The nature of the verbal self-monitor

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Chapter 3

Effects of time pressure on verbal self-monitoring in German-Dutch bilinguals[7]

Abstract

This study addressed how verbal self-monitoring and the Error-Related Negativity (ERN) are affected by time pressure when a task is preformed in a second language as opposed to performance in the native language. German-Dutch bilinguals were required to perform a phoneme monitoring task in Dutch with and without a time pressure manipulation. We obtained an ERN following verbal errors which showed an atypical increase in amplitude under time pressure. This may suggest that under time pressure participants had more interference from their native language, which in turn led to a greater response conflict and thus enhancement of the amplitude of the ERN. This result demonstrates once more that the ERN is sensitive to psycholinguistic manipulations and suggests that the functioning of the verbal self-monitoring system during speaking is comparable to other performance monitoring, such as action monitoring.

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[7] This chapter is based on Ganushchak, L. Y. & Schiller, N. O. (submitted). Effects of time pressure on verbal self-monitoring in German-Dutch bilinguals.

Introduction

Everyday life cannot be imagined to take place in the absence of errors. Errors are often the basis for new strategies, learning, and adaptation. Therefore, a major part of human performance monitoring research is dedicated to error processing. The neural basis of error monitoring has become a key issue in cognitive neuroscience. An interesting component of the Event-Related Potential (ERP) for exploring the functional characteristics of the error monitoring system is the *Error-Related Negativity* (ERN; Falkenstein, Hohnsbein, Hoorman, & Blanke, 1991; Gehring, Goss, Coles, Meyer, & Donchin, 1993). The ERN has a fronto-central scalp distribution and peaks about 80 ms after an overt incorrect response (Bernstein, Scheffers, & Coles, 1995; Holroyd & Yeung, 2003; Scheffers, Coles, Bernstein, Gehring, & Donchin, 1996). Originally, the ERN was thought to arise as a result of conscious *error detection* (Bernstein et al., 1995). This hypothesis assumes a comparison between the internal representation of the intended correct response, arising from ongoing stimulus processing, and the internal representation of the actual response, resulting from the efferent copy of the motor activity. If there is a mismatch between these two representations, then an ERN will be generated (Bernstein et al., 1995; Falkenstein, Hoormann, Christ, & Hohnsbein, 2000; Holroyd & Coles, 2002).

This view has been challenged by the *conflict hypothesis*, which states that the ERN reflects detection of response conflict and not detection of errors *per se* (Botvinick et al., 2001). Response conflict arises when multiple responses compete for selection. Presence of conflicting responses reflects situations where errors are likely to occur. Thus, according to the conflict hypothesis, error detection is not an independent process but based on the presence of response conflict.

Alternatively, the *reinforcement-learning theory* proposed that the ERN may reflect a negative reward-prediction error signal that is elicited when the monitor detects that the consequences of an action are worse than expected. This reward-prediction error signal is coded by the mesencephalic dopamine system and projected to the anterior cingulated cortex (ACC), where the ERN is elicited (Holroyd & Coles, 2002).

A large set of studies on the ERN investigated the functioning of action monitoring. According to the action monitoring model, the action monitor is a feed-forward control mechanism that is used to inhibit and correct a faulty response (Desmurget & Grafton, 2000; Rodríguez-Fornells, Kurzbuch, & Münte, 2002). When the wrong selection of the motor command is generated, a copy of an on-line response is produced and compared to the representation of the correct response. If there is a mismatch between the copy of the on-line response and the representation of the correct response, an error signal is generated and a stop command is initiated (Coles, Scheffers, & Holroyd, 2001).

If the ERN is associated with error processing in action monitoring, can it also be applied to error processing in *verbal monitoring*? Verbal self-monitoring is a crucial part of speech production, especially when one considers that producing speech errors hampers the fluency of speech and can sometimes lead to embarrassment, for instance when taboo words are uttered unintentionally (Motley, Camden, & Baars, 1982). One prominent theory of verbal self-monitoring is the *perceptual-loop theory* proposed by Levelt (1983, 1989). According to this theory, a speech monitoring system checks the intended message for its appropriateness, inspects the speech plan and detects errors prior to its articulation (Postma & Noordanus, 1996; Schiller, 2005, 2006; Schiller, Jansma, Peters, & Levelt, 2006; Wheeldon & Levelt, 1995; Wheeldon & Morgan, 2002), as well as after the speech has become overt (Postma, 2000). Verbal monitoring is achieved via the speech comprehension system.

