

DEVELOPING AND VALIDATING A CANADIAN FRENCH N400 EVENT-RELATED POTENTIAL PARADIGM

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ABSTRACT

A typical N400 event-related potential (ERP) component occurs when the brain detects a semantic contradiction and can be elicited by the canonical experiment where the final word of a sentence contradicts what a listener is expecting to hear. In the absence of an N400 elicitation paradigm in Canadian French, our study sought to develop and validate a Canadian French N400 ERP component elicitation paradigm. To achieve this, we proceeded in two phases. In Phase 1, we created and normed 100 French sentences and obtained the cloze probability and semantic plausibility rating for each sentence through two surveys. In Phase 2, we selected the 80 best sentences. These sentences, having been validated to elicit the N400, constitute the N400 elicitation paradigm. Having a valid N400 elicitation protocol in Canadian French opens new avenues for both research and practice and allows for comparative studies across different populations.

Keywords: N400 ERP component, Cloze probability, Semantic plausibility rating, Canadian French N400 elicitation paradigm, Canadian French

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1. INTRODUCTION

Over the past 30 years, event-related potentials (ERPs) have gained popularity as an innovative method providing a window into the ‘brain’s “view” of cognitive processing by being a direct measure of neocortical activity that tracks brain states continuously and instantaneously’ [2]. ERPs have been meaningfully associated with cognitive processes such as attention [5,6], memory [7], semantic judgment [1,4].

Among the different components elicited by ERPs, the N400 component, a marker of cognitive/language processing, is generated when the brain detects a contradiction or semantic incongruence in a sentence. It can be elicited by the experiment where the end word of a sentence contradicts what a listener is expecting to hear [2,3], as in the example, ‘he takes his coffee with cream and socks’.

N400 responses can only be properly assessed if the sentences, the words and the concepts, are presented in a language that an individual is fluent in. At the moment, normed and validated sentences of this nature are not available in Canadian French, which severely limits the use of this paradigm with French- speakers from the province Québec and elsewhere in Canada. While English sets of sentences exist, these cannot be directly translated into French, rather, sentences must be created and validated to match the characteristics of Canadian French. Such a protocol can be combined with EEG recording capabilities to offer a novel assessment that could provide crucial information by measuring a component of cognitive/language receptive and processing abilities in dominant-French Canadian speakers.

2. AIM OF THE STUDY

The aim of this study was to develop and validate a Canadian French N400 ERP component elicitation paradigm. To achieve this, we proceeded in two phases. In Phase 1, we created and normed 100 French sentences and sought to obtain the cloze probability and semantic plausibility ratings for each sentence through two surveys. In Phase 2, we selected the 80 best sentences that were anticipated to elicit the N400. These sentences were included in the elicitation paradigm seeking to elicit the N400 ERP component in Canadian French-speaking individuals.

3. PHASE 1: STIMULI CREATION AND NORMING

3.1. Methods

3.1.1. Sentence Creation

Before beginning sentence creation, we selected a list of consonant-initial monomorphemic singular nouns that were matched on the following psycholinguistic lexical variables: frequency, length (number of phonemes and syllables), imageability, phonological neighbours, and uniqueness point (Omnilex database). In this way, we ensured that all sentences ended in final-words, i.e. the words that would be expected to elicit a N400 response, that are comparable to one another.

Using these words, we created 100 sentences: 50 with congruent and 50 with incongruent word endings. While the goal was to keep 80 final sentences that would be tested in Phase 2, we initially started with 100 sentences so that we would have the possibility of keeping those sentences that yielded the best results in terms of cloze probability and semantic plausibility. Congruent sentences were meant to lead the listener to correctly predict the final word and be logical (e.g. Paul aime le pepperoni sur sa pizza. “Paul likes pepperoni on his pizza”). Incongruent sentences were meant to surprise the listener who would be predicting the final word based on the sentence context, yet when reaching the end of the sentence, would be faced with an illogical and unrelated word, (e.g. Elle est allée à la boulangerie pour acheter une miche de veste. “She went to the bakery to buy a loaf of vest”).

