-point with the values of topographic dissimilarity of the actual tasks. A time-period criterion of 20 ms of consecutive significant differences and an alpha of 0.01 were applied.

Then, a global topographic ERP (map) pattern analysis called spatio-temporal segmentation was run. This procedure segments ERPs in periods of quasi-stable global electrophysiological pattern at scalp (i.e. topographic maps or ERP microstates) by compressing the variability of ERPs in a series of template maps which summarize the data and serve to determine which topographic template best explains participants' ERP responses to each experimental condition (Pascual-Marqui et al. 1995; Michel & Murray 2012). The spatio-temporal segmentation was applied to the group-averaged data of PN and DN separately on the stimulus-aligned and on the response-aligned ERPs. We used a modified hierarchical clustering algorithm (Murray et al. 2008), the agglomerative hierarchical clustering, to determine the most dominant electric field configurations at the scalp (topographic ERP maps). The selection of the optimal number of ERP maps that best explain the group-averaged data across conditions was based on a combination of a cross-validation and the Krzanovski-Lai criterion (see Murray et al. 2008). Statistical smoothing was applied to remove temporally isolated topographic maps with low explanatory power. This procedure is described in detail in Pascual-Marqui et al. (1995) and step by step tutorials are provided in Brunet et al. (2011) and Murray et al. (2008, see also Koenig et al. 2014). In accordance with the criteria for the local ERP waveform analyses, a given ERP topography had to be present ≥20ms.

The pattern of topographic map templates observed in the group-averaged data was statistically tested by comparing each of these map templates with the moment-by-moment scalp topography (from stimulus onset to 100 ms before articulation) of individual ERPs in each task. This procedure referred to as ‘fitting’ allows one to establish how well a topographic template map explains single participant responses in each condition. Each data sampling point in each condition was labelled according to the template map with which it best correlated spatially, yielding a measure of map presence in each individual data, its duration and the global explained variance (GEV). These measures are then used to statistically test topographic differences across tasks. To test the effect of the psycholinguistic properties of the target words and of the eliciting stimuli, the same fitting procedure was applied to single trials and the measures of duration and GEV were used to assess the effect of task-specific psycholinguistic predictors to the periods of topographic stability, following the method described in Valente, Bürki and Laganaro (2014) and using the same multiple regression approach using mixed effects models as described for the behavioural analyses.

## Behavioural results

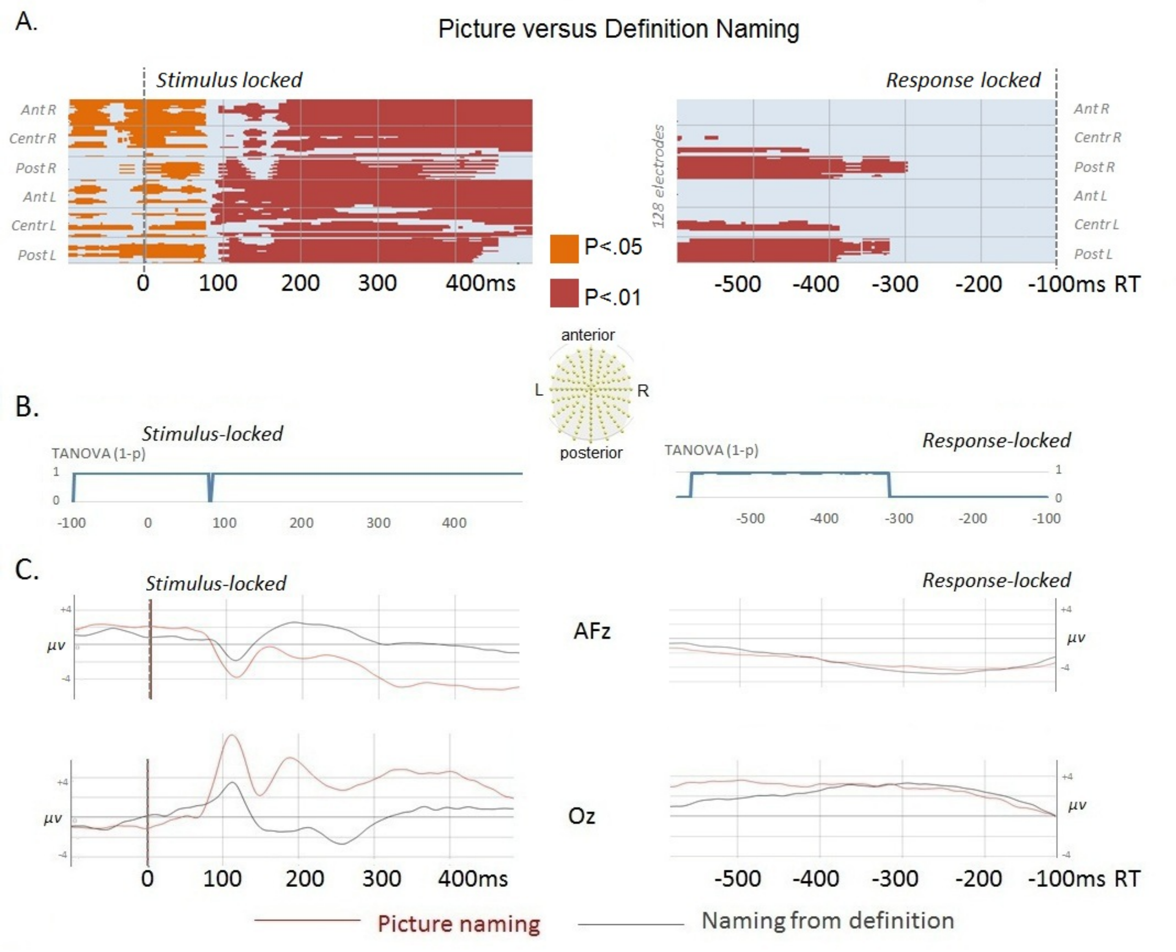
The behavioral analyses were performed on the 18 subjects retained for the ERP analysis. Mean correct production was 85% in the naming from definition (ND) task and 93% in picture naming (PN). After removal of production latencies beyond 3 standard deviations (1.7% of the data), mean production latencies were 806 ms (SD=202 ms) in PN and 1173 ms (SD=365) in ND. The task effect was significant (F(1, 4950)= 2456, p<.0001), with faster RTs in naming than in definition, without interaction with task order (F(1, 4942)= 1.4, p= 0.234) and no main effect of task order (F<1). For the psycholinguistic predictors, separate models were run for each task with the common and the task-specific psycholinguistic variables and repetition (run). As several variable interacted with repetition, in Table 1 we report the models separately for first and second run.