Previous studies showed that an ERN can also be elicited by verbal errors (e.g., Ganushchak & Schiller, 2006, in press; Masaki, Tanaka, Takasawa, & Yamazaki, 2001; Möller, Jansma, Rodríguez-Fornells, & Münte, 2007; Sebastián-Gallés, Rodríguez-Fornells, Diego-Balaguer, & Díaz, 2006). In the present study, we investigated the relationship between the ERN and verbal-monitoring in a non-native language. Nowadays, bilingualism is the rule rather than an exception (Costa & Santesteban, 2006), certainly in large parts of Europe with its multilingual societies. However, very little is known about monitoring of one's speech in a second language. Increased knowledge about the error monitoring system in monolingual and bilingual speech production may improve our understanding of some disorders where verbal-monitoring is implicated, such as aphasia (for an overview see Oomen, Postma, & Kolk, 2001), stuttering (e.g., Lickley, Hartsuiker, Corley, Russell, & Nelson, 2005), and schizophrenia (for overview see Seal, Aleman, & McGuire, 2004).

The present work is a follow-up of a study by Ganushchak and Schiller (2006). These authors addressed the questions whether or not an ERN occurs after verbal error detection and whether a potential ERN is affected by a time pressure manipulation. They employed a phoneme monitoring go/nogo task, previously used in language production and verbal monitoring research (e.g., Schiller, 2005; Wheeldon & Levelt, 1995; Wheeldon & Morgan, 2002). In the particular task employed by Ganushchak and Schiller, participants were required to internally name pictures and press a button if a particular target phoneme was present in the name of the picture. For example, if the target phoneme was /b/ and the target picture was *bear*, then participants were required to press a corresponding button. Thus, participants were asked to monitor their own internal speech production. Ganushchak and Schiller (2006) successfully obtained an ERN following verbal errors and showed a typical decrease in amplitude under conditions of time pressure. The authors suggested that the functioning of the verbal monitor is comparable to other performance monitoring, such as action monitoring.

In the present study, we used the identical set up of the experiment described in Ganushchak and Schiller (2006). However, participants in the current study were German-Dutch bilinguals and were asked to perform a phoneme monitoring task in their second language, i.e. Dutch. The main question addressed in the current study was: How is the ERN affected by time pressure when a verbal monitoring task is performed in a second language? The monitoring task might be more difficult when performed in a second language, as compared to performing the same task in a native language. This difficulty might arise from co-activation of both native and second languages thereby leading to a higher conflict between potential responses. However, there is increasing evidence that native and foreign languages are based on the same neural substrate (e.g., Klein et al., 1995, 1999; Perani et al., 1998). Moreover, in the existing literature, there is no evidence suggesting that the ERN would be affected differently in a second language. Therefore, it is plausible to assume that verbal monitoring would work in a similar way in bilingual context as compared to monolingual context. Thus, similar to the Ganushchak and Schiller (2006) study we expected to find more erroneous responses and a smaller ERN under time pressure than in the absence of time pressure.

Methods

Participants

Twenty-one students of Maastricht University (20 females; mean age: 23.6 years) participated in the experiment. All participants were right-handed, German-Dutch bilinguals and came from the same population as the bilingual speakers described in Christoffels, Firk, and Schiller (2007). Participants received course credits or a financial reward for their participation in the experiment and gave written informed consent prior to participating in the study. All participants were native German speakers and completed an intensive Dutch language course prior to starting their undergraduate study in the Netherlands. They studied in the Netherlands for at least 2 years (mean: 2.8) and usually lived in the Netherlands. Most classes at the undergraduate level are given in Dutch, teaching materials are in Dutch or English. In their daily lives, the participants typically speak Dutch at university.

Their level of proficiency was assessed with a self-rating questionnaire and a vocabulary test based on lexical decision. Both tests were completed after the experiment. Participants rated their language proficiency in two domains (active and passive knowledge) on a 10 point scale (1 = very low, 10 = native level). The mean score for active and passive knowledge of Dutch was 8.4. The vocabulary test was a Dutch version of an English non-speeded lexical decision task that was originally developed by Meara (1996). It consisted of 60 items, i.e. 40 low-frequency words and 20 non-words. Participants had to decide whether or not a presented letter string formed a correct Dutch word. Two ways of scoring were employed: the mean percentage of correctly recognized words and correctly rejected non-words and Meara's M (Δ M; see Christoffels et al., 2007). Δ M lies between 0 and 1 and represents the proportion of words within the given frequency range that is known by a participant. The results are summarized in Table 1.

