The nature of the verbal self-monitor

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Chapter 7
General Discussion

This thesis investigated the neurocognitive correlates of verbal self-monitor in healthy adults. It further focused on various factors that can interfere with normal functioning of the verbal self-monitoring system, e.g., time pressure, auditory interference, motivation of speakers, semantic context, and multilingual context. Brain activity was measured using electroencephalography (EEG). This is a non-invasive technique that allows the investigation of on-line information processing in the brain. Particularly, in this thesis the Error-Related Negativity (ERN) was of interest. The ERN is an event-related potential (ERP), which is associated with the working of a general performance monitor.

The studies in this thesis provide empirical evidence that the ERN can be observed after verbal errors and can be affected by linguistic manipulations (e.g., lexical conflict, Chapters 3 and 5). Presence of the ERN after verbal errors might suggest that the verbal monitor works in a similar way as a more general performance monitor. We have shown that the verbal self monitor is affected by time pressure. However, the effect of time pressure on verbal self-monitoring is dependent on whether a task is performed in a native language (Chapter 2) or in a second language (Chapter 3). Further, the verbal monitor is sensitive to auditory interference (Chapter 4), motivation and semantic context (Chapter 5), and bilingual context (Chapter 6). The main findings of this thesis will be discussed below.

In Chapter 2, we addressed the question whether or not an ERN occurs after verbal error detection and whether or not it is affected by time pressure. We found that participants made more errors and showed a decrease in amplitude of the ERN under severe time pressure. Why is verbal monitoring affected by time pressure? According to Levelt (1989), verbal self-monitoring is a controlled process, and therefore resource-limited. In the computational implementation of Levelt's model of speech production (WEAVER++; see Levelt, Roelofs, & Meyer, 1999; Roelofs, 1992) it is argued that speech errors may occur when WEAVER++ skips verification to gain speed in order to obtain a higher speech rate. Thus, more errors are to be expected at higher speech rates (Levelt et al., 1999). It is also possible that under time pressure the inner loop has less time to monitor the phonetic plan. Under such conditions, more errors pass undetected or corrective processes are not activated fast enough (Levelt, 1989). This is supported by our EEG data. The amplitude of the ERN decreased under time pressure. It is likely that the verbal monitor checks an abstract phonological representation by screening for mismatches between intended and actual verbal responses. Thus, the verbal outcome is compared with the original intention, and if there is a mismatch, then an error is detected. This is in accordance with the *perceptual-*

loop theory by Levelt (1983). Similarly, the action monitor compares the representation of the correct response with the copy of an on-line response. If there is a mismatch between actual and intended response, an error signal is generated (e.g., Desmurget & Grafton, 2000). Under time pressure, there might not be enough time available to make an optimal comparison between correct and actual responses. As a result, a weaker ERN is generated.

Interestingly, in the study described in Chapter 3, we asked participants to perform the same task as in Chapter 2 (i.e., a phoneme-monitoring task with and without time pressure manipulation). The difference between these studies is that in Chapter 2 native Dutch speakers performed task in Dutch, whereas in Chapter 3 native German speakers performed the task in their second language, i.e., Dutch. As native Dutch speakers, German native speakers made more errors under time pressure compared to no time pressure. 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; see Chapter 2). Surprisingly, we did not find the typical decrease of amplitude of the ERN under time pressure when the task was performed in a second language. On the contrary, we observed enhanced ERN under time pressure, as compared to the control condition.

How can we explain this reversed effect of time pressure on the ERN? 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 are aphasic (e.g., Fabbro, Skrap, & Aglioti, 2000), under stress (e.g., Dornik, 1979, 1980; Grosjean, 1982), or undergo brain stimulation (e.g., Holtzheimer, Fawaz, Wilson, & Avery, 2005). It is possible that under time pressure participants had more difficulty inhibiting their dominant native language and experienced more intrusions from it. 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, which made it more difficult for the monitor to verify which response was correct and which was erroneous. This in turn may have led to more response conflict and higher amplitudes of the ERN (e.g., Botvinick et al., 2001, Yeung et al., 2004).

Presumably, the increased amplitude of the ERN under time pressure when the task is performed in a second language 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). Bilingual participants in the present study completed a Dutch course 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.