3.1.2. Sentence Norming

To establish acceptability norms for the 100 newly created sentences we created two surveys. In the semantic plausibility survey, participants were asked to rate whether each of the 100 sentences made sense using a 1-5 Likert rating scale (1 corresponding to La phrase est tout à fait logique, “The sentence makes perfect sense.” and 5 corresponding to La phrase est complètement illogique, “The sentence makes no sense at all”). The sentence completion survey determined the cloze probability of the same 100 sentences. In this survey, the last word from each sentence was omitted and participants were instructed to write down the first word that came to mind that would complete the sentence in a way that made sense. Before the survey, each participant completed a language assessment questionnaire to confirm French language dominance (Questionnaire des antécédents langagiers- version courte) [8].

3.1.3. Participants

Participants were 183 adults who ranged in age between 18 and 87 years (mean: 34.4, SD: 19). All were dominant speakers of Canadian French and were recruited from the Montréal, Québec area. 91 participants completed the Semantic Plausibility survey and 92 completed the Sentence Completion survey. Participants were recruited in person and, following their verbal consent, each completed only one survey. All had completed secondary school and 29% had an undergraduate or a graduate degree, 53% were completing an undergraduate degree.

Participant recruitment was carried out at undergraduate and graduate classes at Université de Montréal, at CISSS de Laval - Jewish Rehabilitation Hospital, and in the community in the Montréal area. Data collection was spread across these various locations to promote representation of people from diverse educational backgrounds and from a wide age range. Participation was voluntary, with no compensation. The study was approved by the research ethics board of the Centre for Interdisciplinary Research in Rehabilitation of Greater Montreal (CRIR).

3.2. Analytic Design

All 100 sentences were tested in both surveys thus allowing us to calculate a semantic probability score and a cloze probability for each.

3.2.1. Semantic Plausibility Survey

To determine the semantic plausibility of each sentence, we tallied the participants' ratings for each sentence. For a congruent sentence to be eligible for Phase 2 it had to meet the following criteria: 1) 80% or more of the participants gave it a semantic plausibility rating of either 1 or 2 and 2) the average rating was under 2. Conversely, for an incongruent sentence to be eligible it had to meet the following criteria: 80% or more of participants selected a semantic plausibility rating of 4 or 5 and the average rating was over 4.

3.2.2. Sentence Completion Survey

To determine the cloze probability of each sentence, we tallied the participants' word responses for each sentence. For a congruent sentence to be eligible for Phase 2, it had to meet the following criterion: the cloze probability for the target word was equal to or exceeded 80%. Conversely, for an incongruent sentence to be eligible it had to meet the following criteria: 1) the cloze probability of the target word was 0% and 2) participants entered another word (or synonym) that reached a cloze probability of 80% or above.

3.3. Results

Of the total 100 sentences comprising the initial set, 80 met the criteria to be included in Phase 2. Selection of the 80 best sentences to generate an N400 event-related potential in Phase 2 was based on their scores according to the criteria mentioned in 3.2.1 and 3.2.2. (The final list of stimuli is available here. -Add link here-).

4. PHASE 2: N400 EVENT-RELATED POTENTIAL VALIDATION

4.1. Methods

4.1.1. Creation of the Auditory Stimulation Paradigm

Each of the 80 sentences selected in Phase 1 was spoken aloud by a native Canadian French speaker, and audio-recorded in mono mode using version 2.1.0 of Audacity(R) recording and editing software. The resultant auditory files were noise-removed, converted to stereo channel, and normalized against each other for intensity. The onset of the first, second, penultimate and terminal words of each sentence was recorded at millisecond precision using version 6.0.14 of Praat speech analysis

software. Each auditory file and its associated markers were imported into the Presentation 2018 experiment control software to generate a stimulation paradigm of randomized sentences. The inter-stimulus interval was set at 3 seconds. Word onset files were used to generate markers that were subsequently synchronized with neurophysiological recordings.