[Table 1 about here]

Two target word properties, namely familiarity with the concept and word age of acquisition affected production latencies in both tasks in the expected direction (longer RTs for late acquired and for less familiar items). AoA effects were observed in both tasks independent of run. Animacy only affected RTs in definition, with shorter RTs for non-living than for living objects in the second repetition. Familiarity interacted with run: it affected only the first presentation in PN and the second run in ND. In addition one property of the corresponding eliciting stimuli affected RTs in each task: name agreement PN (the degree of association between the picture and the corresponding modal name) and the length of the eliciting sentence in ND. The latter variable only affected the first run in ND.

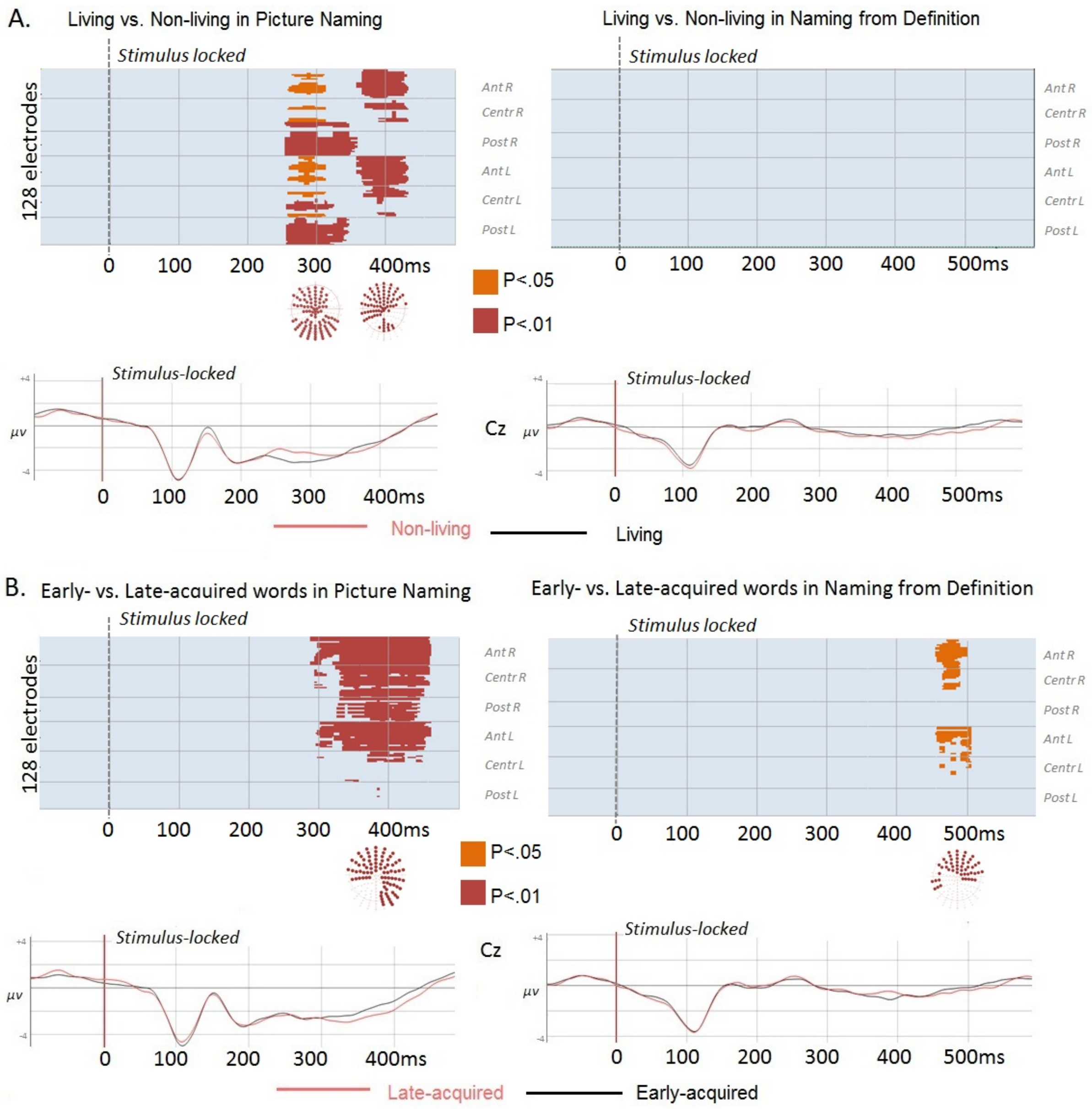
### *ERP results*

The between task comparison on the stimulus-locked ERPs revealed modulations of waveform amplitudes (Figure 1.A) on most of the 128 channels on throughout the stimulus-locked ERPs and up to 300 ms before the vocal onset in the response-locked data.. The global dissimilarity (TANOVA) analysis (Figure 1.B) also revealed significant differences between tasks from stimulus to 300 ms before articulation.



[Figure 1 about here]

Significant modulations of amplitudes by Animacy were observed only in PN (Figure 2.A). Consistent differences between living and non-living items were observed on central anterior and right and left posterior electrodes from ~270 to 350 ms. A second period of different amplitudes appeared around 400 ms on anterior and central-left sites. Word age of acquisition modulated amplitudes in both tasks: amplitudes differed between early and late-acquired words between 300 and 400 ms in picture naming and 150 ms later (from 450 to 500 ms) in naming from definition. These effects were on anterior channels in both tasks (Figure 2.B) with additional right posterior channels in ND.