In the Chapter 3, we observed that performing the task in a second language reversed the effect of time pressure on the ERN, compared to the effects of time pressure when the same task was performed in the native language. This suggests that the ERN was sensitive to the verbal manipulations. In the following chapter, Chapter 4, we have manipulated the presence and relatedness of auditory distractors to further investigate the effects of verbal manipulation on the ERN. Participants were required to perform a phoneme-monitoring task with semantically related distractors, semantically unrelated ones, or in the absence of distractors. Error rate was independent of distractors to a target picture. This was somewhat unexpected. According to the perceptual loop theory, the verbal monitor proceeds through the speech comprehension system (Levelt et al., 1999). The same system is used for processing auditory input from others. Thus, in presence of auditory distractors, the comprehension system must process auditory input and simultaneously monitor inner speech, which inevitably should lead to a higher error rate. This suggests that the verbal monitoring may be more independent of the comprehension system than the perceptual loop theory presumes. Research on aphasic patients, for instance, demonstrated a double dissociation between the comprehension and the monitoring system (e.g., intact comprehension but impaired monitoring or vice versa; Marshall, Robson, Pring, & Chiat, 1998; Marshall, Rappaport, & Garcia-Bunuel, 1985).

However, we did observe a typical increase in response latencies for semantically related relative to semantically unrelated distractors (Damian et al., 2001; Schriefers et al., 1990). Additionally, the amplitude of the ERN was larger on trials when distractors were semantically related to the target picture compared to semantically unrelated ones. Semantically related distractors presumably co-activate, through the spreading of activation, multiple concepts that are semantically related to one another (Maess, Friederici, Damian, Meyer, & Levelt, 2002). Hence, there are multiple plausible entries that are simultaneously active and compete for lexical selection (but see Finkbeiner et al., 2006 and Mahon et al., 2007). Hence, in the semantically related condition at the time of a response there may be more conflict between competing responses than in the semantically unrelated condition or in the absence of distractor words, thereby leading to a larger ERN amplitude. The verbal self-monitor needs to verify on-line whether the correct entry was chosen from the pool of competing items, which in turn leads to slower responses. In the unrelated condition, however, such verification might not be as relevant, since unrelated distractors do not lead to activation of related concepts, and therefore less competition may be present at the time of the response.

This finding was replicated and extended in a study described in the Chapter 5. Contrary to the previous studies, where we used a phoneme-monitoring task (Chapters 2, 3, and 4), in the Chapter 5 we employed a picture naming task. Even though a phoneme monitoring task is verbal in nature and involves monitoring of internal speech production, it is possible that at least some errors found in phoneme-monitoring were motor slips and not verbal errors *per se*. In contrast, in the task described in the Chapter 5, all given responses were verbal. Participants were required to name pictures in a semantic context, in which all pictures were from the same semantic category, and in a mixed context, in which all pictures were from different semantic categories. Additionally, we manipulated participants' motivation, i.e. for errors in the high-motivation condition, participants were told to be financially punished, whereas for errors in the low-motivation condition, participants received neither financial punishment nor reward.

We found a typical semantic interference effect (Damian et al., 2001; Lupker, 1979; Schriefers, Meyer, & Levelt, 1990; Schnur et al., 2006; Vitkovitch & Humphreys, 1991). Participants were slower and made more errors in naming pictures in semantically related blocks as opposed to mixed blocks. Additionally, we observed enhanced ERN in semantically related blocks than in mixed blocks. The enhancement of the ERN and selection latencies in semantically related blocks was most likely due to the simultaneous activation of competing lexical items, which in turn led to a higher conflict at a time of response. This is in accordance with the results that we showed in the previous study, where amplitude of the ERN was larger in presence of semantically related distractors than semantically unrelated ones (Chapter 4). We argue that due to the simultaneous activation of competing items, the verbal self-monitor is presumably more alert in the semantically related context than in the mixed context in order to validate whether the given response was correct or not.