Materials

Eighty-one simple line drawings were used as pictures in this experiment (61 for experimental blocks and 20 for a practice block; see Appendix for the list of stimuli used in the experimental blocks). The labels of all pictures were monosyllabic Dutch words (e.g., *heks* 'witch', *brood* 'bread', etc.). Per target phoneme, labels were matched on word length and frequency (see Table 2), i.e. all picture names had a moderate frequency of occurrence between 10 and 100 per million according to the CELEX database (CEnter for LEXical information, Nijmegen; Baayen, Piepenbrock, & Gulikers, 1995). Picture labels all started with consonants. The position of the target phoneme was equated across the stimuli.

Table 1. Vocabulary test.

	Mean	SD
% correctly recognized words	55.42	15.37
% correctly rejected words	85.89	10.56
Mean of correct words and non-words	67.56	9.45
Δ M	0.29	0.12

Design

The experiment included two experimental conditions: a control condition (CC) and a time pressure (TP) condition. In addition to the experimental conditions, a learning phase, two practice blocks, and two picture naming tasks were administered. The duration of the stimulus presentation during the control and time pressure conditions was computed separately for each participant. The duration of the stimulus presentation in the control condition was 85% of the reaction time (RT) obtained from the practice block (e.g., if the mean RT during the practice block was 1,000 ms, then the duration of the stimuli in the CC was 850 ms). The mean RT of the CC was used to compute the stimulus duration for the TP condition. The RTs of the CC and not of the initial practice block were used for computation of the TP condition because the average RTs of the CC were based on more trials than RTs from the practice block. Participants were also more familiar with the task during the CC than during the practice block. Stimulus presentation in the TP condition was 75% of the RT of the CC (e.g., if stimulus presentation was 850 ms in the CC, then the duration of the stimulus in the TP condition was 638 ms). The percentages for computing the deadlines in this study were identical to the ones used in the previous study by Ganushchak and Schiller (2006). This was done in order to increase comparability between findings of these two studies. Prior to the experimental blocks, in the CC and TP condition participants were required to repeat a practice block in order to adapt to the new timing. The time between the onset of the picture presentation and the next trial was taken as response time.

CC and TP condition each consisted of eight experimental blocks and one practice block.

In each block, participants were asked to monitor for a different target phoneme. The target phonemes were /t/, /k/, /p/, /n/, /m/, /l/, /s/, and /r/; the phoneme /b/ was used in the practice trials. In all blocks, pictures were presented one by one on a computer screen. Experimental blocks consisted of a total of 300 trials (mean 37.5 trials per block; with the exception of the practice block, which consisted of 20 trials). None of the pictures used for the practice block appeared as a target picture in the experimental conditions. Trials (i.e. order of pictures) were randomized across all blocks and for each participant. Each picture was repeated four times: twice as a target (go trials) and twice as a non-target (nogo trials). Each time, participants were asked to monitor for a different phoneme. For instance, for the picture name *ster* ('star') participants were asked to monitor once for phoneme /t/ and once for the phoneme /s/ when *ster* was a target. When *ster* was a non-target, participants were asked to monitor for /l/ and /n/.

Table 2. Lexico-statistical characteristics of the target words.

Target phoneme	Example (English translation)	Mean CELEX frequency (per one million words)	Mean length in segments
t	troon ('throne')	23.2	4.5
k	kraan ('faucet')	28.4	4.2
p	paard ('horse')	33.1	4.1
n	naald ('needle')	30.6	4.2
m	maan ('moon')	33.3	4.0
l	lamp ('lamp')	33.5	4.6
s	schoen ('shoe')	31.9	4.5
r	riem ('belt')	29.9	4.3

During the learning phase, the names of the pictures were presented via head phones. The picture remained in view for 3,000 ms or until the response button was pressed. In the picture naming tasks, the pictures were presented without their corresponding names and disappeared from the screen as soon as the voice key was activated or after the response deadline was reached, which was identical to the time set for the control and the time pressure conditions.

Procedure

Participants were tested individually while seated in a sound-proof booth. They were asked to carry out a learning phase, a practice block, a picture naming task, and then the CC; this was followed by a second practice block, a second picture naming task, and the TP condition. During the learning phase, participants were familiarized with the pictures and their corresponding names. In the picture naming task, participants were asked to overtly name pictures with the labels they learned during the learning phase. The timing of the second practice block and second picture naming task was identical to the one used in the phoneme-monitoring task in the TP condition. The purpose of the second picture naming task was to assure that participants had enough time to access and retrieve the name of the picture in the given time window.