[Figure 2 about here]

Spatio-temporal analysis

A spatio-temporal segmentation analysis was run separately on the stimulus-locked and on the response-locked grand-averaged ERPs of the two tasks. The cross-validation and the Krzanovski-Lai criteria indicated 10 different periods of quasi-stable electrophysiological activity at scalp on the stimulus-aligned data accounting for 96.24% of the variance. On the response-aligned (last 500 ms) three topographic maps were identified accounting for 97.88% of the variance. Two out of the 3 maps observed in the response-aligned data were correlated above 98% with two maps from the stimulus-locked segmentation and were therefore removed for the back-fitting procedure, in which 11 map templates were retained (see Figure 3).

The 11 different microstates were fitted back to the individual ERPs in three periods: from 100ms before stimulus onset to the end of the P100 component (140 ms after stimulus onset) with map templates M1,M 2 and M3; from 141 to 500 ms following stimulus onset (map templates M4,M5, M6, M7, M8, M9, M10) and on the response-locked data from which the overlapping signal with the stimulus-locked data was removed according to each individual production latency in each task (map templates M9, M10 and M11). The presence of each map template in the individual ERPs is summarized in appendix A1 along with the GEV and mean duration.

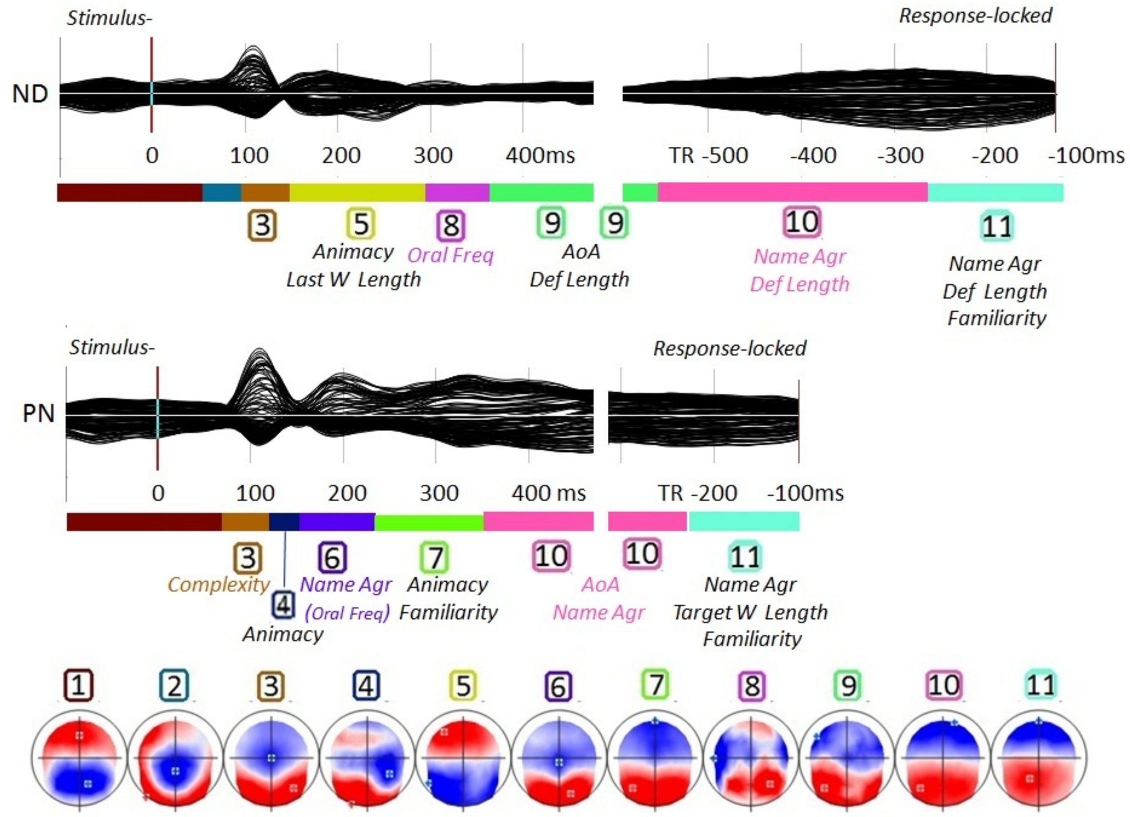
There was no significant difference on the period of stable global electrophysiological pattern corresponding to M1 in Figure 3 across the two tasks, whereas the second period of topographic stability (M2) was more present in ND than in PN (Pearson $\chi^2$=7.2, p<.01). The P100 component had the same topography (map M3) across tasks despite lower amplitudes for written stimuli (ND) than for pictures. This was also reflected in mean glogal fit power (Gfp) values, which were higher in the picture naming than in definition (Wilcoxon z=-3.5, p<.001), despite similar GEV (respectively 39% and 42%, z=-1.1, p=.28). Map M4 which characterized the grand-average of the picture naming data in the time-period 140-170 ms was actually present only in less than half of the subjects with very low GEV and no significant difference across tasks. On the following periods of stable global electrophysiological activity the fitting in the individual ERPs confirmed the results observed on the grand-average: topographic maps M5, M8 and M9 had higher presence in ND than PN (M5: $\chi^2$=13.7, p<.001; M8: $\chi^2$=8.8, p<.01, M9: $\chi^2$=10.6, p<.01), while maps M6 and M7 were more present and had larger GEV in the ERPs from the PN than the ND task (M6: $\chi^2$=4.9, p<.05; M7: $\chi^2$=14.6, p<.001). The last two periods of stable electrophysiological patterns (maps M10 and M11) were present in most subjects in both tasks. There was no significant difference across tasks on duration and GEV of M10 (both z<1), which onset was 150 ms later in ND than in PN (z=-3.3, p<.01). Map M11 lasted 70 ms longer in definition (z=-2.3, p=.02), with similar GEV across tasks (z=-1.6, p=.1).

To summarize, similar global ERP patterns across tasks only appeared in the P100 time-window and in the response-locked periods although shifted across tasks and with different durations.