The motivation manipulation had no effect on naming latencies or error rates, which indicates that participants did not develop different response strategies in the high-motivation and the low-motivation conditions. In the electrophysiological data, we saw a clear ERN on error trials compared to correct trials. However, the amplitude and the latency of the ERN were affected by the motivation manipulation. We observed enhanced and delayed ERN in the high-motivation condition, compared to the low-motivation condition. In the high-motivation condition, errors had more severe consequences for participants than in the low-motivation condition. It is plausible that the ERN is sensitive to the motivational significance of errors (Hajcak et al., 2005). Under circumstances when errors have more severe consequences, e.g. when giving a speech, the verbal monitor has to be more alert in order to verify whether or not the selected response was correct. It is possible that a delayed ERN latency reflects prolonged error-monitoring mechanism (Johannes et al., 2001). In the high-motivation condition, error monitoring may have been slowed in order to verify that the selected response is indeed a correct response. In the low-motivation conditions, such verification was faster and of less significance, since errors did not have severe consequences.

The goal of the study described in Chapter 6 was to investigate how the ERN is affected by conflict in a bilingual situation. Dutch-English bilinguals saw Dutch words in white print that needed to be classified (right or left button-press) according to their grammatical gender. Furthermore, they were presented with colored words that were to be classified on the basis of their color. Colored words consisted of Dutch common and neuter gender words and their English translations. Performance was more erroneous on incongruent trials, in which there was a mismatch between color and gender response mapping, compared to congruent trials, i.e. in case no such discrepancy was present. We obtained an ERN following incorrect classifications for colored words which was larger for incongruent than congruent trials. Higher error rates and enhanced amplitude of the ERN on incongruent trials were independent of the language in which target words were presented. This may suggest that when multiple languages are active, the verbal monitor has more difficulty to keep languages separated. Therefore, it may suffer more from intrusions from a second language, resulting in more response conflict and more error-prone performance. These results also provide evidence that under certain circumstances people can transfer some grammatical characteristics of their first language (e.g. gender) to their second language, even if such characteristics are absent from the latter.

Taking all results of our studies together, it seems that there is a conceptual overlap between verbal monitoring and general performance monitoring theories. Both types of monitoring theories independently state that in order to detect an error a monitor compares the representation of a correct response with the copy of an on-line response. It is possible that during verbal monitoring, as well as during executive action monitoring, a copy of the on-line response is created and compared to the representation of the correct response (see Levelt et al., 1999). If there is a mismatch between them, an error signal is generated and corrective processes can be started – similar to action monitoring (see Desmurget & Grafton, 2000; Rodríguez-Fornells et al., 2002). In a series of experiments we showed a typical ERN in a various tasks in which performance was dependent on a verbal judgment (Chapters 2, 3, 4, 5, and 6). More specifically, in Chapters 3 and 5, we showed that the ERN was not only present after verbal errors, but was also affected by lexical conflict, which presumably was the result of simultaneous activation of multiple concepts from the same semantic category. Additionally, there is further recent evidence that verbal errors activate the anterior cingulated cortex (ACC) and medial frontal cortex (SMA; Möller, Jansma, Rodríguez-Fornells, & Münte, 2007). A typical ERN has been located within the ACC/SMA region (Dehaene et al., 1994). Based on this evidence, we suggest that verbal monitoring is not a process separate from but rather a special case of general performance monitoring.

Interestingly, in Chapters 2 and 4 we also demonstrated an ERN-like response on incorrect go-trials (i.e. misses). This type of negativity was present only after misses and not during the correct nogo trials. It had the same characteristics as a typical ERN, i.e. it peaked at fronto-central sites and was initiated at the time of mean response latency. Additionally, the negative deflection after misses was affected by time pressure (Chapter 2) in a similar way as the ERN following false alarms. The amplitude of the negativity after misses decreased under time pressure, as compared to its amplitude during the control condition (Chapter 2). Unfortunately, in the Chapter 4, we did not have enough trials to investigate whether or not the auditory distractors had an effect on the ERN-like response after misses. We think that the negative deflection after misses can be interpreted as an ERN-like response. This is particularly interesting since the literature on the ERN available so far mainly reports a negative deflection after *overt* motor errors. Critically, however, misses are errors which are characterized by the absence of such overt motor responses.

To conclude, our findings provide converging evidence that verbal monitoring might be a special case of general performance monitoring instead of a completely separate process. Furthermore, our results suggest that the ERN can be used as an electrophysiological marker of error processing in psycholinguistic research.

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