Prior to practice and experimental blocks, participants received an auditory sample of the phoneme they were required to monitor (e.g., *Reageer nu op de klank /l/ zoals in tafel, spelen, verhaal* 'React now to the sound /l/ like in table, play, tale'). Participants had to press a button if a target phoneme was present in the picture name (i.e. go trials). When there was no target phoneme in the name of the picture, participants were required to withhold a response (i.e. nogo trials). Participants were instructed to give all responses for go trials with their right hand. Button-press latencies were recorded from the onset of the picture. At the end of the experimental session, participants were asked to fill out a questionnaire to asses their proficiency level. Participants were asked to perform the task in Dutch. Dutch was used in the instructions and in the conversations between experimenter and participants.

Apparatus and Recordings

The electroencephalogram (EEG) was recorded from 29 scalp sites (extended version of the 10/20 system) using tin electrodes mounted to an electrode cap. The EEG signal was sampled at 250 Hz with band-pass filter from 0.05 to 30 Hz. An electrode at the left mastoid was used for on-line referencing of the scalp electrodes. Off-line analysis included re-referencing of the scalp electrodes to the average activity of two electrodes placed on the left and right mastoids. Eye movements were recorded to allow off-line rejection of contaminated trials. Lateral eye movements were measured using a bipolar montage of two electrodes placed on the right and left external canthus. Eye blinks and vertical eye movements were measured using a bipolar montage of two electrodes placed above and below the left eye. Impedance level for all electrodes was kept below 5 kΩ.

Data analysis

Epochs of 1,300 ms (from –400 ms to +900 ms) were obtained including a 200 ms pre-response baseline. The EEG signal was corrected for vertical electrooculogram (EOG) artifacts, using the ocular reduction method described in Anderer, Satety, Kinsperger, and Semlitsch (1987). For the ERN, averaging was done across false alarms. False alarm trials were compared with correct go trials. The amplitude of the ERN was derived from each individual's response-locked average waveforms after filtering with a band pass, zero phase shift filter (frequency range: 1-12 Hz). The ERN was quantified by peak-to-peak measurements that were calculated to determine baseline-independent amplitudes of negative deflections by subtracting the amplitude of the preceding positive peak from the negative peak of this component (Falkenstein et al., 2000). Thus, the amplitude of the ERN was defined as the difference between the most negative peak in a window from 0 to 150 ms following the response and the most positive peak from –50 to 0 ms preceding the ERN (Falkenstein et al., 2000). The amplitude of the ERN was recorded for each condition at Fz, FCz, and Cz electrode sites.