To try to further gain insight into the task-specific periods of topographic stability, we seek which properties of the eliciting stimuli and of the target words affect the GEV and duration of each period of quasi-stable electrophysiological pattern. For this purpose the 11 microstates were fitted back to the single trials ERPs (2132 in PN and 1848 in ND). The same fitting periods as described above for fitting in the individual ERPs were used, but only task-specific topographic maps were fitted in the 140-500 ms period. Presence, GEV and duration of each of the 11 periods of quasi-stable electrophysiological activity at scalp in single trials are summarized in appendix A2.

The same mixed-effects regression approach using the Step function as described for the behavioral data was conducted on the properties (GEV and duration) of each period of stable electrophysiological patterns (topographic maps) fitted in single trials separately for each task. To correct for multiple models (one per period of topographic stability from the P100 component to 100ms before articulation, i.e. 6 models for each task) alpha was set at p<.01. Finally, to parallel the Name Agreement variable available *a priori* only for picture naming, an internal measure of Name Agreement was computed for the definition task, operationalized as the percent of expected responses given for each definition (mean=82.6%, SD=18.9). The results on the significant predictors are summarized in

Figure 3 and the complete results of the mixed effect models is available in the appendix A3. The statistical analyses on single-trials indicate that for naming by definition, the variables animacy and last word length modulated the GEV and duration of map M5 (last word length interacted with repetition and was only significant at second presentation). Oral frequency of the word to be produced predicted the duration of the period of topographic stability M8; word age of acquisition modulated the duration of map M9, map M10 was affected by Name agreement, and map M11 by Name agreement and the familiarity with the concept. Finally, the length of the definition sentence affected the GEV or duration of all the three last microstates (M9, M10, M11). Notice that repetition (run) affected all periods of topographic stability, but it only interacted with Last Word Length on Map 5. For picture naming, visual complexity affected the GEV of map M3. The GEV and duration of Map M4 were modulated by animacy. The duration of Map 6 was modulated by Name Agreement. Note though that Oral frequency did not reach our alpha criterion of 0.01, but it predicted duration of map M6 at p=.013 (Estimate=-2.75, SE=1.11, t=-2.47). The GEV and duration of M7 were predicted by animacy and familiarity with the concept. An effect of AoA and Name Agreement were found on M10 whereas M11 was sensitive to Name Agreement, Familiarity and the length of the target word.



[Figure 3 about here]

## Discussion

Direct comparison between picture naming and naming from definition revealed different waveforms and periods of stable topographic patterns after the P100 component and until 400-500 ms, confirming the involvement of different, task-specific, neural networks. Similar electrophysiological patterns only appeared in the last time-period of the response-aligned ERPs with later onsets and longer duration of the same periods of stable topographic configurations in ND. Later onset across tasks was also observed for the effect of word age of acquisition on waveform amplitudes: AoA modulated response-aligned ERPs in both tasks, but with a 100 ms shift in ND relative to PN. Producing words from definitions in which only the last word could disambiguate the concept was also slower than producing words from pictures, which is in line with the shifts of AoA effects and of the response-locked common electrophysiological patterns.

Hence, whereas a first interim conclusion is that referential and inferential word production seem to involve different neural networks up to 400-500 ms and similar electrophysiological patterns from then to articulation (but with different time distribution) only the analysis of the psycholinguistic factors affecting these task-specific ERP correlates will provide information on the underlying cognitive processes.

### *The P100 component*

Only amplitude differences were observed on the P100 component. The larger amplitudes in the P100 time-period for picture naming are likely due to the complexity of pictures relative to words, i.e. to the specific stimuli used to elicit naming in the two tasks. The effect of visual complexity on the GEV of the P100 map (M3) observed in picture naming also converges with this interpretation.

### *Lexical-semantic processes*

Periods of topographic stability were task-specific after the P100 component (maps M5, M8, M9 in naming from definition and M4, M6, M7 in picture naming). These task-specific microstates observed up to 500 ms post stimulus onset likely reflect different lexical-semantic processing. Interestingly, these task-specific periods of stable electrophysiological patterns were predicted by some common and some task-specific psycholinguistic variables, which can be discussed in relationship with cognitive processes underlying word retrieval.

### *Lexical-semantic processes in ND*

The manipulated semantic factor (animacy) affected the GEV of the period of topographic stability labeled M5, which was specific to definition. The period corresponding to M5 had higher GEV for living than for non-living items. The following task-specific period of topographic stability (M8) was affected by the oral lexical frequency of the target word, with shorter duration for higher frequencies. Lexical frequency refers to the frequency a word is used in the language and has been previously associated with lexical selection in picture naming ERPs (Strijkers et al. 2010). Here it may indicate that lexical retrieval is engaged in naming from definition from about 300 ms. This interpretation also converges with the observation that the preceding period is affected by the properties of the eliciting stimuli (length of the last word in definition) and by semantic properties of the target (animacy).

### *Lexical-semantic processes in PN*

According to previous research, lexical selection in picture naming is thought to be engaged around 200 ms (Strijkers et al. 2010; Indefrey 2011), i.e. in the period corresponding to the period of topographic stability labeled M6. Here, as in previous ERP studies (Valente et al. 2014), no significant effect of lexical frequency was observed in picture naming using conservative alpha correction criteria for multiple comparisons, but lexical frequency effects were observed at lower alpha levels. Yet, the period corresponding to the P2/N2 component was also affected by name agreement, a variable that reflects the degree of association between the picture and the corresponding modal name. The effect of NA in picture naming has been previously associated with lexical encoding (Johnson, Paivio, & Clark 1996, Alario et al. 2004). Hence, the marginal lexical frequency effect along with an effect of name agreement on the P2/N2 component (M6) strongly suggest that lexical selection is engaged during this time-window in PN. The period of topographic stability preceding the time-window associated with lexical selection (M4 in PN) was modulated by the manipulated semantic variable animacy. Unlike in ND however, a second later period of quasi-stable electrophysiological stability was also affected by semantic predictors in PN (M7, from about 250 to about 350 ms), corresponding to the time-window of modulations of waveform amplitudes by animacy (see Figure 2).