4.1.2. Participants

Participants were 27 dominant French-speaking individuals with normal hearing who ranged in age between 18 and 85 years. A new set of participants were selected for Phase 2. Participants were excluded if they had any developmental, acquired or degenerative neurological deficits, including epilepsy, traumatic brain injury and Alzheimer's disease. Language dominance was established using the Questionnaire des antécédents langagiers- version courte [8].

4.1.3. Electroencephalographic Recording and Pre-processing

High-density electroencephalography (hdEEG) was recorded from each participant using a 128-channel system from Electrical Geodesics Incorporated, while the auditory stimulation paradigm was presented through stereo speakers located on either side of the participant. EEG data were recorded at a frequency of 500 Hz. and referenced to the vertex. Participants were instructed to minimize movement and listen to each sentence with their eyes open. After each sentence, participants were asked to press a YES or NO button to indicate if the sentence was semantically logical or illogical. EEG corresponding to sentences with an incorrect behavioural response were removed from subsequent analyses.

After the experiment, EEG signals were bandpass filtered between 0.1 and 50 Hz and re-referenced to an average reference. An investigator experienced in reading electroencephalograms visually inspected the data to reject epochs and channels with noise or non-physiological artifacts. An independent component analysis (ICA) was conducted to identify and remove artifacts related to eye blinks and eye movements.

4.1.4. Event-related Potential Analysis

Event-related potential analysis was conducted in Brain Vision Analyzer 2 using the pre-processed EEG from each participant. EEG was segmented 200 ms prior to and 800 ms following the onset of the final word of each sentence, baseline corrected, and divided into two groups

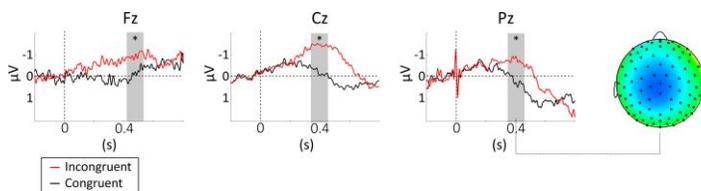
corresponding to congruent and incongruent sentences. Segments that contained significant noise were excluded from subsequent analyses. EEG were then averaged across each electrode to generate subject-averaged waveforms for congruent and incongruent sentences. For each participant average, mean amplitude was calculated around the peak using a window of 24 data points (12 points on each side). Mean amplitude was calculated for both the congruent and incongruent averages of each participant. Difference waves were generated on 9 electrode sites (F3, Fz, F4, C3, Cz, C4, P3, Pz, P4) and differences between the mean amplitudes of each condition were compared using a repeated measures analysis of variance (ANOVA) with condition as a factor.

4.2. Results

Grand-average waveforms for congruent and incongruent sentences are presented in Figure 1. The differences in the waveforms revealed a significant N400 in parietal areas generated by the incongruent sentences.

A local negative peak was detected for each channel of the incongruent stimulus grand average (via Brain Vision Analyzer 2's Peak Detection transformation across a window of 300-500ms post-stimuli).

Figure 1: Grand average waveforms for congruent and incongruent sentences.



5. DISCUSSION

The Canadian French N400 ERP elicitation paradigm developed in this study can be used to successfully elicit the N400 in dominant French-speaking Canadian healthy adults. The paradigm complements similar ones existing in other languages and its use can extend to a variety of settings and contexts involving French-speaking Canadian individuals. This paradigm will also allow for the inclusion of French-speaking individuals in studies currently conducted in English that use N400 elicitation to assess responsiveness in individuals who, following stroke or other traumatic brain injury, are exhibiting

minimal states of consciousness or disorders of consciousness.

If an N400 is elicited in a behaviourally unresponsive individual, this can be used as a marker of both their level of awareness and their ability to process language. Emerging evidence demonstrates that over 40% of behaviourally unresponsive individuals are misdiagnosed (i.e. considered unconscious when they in fact possess some ability to respond to commands). Having a valid N400 elicitation protocol in Canadian French opens new avenues for both research and practice and allows for comparative studies across different populations.

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