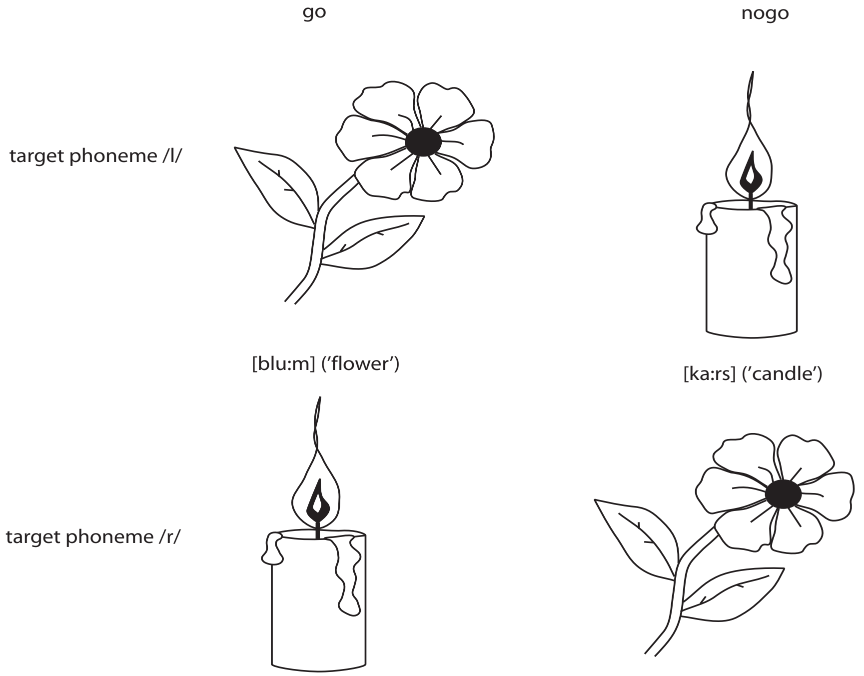

Figure 1. Example of go and nogo trials for two target phonemes. In the figure, Dutch picture names are written in phonetic code (taken from the CELEX database) and English translations are provided in brackets. Each picture depicted here represents a separate trial. Each picture appeared in the task as a go and a nogo trial. At the beginning of a block, participants were instructed for which phoneme they had to monitor.

Results

Behavioral data

RTs shorter than 300 ms and longer than 1,500 ms were excluded from the analysis, which resulted in a loss of 0.7% of all trials. An ANOVA with Time Pressure as independent variable and button-press latencies as dependent variable revealed a significant effect of Time Pressure ($F(1, 38) = 348.63$, $MS_e = 1008.12$, $p < .001$). Participants were significantly faster during the TP condition (671 ms, SD = 21) than the CC (865 ms, SD = 23). A similar analysis with number of errors as dependent variable also demonstrated a significant effect of Time Pressure ($F(1, 38) = 22.80$, $MS_e = 58.46$, $p < .001$). Participants made on average 8.75% errors (8.0% false alarms) in the TP condition and 6.9% (5.5% false alarms) errors in the CC.

The picture naming task was used to asses whether participants had enough time to retrieve the name of the picture from their lexicon during the TP condition. To investigate this, a repeated measures ANOVA was run for the picture naming task with Time Pressure as independent variable. Number of errors during the picture naming task significantly decreased in TP condition when compared to the CC ($F(1, 38) = 84.42$, $MS_e = 5.09$, $p < .001$). Hence, we argue that in the TP condition there was enough time available for participants to successfully retrieve the name of the pictures from their lexicon.

Electrophysiological data

The ERN was revealed in response-locked ERP averages for false alarms. There was no negative deflection observed in the ERP waveforms for correct trials during visual inspection of the EEG waves. Figure 2A provides an overview of the response-locked averaged ERP waveforms for correct and incorrect trials across conditions (CC and TP) and electrodes (Fz, FCz, and Cz). The ERN obtained in the present study showed a frontal distribution (see Figure 2B for a topographical representation of the ERN across CC and TP conditions).

An ANOVA with Time Pressure as independent variable and amplitude of the ERN as dependent variable revealed a significant effect of Time Pressure ($F(1, 38) = 4.68$, $MS_e = 46.19$, $p < .05$). Interestingly, German-Dutch bilinguals showed enhanced amplitude of the ERN in the TP condition compared to the CC. To investigate whether or not Time Pressure elicited higher ERP amplitudes in general rather than specifically on the ERN, we ran a 2 (correct vs. error) by 2 (CC vs. TP) ANOVA. More specifically, we used a mean area analysis for investigating effects of Time Pressure on correct and erroneous trials, as it was impossible to identify peaks for correct trials on a trial-by-trial basis. The time window of interest was 0 – 100 ms after the overt response. The analysis showed a significant interaction between Correctness of Response and Time Pressure ($F(1, 20) = 5.58$, $MS_e = 9.20$, $p < .05$). Time Pressure had an effect only for erroneous trials and not for correct trials ($F(1, 20) = 6.96$, $MS_e = 7.87$, $p < .05$ and $F < 1$, respectively). These results are striking and unexpected. Therefore, we looked at how participants behaved at a single subject level. We found that 73% of the participants (16 out of 21) showed an enhanced ERN under time pressure compared to the absence of time pressure, while 27% of the participants (5 out of 21) showed lower amplitudes of the ERN under time pressure compared to the control condition.