*Different semantic processing between the two tasks*

As discussed above, lexical selection is likely engaged around 200 ms in PN and around 300 ms in ND. The distribution of the microstates affected by semantic variables, relatively to the time-windows of lexical selection, differ across tasks and suggest that lexical retrieval is underpinned by a different set of cognitive operations.

The manipulated semantic variable (animacy) affects ERP time-periods (M5) preceding the one associated with lexical selection in ND, and both a preceding (M4) and a following (M7) period in PN. First, there are qualitative differences among the three maps that are affected by Animacy that need to be addressed. Map 5 in ND and map 7 in PN display comparable GEV values and are affected by Animacy in the same direction (lower GEV for animate). Opposite effects are found for map M4 in PN, which also displays lower GEV values and has a shorter average duration relative to maps M5 and M7. Hence, these maps should be treated separately.

The stable electrophysiological activity labeled M4 occurred between 140 and 180 ms post picture onset. It has been suggested that the kind of conceptual information manipulated in the present study ("living" versus "non-living") was relevant for conceptual processes preceding lemma retrieval (Indefrey 2011) and previous ERP studies found that this information was available around 150-200 ms during picture processing in tasks that do not involve naming (Thorpe et al. 1996; Zhang & Damian 2009; but see Schmitt et al. 2000 with naming). Map M4 could thus reflect early category-related activity (see Thorpe 2009) related to pictures that could be not relevant in naming by definition. Such abstract information or coarse processing (Wu et al., 2015) would be different from how much specific features of the items are retrieved. In fact, as also suggested by Indefrey (2011), the retrieval of other types or deeper conceptual information could take longer and therefore be achieved later on, in parallel to other processing stages in picture naming (see also Abdel Rahman and Sommer 2003). Maps M7 and M5, respectively in picture naming and naming by definition, could therefore reflect the retrieval of such deeper conceptual information. This is coherent with recent work suggesting that the retrieval of action-related conceptual information is available around 250-300 ms in picture naming tasks (Fargier & Laganaro 2015), as well as with evidence for semantic processes extending to 300-400 ms after picture presentation in picture classification (Shendan and Maher, 2009) and naming (Poch et al. 2015 ) tasks. If these periods of stable electrophysiological activity correspond to the retrieval of conceptual information, then it occurs earlier and precedes lexical selection in naming by definition. As stated by Marconi (1997), inferential processing requires to manage the semantic network in order to extract the correct name whereas referential processing requires to find the correct name for a depicted object after it has been categorized in the semantic lexicon. In other terms, in inferential naming information are combined for word retrieval whereas word retrieval is triggered by object recognition in referential naming, in which the semantic information is enriched in parallel with word retrieval. The requirement of such a different set of operations, and different underlying neural generators, is thus illustrated by the differences in the topographies likely related to lexical-semantic retrieval. The present data cannot inform however on whether the same or different amount of information is retrieved in naming by definition and picture naming.

Taken together, the observation that animacy modulates ERPs in the first 400 ms in both tasks indicates that semantic processes are engaged in this time-window although at different time-periods and associated with different, task-specific, neural networks. It also indicates that in the inferential task the concept corresponding to the target word is being processed within the first 300 ms following the presentation of the last word in definition and precedes lexical selection, likely occurring in the time-window affected by the target word lexical frequency (M8). It should be reminded that the definitions could only be completely disambiguated with the last phrase, but the preceding sentence already provided a cue at least towards the semantic category of the target. It is therefore possible that in the 140-300 ms time-window recognition of the written word and inferential processes on the elicited word take place in parallel. This concurs with the idea that, although similar information might be retrieved in both tasks, the combinatorial versus recognition operations that lead to it are supported by different neural networks.

### *From 400-500 ms to articulation*

From 400 ms in PN and after 500 ms in ND the same periods of quasi stable global scalp potentials were observed in the two task, although with different distribution, and with different waveform amplitudes only in the time-period extending from -400 to -300 ms preceding articulation. This likely indicates that in contrast to lexical-semantic knowledge, the retrieval of lexical-phonological information is underpinned by the same neural networks no matter the task. Crucially, the onset of the shared ERP periods is close to the time-window of ERP modulation by AoA in each task (300-450ms in picture naming and around 450 to 500 ms in definition). Word age of acquisition affected both inferential and referential naming latencies and ERPs. AoA corresponds to the subjective rating of the age at which a word has been acquired and its effect has been repeatedly reported in picture naming tasks, both on latencies (Chalard & Bonin 2006; Kittredge et al. 2008; Morrison & Ellis 1995; Morrison et al. 1992) and on ERPs (Laganaro and Perret 2011; Perret et al. 2014; Valente et al. 2014). Most behavioural and ERP studies converge towards a lexical-phonological locus of AoA effects (see Bonin et al., 2006; Perret et al. 2014). In previous electrophysiological studies using picture naming, AoA modulated ERPs at about ~350-400 msec after picture presentation, which is also the time-window of the temporal signature in PN in the present study. AoA also affected the periods of topographic stability observed in other time-windows: the duration of map M9 in definition and the GEV and the duration of map M10 in picture naming, with longer lasting periods of stable topographic patterns in both cases. Following this rationale, word form encoding is engaged after about 400 ms in PN and after 500 ms in ND. The processes involved in word form encoding, likely lexical-phonological encoding and articulatory planning, are underpinned by common neural networks for PN and for ND. However, the time-period from the onset of the AoA effect to the onset of articulation is longer for ND than for PN.

For picture naming it has been suggested previously that response monitoring also takes place during the time-period preceding articulation. Internal monitoring is indicative of the representational strength of an item, which is corroborated here by the effect of NA and familiarity on this period. Effects of the force of association between a picture and its corresponding modal name have been previously reported in late time-windows (Cheng et al. 2010; Valente et al. 2014). ERP modulation by NA seems to reflect uncertainty about the word to produce, with longer latencies when uncertainty is higher (NA is lower). It is very likely that the longer period from the onset of AoA effects to articulation in ND relative to PN corresponds to higher uncertainty relative to the name corresponding to the definition. This is supported by the similar effect of NA on the last two topographic patterns (M10 and M11) as well as by the results of the study by Marconi and colleagues (2013) who reported higher rates of errors in the inferential task relative to picture naming. Also in favor of an enhanced monitoring in naming by definition is that the length of the definition affected the last three periods of stable electrical configuration at scalp. Self-monitoring is thought to be temporally adjacent to phonological encoding (Wheeldon & Levelt, 1995) which converges with the effect of NA and length of the definition sentence. However, the latter effect may also be due by the fact that participants keep the definition sentence in working memory throughout word planning. In such case, name agreement may reflect a similar monitoring process in both tasks, whereas in ND additional working memory load is involved.