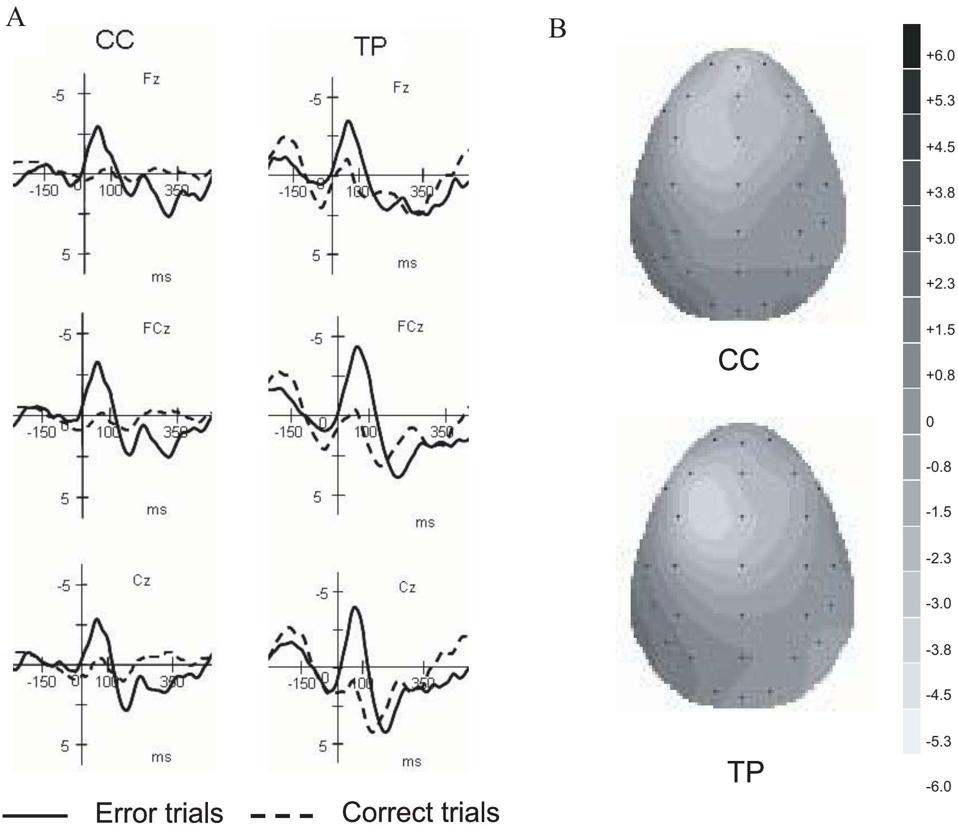

Figure 2. A: Averaged ERP waveforms for all incorrect versus correct trials across conditions and electrodes (CC – control condition, TP – time pressure condition). Correct and incorrect trials were matched on RTs and number of trials.
B: Topographic maps of the ERN amplitude between 0 and 100 ms after response onset. Negative regions depicted in light gray.

In the CC, there appeared to be a second negative peak at around 200 ms after the response, which was smaller in the TP condition. To test whether or not there was a significant difference between conditions we used a mean area analysis in the time window of 140 – 270 ms. A 2 (correct vs. error) by 2 (CC vs. TP) ANOVA revealed no significant effects of Time Pressure and Correctness of Response ($F(1, 20) = 4.07$, $MS_e = 34.62$, n.s. and $F < 1$, respectively) nor an interaction between these two factors ($F < 1$).

Discussion

The goal of the present study was to investigate how the ERN is affected by time pressure when a verbal self-monitoring task is performed in a second language as opposed to performance in the native language. We demonstrated that participants made more errors under time pressure. This is in accordance with previous findings (e.g., Ganushchak & Schiller, 2006; Oomen & Postma, 2001). Contrary to previously reported findings, however, we observed an increase in the amplitude of the ERN under time pressure as compared to a control condition. In the action monitoring as well as verbal monitoring literature, it has been shown that the ERN decreases under time pressure (Falkenstein et al., 1991; Ganushchak & Schiller, 2006; Gehring et al., 1993). Presumably, a monitoring system compares the representation of the correct response with the copy of an on-line response. If there is a mismatch between actual and intended motor or verbal response, an error signal is generated (e.g., Desmurget & Grafton, 2000; Levelt, 1983). Under time pressure, there might not be enough time available to make an optimal comparison between intended and actual responses. As a result, a weaker signal is sent to the remedial action system thereby decreasing the amplitude of the ERN. In terms of the reinforcement-learning theory, errors induce a phasic decrease in mesencephalic dopaminergic activity when ongoing events are determined to be worse than expected (Holroyd & Coles, 2002). However, under time pressure, due to the lack of time or cognitive resources, the monitoring system might not be able to make an optimal evaluation of current events and events that were predicted. Therefore, a weaker ERN is generated.