### *Parallel vs. serial processing in PN*

In this study, specific psycholinguistic variables associated to specific word planning stages were used as a tool to determine which aspects of the cognitive models based on PN (e.g. Indefrey & Levelt, 2004) may apply to ND. In line with that, such parametric analyses can also inform on whether there is some degree of parallel processing as suggested recently for picture naming (Miozzo et al., 2015; see also Strijkers & Costa, 2016; Munding et al., 2016). This idea would be supported for instance if two variables supposed to relate to different word encoding processes would affect the same ERP components or topographic patterns. Indeed, Miozzo et al. (2015) found that semantic features and a composite predictor of word form both modulated MEG signal around 150-200 ms. This was taken to suggest parallel phonological and semantic processing as early as 150 ms post picture onset (but see Indefrey 2016 for a criticism on the relevance of the word form predictor used). The present data rather suggest that semantic and phonological processes are distinct and ordered serially as indicated by earlier effects of animacy (275-350 ms) relative to the effects of AoA (starting around 350 ms) on ERPs (see Figure 2) and topographic patterns (see Figure 3) for picture naming. Nevertheless, it should be acknowledged that the semantic variable animacy modulated the topographic pattern M7 in picture naming which occurs after the putative onset of lexical selection (P2/N2 component). This is compatible with the idea that while lexical selection starts when semantic representations are sufficiently fine-grained to allow the selection of a specific lexical item, it does not mean that semantic retrieval must be complete (Mahon & Navarrete, 2016). Although it suggests that semantic retrieval continues in parallel to word encoding, the issue of the way activation flows during word encoding is still an ongoing debate for picture naming (Munding et al., 2016). There seems to be no indication however in the data reported for naming by definition that could inform on this for inferential naming.

### *Conclusions*

As predicted in the Introduction, inferential naming involves different lexical-semantic processes than referential naming. The present data clearly points to different sets of conceptual and brain processes in the two tasks up to the common lexical-phonological processes. In particular, we suggested that the retrieval of conceptual information precedes lexical selection in naming by definition, whereas word retrieval is triggered by object recognition in referential naming, in which the semantic information is enriched in parallel with word retrieval. This study contributes to better detail lexical access in speech production but questions to what extent semantic retrieval can be by-passed in referential naming relatively to inferential naming.

The exact differences in the content and amounts of semantic information which are retrieved in naming by definition and in picture naming needs however further investigation.

## References

Abdel Rahman R, Sommer W (2003) Does phonological encoding in speech production always follow the retrieval of semantic knowledge? Electrophysiological evidence for parallel processing. Brain Res Cogn Brain Res 16:372–382.

Alario FX, Ferrand L (1999) A set of 400 pictures standardized for French: norms for name agreement, image agreement, familiarity, visual complexity, image variability, and age of acquisition. Behav Res Methods Instrum Comput J Psychon Soc Inc 31:531–552.

Alario FX, Ferrand L, Laganaro M, et al (2004) Predictors of picture naming speed. Behav Res Methods Instrum Comput J Psychon Soc Inc 36:140–155.

Baayen RH, Davidson DJ, Bates DM (2008) Mixed-effects modeling with crossed random effects for subjects and items. J Mem Lang 59:390–412. doi: 10.1016/j.jml.2007.12.005

Bates, D., Maechler, M., Bolker, B., and Walker, S. (2014). lme4: Linear mixed-effects models using Eigen and S4. R package version 1.0-6. http://CRAN.R-project.org/package=lme4

Bell BD, Seidenberg M, Hermann BP, Douville K (2003) Visual and auditory naming in patients with left or bilateral temporal lobe epilepsy. Epilepsy Res 55:29–37.

Brennen T, David D, Fluchaire I, Pellat J (1996) Naming faces and objects without comprehension - a case study. Cogn Neuropsychol 13:93–110.

Brown AS (1991) A review of the tip-of-the-tongue experience. Psychol Bull 109:204–223.

Brunet D, Murray MM, Michel CM (2011) Spatiotemporal Analysis of Multichannel EEG: CARTOOL. Comput Intell Neurosci. doi: 10.1155/2011/813870

Burke DM, MacKay DG, Worthley JS, Wade E (1991) On the tip of the tongue: What causes word finding failures in young and older adults? J Mem Lang 30:542–579. doi: 10.1016/0749-596X(91)90026-G

Caramazza A, Miozzo M (1997) The relation between syntactic and phonological knowledge in lexical access: evidence from the “tip-of-the-tongue” phenomenon. Cognition 64:309–343.

Chalard M, & Bonin P (2006) Age-of-acquisition effects in picture naming: Are they structural and/or semantic in nature? Visual Cognition, 13(7-8), 864-883.

Changeux J-P & Michel CM (2004) Mechanisms of neural integration at the brain scale level: the neuronal workspace and microstate models. In: S. Grillner and A.M. Grabyel (Eds.) Microcircuits: The Interface between Neurons and Global Brain Function. (pp. 347-370). Cambridge, MA: The MIT Press.

Cheng X, Schafer G, Akyürek EG (2010) Name agreement in picture naming: an ERP study. Int J Psychophysiol Off J Int Organ Psychophysiol 76:130–141. doi: 10.1016/j.ijpsycho.2010.03.003

Cree GS, McRae K (2003) Analyzing the factors underlying the structure and computation of the meaning of chipmunk, cherry, chisel, cheese, and cello (and many other such concrete nouns). J Exp Psychol Gen 132:163–201.

Damasio H, Grabowski TJ, Tranel D, et al (1996) A neural basis for lexical retrieval. Nature 380:499–505.

Dell GS (1986) A spreading-activation theory of retrieval in sentence production. Psychol Rev 93:283–321.

Dhooge E, Hartsuiker RJ (2010) The distractor frequency effect in picture-word interference: Evidence for response exclusion. J Exp Psychol Learn Mem Cogn 36:878–891. doi: 10.1037/a0019128

Fargier R, Laganaro M (2015) Neural dynamics of object noun, action verb and action noun production in picture naming. Brain Lang 150:129–142. doi: 10.1016/j.bandl.2015.09.004

Glaser WR (1992) Picture naming. Cognition 42:61–105.

Goldstein H (1987) Multilevel covariance component models. Biometrika 74:430–431. doi: 10.1093/biomet/74.2.430

Goldstein H (1995) Multilevel Statistical Models, Arnold. Londres

Hamberger MJ, Seidel WT (2003) Auditory and visual naming tests: normative and patient data for accuracy, response time, and tip-of-the-tongue. J Int Neuropsychol Soc JINS 9:479–489.

Heilman KM, Tucker DM, Valenstein E (1976) A case of mixed transcortical aphasia with intact naming. Brain J Neurol 99:415–426.

Indefrey P (2016) On putative shortcomings and dangerous future avenues: response to Strijkers & Costa. Language, Cognition and Neuroscience. doi:10.1080/23273798.2015.1128554

Indefrey P (2011). The spatial and temporal signatures of word production components: a critical update. Frontiers in Psychology, 2, 255. doi:10.3389/fpsyg.2011.00255

Indefrey P, Levelt WJM (2004) The spatial and temporal signatures of word production components. Cognition, 92(1-2), 101–144. doi:10.1016/j.cognition.2002.06.001

Johnson CJ, Paivio A, Clark JM (1996) Cognitive components of picture naming. Psychol Bull 120:113–139.

Kiefer M (2001) Perceptual and semantic sources of category-specific effects: event-related potentials during picture and word categorization. Mem Cognit 29:100–116.

Kittredge AK, Dell GS, Verkuilen J, Schwartz MF (2008) Where is the effect of frequency in word production? Insights from aphasic picture-naming errors. Cogn Neuropsychol 25:463–492. doi: 10.1080/02643290701674851

Koenig T, Stein M, Grieder M, Kottlow M (2014) A tutorial on data-driven methods for statistically assessing ERP topographies. Brain Topogr 27:72–83. doi: 10.1007/s10548-013-0310-1

Koukkou M, Lehman D (1970) EEG correlates of learning in sleep experiments with humans. Electroencephalogr Clin Neurophysiol 28:101.

Kremin H (1986) Spared naming without comprehension. J Neurolinguistics 2:131–150.

Kremin H (1988) Independence of access to meaning and to phonology : Arguments for direct non-semantic pathways for the naming of written words and pictures. In: Perspectives on cognitive neuropsychology, Lawrence Erlbaum. Londres, pp 231–252

Laganaro M, Perret C (2011) Comparing electrophysiological correlates of word production in immediate and delayed naming through the analysis of word age of acquisition effects. Brain Topogr 24:19–29. doi: 10.1007/s10548-010-0162-x

Lehmann D, Skrandies W (1980) Reference-free identification of components of checkerboard-evoked multichannel potential fields. Electroencephalogr Clin Neurophysiol 48:609–621.

Lehmann D, Strik WK, Henggeler B, Koenig T & Koukkou, M., (1998) Brain electric microstates and momentary conscious mind states as building blocks of spontaneous thinking: I. Visual imagery and abstract thoughts. International Journal of Psychophysiology, 29, 1-11.

Levelt WJ, Roelofs A, Meyer AS (1999) A theory of lexical access in speech production. Behav Brain Sci 22:1–38; discussion 38–75.

Mahon BZ, Navarrete E (2016) Modelling lexical access in speech production as a ballistic process. Language, Cognition and Neuroscience. doi:10.1080/23273798.2015.1129060

Marconi D. Lexical competence. Cambridge: MIT Press, 1997.

Marconi D, Manenti R, Catricalà E, et al (2013) The neural substrates of inferential and referential semantic processing. Cortex J Devoted Study Nerv Syst Behav 49:2055–2066. doi: 10.1016/j.cortex.2012.08.001

Maris E, Oostenveld R (2007) Nonparametric statistical testing of EEG- and MEG-data. J. Neurosci. Methods, 164, pp. 177–190.

Martin A, Chao LL (2001) Semantic memory and the brain: structure and processes. CurrOpinNeurobiol 11:194–201.

Michel CM & He B (2011) EEG mapping and source imaging. In D.L. Schomer and F.H. Lopes da Silva (eds). Niedermeyer’s Electroencephalography. Philadelphia: Wolters Kluwer.

Michel, C.M., Koenig, T., Brandeis, D., Gianotti, L.R.R. (2009). Electric neuroimaging. Cambridge University Press, Cambridge.

Michel CM, Murray MM (2012) Towards the utilization of EEG as a brain imaging tool. NeuroImage 61:371–385. doi: 10.1016/j.neuroimage.2011.12.039

Miozzo M, Pulvermuller F, Hauk O. (2015) Early Parallel Activation of Semantics and Phonology in Picture Naming: Evidence from a Multiple Linear Regression MEG Study. Cereb Cortex.25(10):3343–55.

Morrison CM & Ellis AW (1995) The roles of word frequency and age of acquisition in word naming and lexical decision. Journal of Experimental Psychology: Learning, Memory & Cognition, 21, 116-133.

Morrison CM, Ellis AW & Quinlan PT (1992) Age of acquisition, not word frequencw, affects object naming, not object recognition. Memory and Cognition, 20, 705-714.

Munding D, Dubarry AS, Alario FX (2016). On the cortical dynamics of word production : A review of the MEG evidence. *Language, Cognition and Neuroscience.* doi: 10.1080/23273798.2015.107185

Murray MM, Brunet D, Michel CM (2008) Topographic ERP analyses: a step-by-step tutorial review. Brain Topogr 20:249–264. doi: 10.1007/s10548-008-0054-5

New B, Pallier C, Brysbaert M, Ferrand L (2004) Lexique 2: a new French lexical database. Behav Res Methods Instrum Comput J Psychon Soc Inc 36:516–524.