Why did we observe an increase in the amplitude of the ERN under time pressure in a bilingual context, but not in a monolingual context? Assuming that verbal self-monitoring works similarly in first and second language (Kormos, 1999; Poulisse, 2000; Van Hest, 1996) one would predict that a monitoring system can compare the representation of the correct response with the copy of an on-line response in the second language. If there is a mismatch between actual and intended verbal response, an error signal should be generated and under time pressure this signal should be weaker, thereby decreasing the amplitude of the ERN in bilinguals as well as monolinguals. However, we obtained an enhanced ERN under time pressure compared to the absence of time pressure. How can we explain this reversed effect of time pressure on the ERN in bilinguals?

We would like to propose the following possibility: Participants, in the present study, were bilingual German-Dutch students, who were requested to perform a phoneme-monitoring task in their second language, i.e. Dutch. In order to perform this task, participants presumably had to suppress their more dominant mother tongue to generate a Dutch name of the picture and determine whether or not the target phoneme was present in the name of the picture. It has long been known that switches between languages can occur unintentionally, for instance when bilingual speakers became aphasic (e.g., Fabbro, Skrap, & Aglioti, 2000), undergo brain stimulation (e.g., Holtzheimer, Fawaz, Wilson, & Avery, 2005), or under psychological stress (e.g., Dornik, 1979, 1980; Grosjean, 1982). According to Levelt (1989), monitoring involves controlled processing that requires attentional control. In a second language, a considerable lower number of cognitive processes are automatic, and thus need more attention than in the first language (Kormos, 1999). It is possible that under time pressure participants had more difficulty inhibiting their dominant native language and experienced more intrusions from it.

Rodríguez-Fornells et al. (2005) demonstrated that bilinguals cope with second language interference during language production by recruiting 'executive function' brain areas, i.e. the left prefrontal cortex, the supplementary motor area, and the left middle prefrontal cortex. These areas might be crucial in inhibiting the production of irrelevant, non-target language words (Rodríguez-Fornells et al., 2005). It is possible that under time pressure, inhibition of the non-target words was less successful than in the absence of time pressure. There is evidence from bilingual word recognition that even in a monolingual task alternative lexical candidates in the other language are accessed (for a review see Kroll & Dijkstra, 2002) and phonologically activated (Costa et al., 2000; Colomé, 2001; Rodríguez-Fornells et al., 2005; but see Hermans et al., 1998). Hence, it is possible that at the time of the response, there was not only the Dutch name of the picture active but also the German name. During execution of the monitoring task in a native language (Ganushchak & Schiller, 2006), it is unlikely that there were intrusions from a less dominant second language, which means that the monitor did not need to deal with resolving a competition between multiple responses. In contrast, performing the task in a second language could have required a resolution of response competition between an inappropriate response (e.g., a phoneme from a German word) and a correct response (e.g., a phoneme from a Dutch word). Activation of both German and Dutch names could have resulted in more response conflict and thus higher amplitudes of the ERN (e.g., Botvinick et al., 2001; Yeung et al., 2004). The possible generator of the ERN is the anterior cingulated cortex (ACC; Dehaene et al., 1994). In a previous literature, the ACC and the inferior frontal cortex are implicated in error processing (e.g., Menon et al., 2001). The ACC is thought to monitor competition between processes that conflict during task performance (Carter et al., 1998).

Suggestively, the increased amplitude of the ERN under time pressure in bilingual context might be dependent on the proficiency of second-language speakers. Proficiency is a determining factor in the ease with which bilinguals control and regulate their two (or more) languages (Meuter, 2005). Participants in the present study completed a course of Dutch language and studied at a Dutch university. However, they were not balanced bilinguals. It is possible that highly proficient, balanced bilinguals will be more successful in suppressing a language not required for the task and thus have less or no interference of the native language in the second-language context. Therefore, it is plausible that the amplitude of the ERN will show a typical decrease under time pressure when highly proficient second-language speakers perform the task.

One potential problem of the current study is the order of experimental conditions, i.e.

the time pressure condition was always preceded by the control condition. It is possible that in the TP condition, participants were more experienced in the task than in the CC, and therefore the findings of the experiment could be attributed to a practice effect. However, if practice played a significant role here, then one would expect that participants performed the task more accurately and made fewer errors in the TP condition that the CC. The findings of the current study demonstrate the opposite, i.e. participants made more errors under time pressure than in the absence of time pressure. Thus, we believe that in the present study practice did not have a large influence on performance.