Pascual-Marqui RD, Michel CM, Lehmann D (1995) Segmentation of brain electrical activity into microstates: model estimation and validation. IEEE Trans Biomed Eng 42:658–665. doi: 10.1109/10.391164

Paz-Caballero D, Cuetos F, Dobarro A (2006) Electrophysiological evidence for a natural/artifactual dissociation. Brain Res 1067:189–200. doi: 10.1016/j.brainres.2005.10.046

Perret C, Bonin P, Laganaro M (2014) Exploring the multiple-level hypothesis of AoA effects in spoken and written object naming using a topographic ERP analysis. Brain Lang 135:20–31. doi: 10.1016/j.bandl.2014.04.006

Perrin F, Pernier J, Bertrand O, et al (1987) Mapping of scalp potentials by surface spline interpolation. Electroencephalogr Clin Neurophysiol 66:75–81.

Poch C, Garrido MI, Igoa JM, et al (2015) Time-varying effective connectivity during visual object naming as a function of semantic demands. J Neurosci Off J Soc Neurosci 35:8768–8776. doi: 10.1523/JNEUROSCI.4888-14.2015

Protopapas A (2007) CheckVocal: a program to facilitate checking the accuracy and response time of vocal responses from DMDX. Behav Res Methods 39:859–862.

Race DS, Tsapkini K, Crinion J, et al (2013) An area essential for linking word meanings to word forms: evidence from primary progressive aphasia. Brain Lang 127:167–176. doi: 10.1016/j.bandl.2013.09.004

Sartori G, Lombardi L (2004) Semantic relevance and semantic disorders. J Cogn Neurosci 16:439–452. doi: 10.1162/089892904322926773

Schendan HE, Maher SM (2009) Object knowledge during entry-level categorization is activated and modified by implicit memory after 200 ms. NeuroImage 44:1423–1438. doi: 10.1016/j.neuroimage.2008.09.061

Schmitt BM, Münte TF, Kutas M (2000) Electrophysiological estimates of the time course of semantic and phonological encoding during implicit picture naming. Psychophysiology 37:473–484

Silveri MC, Colosimo C (1995) Hypothesis on the nature of comprehension deficit in a patient with transcortical mixed aphasia with preserved naming. Brain Lang 49:1–26. doi: 10.1006/brln.1995.1019

Strijkers K, Costa A (2016) On words and brains: linking psycholinguistics with neural dynamics in speech production. Language, Cognition and Neuroscience. doi:10.1080/23273798.2016.1158845

Strijkers K, Costa A, Thierry G (2010) Tracking lexical access in speech production: electrophysiological correlates of word frequency and cognate effects. Cereb Cortex N Y N 1991 20:912–928. doi: 10.1093/cercor/bhp153

Thorpe S, Fize D, Marlot C (1996) Speed of processing in the human visual system. Nature 381:520–522. doi: 10.1038/381520a0

Thorpe SJ (2009) The speed of categorization in the human visual system. Neuron 62:168–170. doi: 10.1016/j.neuron.2009.04.012

Trebuchon-Da Fonseca A, Guedj E, Alario F-X, et al (2009) Brain regions underlying word finding difficulties in temporal lobe epilepsy. Brain J Neurol 132:2772–2784. doi: 10.1093/brain/awp083

Valente A, Bürki A, Laganaro M (2014) ERP correlates of word production predictors in picture naming: a trial by trial multiple regression analysis from stimulus onset to response. Front Neurosci 8:390. doi: 10.3389/fnins.2014.00390

Warrington EK, Shallice T (1984) Category specific semantic impairments. Brain J Neurol 107 ( Pt 3):829–854.

Wheeldon L & Levelt WJM (1995) Monitoring the time course of phonological encoding. Journal of Memory and Language, 34, 311–334.

Wu C-T, Crouzet SM, Thorpe SJ, Fabre-Thorpe M (2015) At 120 msec you can spot the animal but you don’t yet know it’s a dog. J Cogn Neurosci 27:141–149. doi: 10.1162/jocn_a_00701

Yaniv I, Meyer DE (1987) Activation and metacognition of inaccessible stored information: potential bases for incubation effects in problem solving. J Exp Psychol Learn Mem Cogn 13:187–205.

Zhang Q, Damian MF (2009) The time course of semantic and orthographic encoding in Chinese word production: an event-related potential study. Brain Res 1273:92–105. doi: 10.1016/j.brainres.2009.03.049

## Figure captions

Figure 1. (A) Results of stimulus-locked and response-locked waveform comparisons between tasks (PN vs ND). Values are masked by results of cluster-based non-parametric analysis (only significant values are plotted). Yellow to red points represent significant p values at p<.05 and p<.01. (B). Results of the statistical analysis TANOVA (topographic ANOVA; 1-p values). (C) Examples of group-averaged stimulus-locked and response-locked ERP waveforms (AFz and POz) for PN and ND.

Figure 2. (A) Results of stimulus-locked waveform comparisons between *living* and *non-living* items in the PN and ND tasks. Values are masked by results of cluster-based non-parametric analysis (only significant values are plotted). Location of electrode sites yielding significant difference are presented with examples of group-averaged stimulus-locked ERP waveforms (Cz) for living and non-living items in each task. (B). Results of stimulus-locked waveform comparisons between *early-* and *late-acquired words* in the PN and ND tasks. Values are masked by results of cluster-based non-parametric analysis (only significant values are plotted). Location of electrode sites yielding significant difference and examples of group-averaged stimulus-locked ERP waveforms (Cz) for early- and late-acquired words in each task are provided. In both (A) and (B), yellow to red points represent significant p values at p<.05 and p<.01).

Figure 3. Results of the spatio-temporal analysis displayed under the group-averaged ERPs for each task. The distribution and duration of each period of topographic stability is indicated with different color bars and numbers and the corresponding topographies are displayed on bottom (positive values in red, negative values in blue). The significant predictors and their effect at the level of single trials are summarized under each period of stable electrophysiological activity.