The main manipulation employed in the present study was time pressure. In speeded tasks, there is obviously the possibility of a speed-accuracy trade-off (SAT). One way in which people control their actions occurs when speed or accuracy are more important. As stated above, previous studies that investigated the ERN under time pressure demonstrated that the amplitude of the ERN decreases when participants select speed over accuracy (Falkenstein et al., 1991; Gehring et al., 1993). However, in the present study, we obtained the opposite pattern. The amplitude of the ERN was enhanced under time pressure compared to the absence of time pressure. Therefore, our results cannot be fully accounted by SAT effects.

In summary, we showed that the ERN can successfully be elicited by errors of verbal monitoring and is sensitive to the linguistic context. Performing the task in a second language led to an enhancement of the ERN under time pressure as compared to when time pressure was absent. This effect is reversed when the task is performed in a native language, i.e., the amplitude of the ERN is lower under time pressure than in the absence of time pressure. This provides further evidence that the ERN is sensitive to verbal manipulations and could be used as an electrophysiological marker of error processing in language research.

As a note of caution, we would like to mention that in the present study the required responses were button presses. We believe that the majority of errors observed in the current study are errors of the verbal monitoring system and are based on the incorrect decision about the target phoneme. We cannot completely rule out the possibility, however, that some of the errors could have been due to action slips (i.e. slips of the hand) and not slips of verbal monitoring *per se*. However, this seems unlikely since based on the previous literature, action slips did not lead to an enhancement of the ERN under time pressure (Falkenstein et al., 1991; Gehring et al., 1993). The reversal effect of time pressure on the ERN in multilingual context merits further research, for example, by manipulating the proficiency of participants in their second language.

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Appendix

The list of stimuli used in the experimental blocks. The approximate English translation is given in brackets. Each stimulus appears twice as a target, but each time with a different target phoneme (e.g., *hemd* [‘shirt’] has the target phonemes /t/ and /m/; due to final devoicing, the <d> in *hemd* is pronounced as /t/).

TARGET PHONEME /t/: hemd (shirt), pet (cap), troon (throne), trui (sweater), baard (beard), blad (leaf), net (net), stier (bull), tak (branch), ster (star), tram (tram), bord (plate), fiets (bike), stof (material), kaart (card), trein (train), paard (horse), pot (pot), band (tire), ton (barrel), kast (closet), zwaard (sword), vuist (fist)

TARGET PHONEME /k/: kom (bowl), broek (trousers), markt (market), kraan (tap), kist (chest), kip (chicken), wolk (cloud), tak (branch), heks (witch), knie (knee), jurk (dress), kaars (candle), kaart (card), rok (skirt), kroon (crown), krant (newspaper), kruis (cross), kraag (collar), vork (fork), kaas (cheese), kar (wagon), stok (stick)

TARGET PHONEME /p/: pan (pan), plant (plant), knop (button), pet (cap), kip (chicken), schaap (sheep), pen (pen), trap (stairs), plank (shelf), dorp (village), schip (ship), paard (horse), spoor (rail), pot (pot)

TARGET PHONEME /n/: pan (pan), nest (nest), troon (throne), snor (moustache), knie (knee), pen (pen), naald (needle), knop (button), mand (basket), net (net), band (tire), maan (moon), kroon (crown), krant (newspaper), neus (nose), schoen (shoe), hoorn (horn), ton (burrel), trein (train)

TARGET PHONEME /l/: lamp (lamp), film (film), bloem (flower), plant (plant), naald (needle), plank (shelf), wolk (cloud), fles (bottle), blad (leaf), slot (lock), schaal (dish)

TARGET PHONEME /m/: kom (bowl), muur (wall), riem (belt), hemd (shirt), bloem (flower), mand (basket), film (film), lamp (lamp), mes (knife), markt (market), maan (moon), tram (tram)

TARGET PHONEME /s/: mes (knife), fles (bottle), slot (lock), nest (nest), stier (bull), schaap (sheep), rots (rock), kist (chest), heks (witch), ster (star), fiets (bike), schaal (dish), stof (material), kaas (cheese), gras (grass), schip (ship), schoen (shoe), neus (nose), stok (stick), vuist (fist), kast (closet), kruis (cross)

TARGET PHONEME /r/: muur (wall), riem (belt), dorp (villege), trui (sweater), kraan (tap), broek (trousers), snor (moustache), trap (stars), rots (rock), baard (beard), bord (plate), rok (skirt), gras (grass), kaars (candle), jurk (dress), spoor (rail), hoorn (horn), kar (wagon), zwaard (sword), vork (fork), kraag (collar)