# The nature of the verbal self-monitor

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# Chapter 1
# Introduction

> *"The inner workings of a highly complex*
> *system are often revealed by the way*
> *in which the system breaks down…"*
> *Dell, 1986, p, 284*

Language is a crucial part of our everyday lives. For most of us, there is not a day that passes without exposure to some form of language. Speaking is very fast and seemingly effortless process. In speaking aloud, we produce up to 150 words per minute. However, the speech error rate in normal individuals is not more than 1 error in every 1000 words (Levelt, 1989). Such a low error rate indicates that there must be a monitoring system that checks for errors and corrects them if any are found. It is very important to monitor one's own speech, since 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). For example, saying "I want to spank all the thinkers" instead of "I want to thank all the speakers" (Fromkin's Speech Error Database from the Max Planck Institute for Psycholinguistics). Furthermore, verbal-monitoring is often implicated in disorders such as aphasia (for an overview see Oomen, Postma, & Kolk, 2001), stuttering (Lickley, Hartsuiker, Corley, Russell, & Nelson, 2005), and schizophrenia (for overview see Seal, Aleman, & McGuire, 2004).

This thesis focuses on investigating various factors that interfere with the working of the verbal monitor in normal individuals. Chapter 2 investigates the effects of time pressure on verbal self-monitoring. In the reported EEG experiment, participants were required to perform a phoneme-monitoring task (see Chapter 2 for detailed description of the task) with and without a time pressure manipulation.

Chapter 3 focuses on how verbal self-monitoring is 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.

Chapter 4 investigates how auditory distractors affect workings of the verbal self-monitor. In the described experiment, participants were asked to perform a phoneme-monitoring task. The target stimuli were presented simultaneously with auditory distractors. EEG was recorded through out the whole experiment.

Chapter 5 examines whether motivation and semantic context affects participants' performance using a picture naming task in a semantic blocking paradigm. The semantic context of to-be-named pictures was manipulated; blocks were semantically related (e.g., cat, dog, horse) or semantically unrelated (e.g., cat, table, flute). Motivation was manipulated independently.

Chapter 6 addressed how the Error-Related Negativity (ERN) is affected by conflict in a bilingual context. Dutch-English bilinguals saw Dutch words in white print that needed to be classified according to their grammatical gender and colored words that were to be classified on the basis of their color. Colored words included Dutch common and neuter words, and English translations of those words. EEG was recorded through out the whole experiment.

Finally, in Chapter 7, a short summary is presented, and main findings are discussed.

## 1.1 Verbal self-monitoring in speech production

To this date, the most influential and detailed speech production theory is the theory proposed by Levelt and colleagues (Levelt, 1989, 1999a, 1999b, 2001, Levelt, Roelofs, & Meyer, 1999; see Figure 1). According to this model, speech production consists of a number of steps. First of all, *conceptual preparation* takes place, i.e. the message is generated. A decision is made about what to say and in what order, also word choice and grammatical roles are determined. The output of the conceptual preparation is a preverbal message. The second step of speech production is called *formulation*. Formulation can be divided into *grammatical encoding* and *form encoding*. During grammatical encoding, the syntactic aspects of words are retrieved from the mental lexicon. The mental lexicon stores information about words such as meaning and form. During form encoding, word forms are retrieved based on the output of grammatical encoding. Phonological encoding can start after the word form has been accessed and eventually leads to the phonological representation (i.e. segmental shape and metrical structure) of the morphemes. During *phonetic encoding*, this phonological representation is transformed into a phonetic one, which specifies articulatory commands. Finally, the fully encoded speech plan can be articulated.

One of the crucial processes in speech production is self-monitoring. Speech monitoring or verbal self-monitoring is a process that checks the correctness of the speech flow. Its prime purpose is to detect and correct speech production errors, parts of the speech program or of the actual speech output that do not agree with the speaker's communication purpose or with his/her general linguistic knowledge and standards (Postma, & Kolk, 1993). The monitor, according to Baars (1975) is a mechanism that "listens to" self-produced internal or external feedback, compares this with the intended output, identifies errors, and then computes corrections by using a duplicate copy of the information originally available to the motor system.

To this date, the most influential and detailed verbal self-monitoring theory is the theory proposed by Levelt and colleagues (Levelt, 1983, 1989, 1999a, 1999b, 2001, Levelt, Roelofs, & Meyer, 1999; see Figure 1). The perceptual loop theory suggests one central monitor localized in the conceptualizer (see Figure 1). According to this theory, only certain-end products in the speech production are monitored. Moreover, these end-products are analyzed in a similar way as a speech of other, in other words, through speech comprehension system (Postma, 2000). A distinction is made between *external* and *internal monitoring*. External monitoring is monitoring of speech after it has been articulated and proceeds through the auditory loop, i.e. the signal enters the auditory system and is then processed by the speech comprehension system where the information is parsed and then sent to the *conceptualizer*. In contrast, internal monitoring is covert monitoring of speech production, i.e. monitoring that occurs prior to articulation and has access to more abstract codes, i.e. the phonological planning level (Schiller, 2005, 2006; Schiller, Jansma, Peters, & Levelt, 2006; Wheeldon & Levelt, 1995; Wheeldon & Morgan, 2002). For instance, Wheeldon and Levelt (1995) asked participants to silently generate the Dutch translation of an auditorily presented English word and to monitor their covert production for a specific target segment in the Dutch translation. For example, when participants were presented with the word *hitchhiker* and generated the Dutch translation *lifter*, then they were required to press a button if target phoneme was /t/ (since /t/ is a phoneme of *lifter*) but they withheld their response in case the target phoneme was /k/. The findings of Wheeldon and Levelt (1995) demonstrated that participants were faster in detecting onset as opposed to offset phonemes. Based on their findings the authors concluded that participants indeed monitor an abstract internal speech code during a segment/phoneme-monitoring task. The function of this inner loop is to inspect the speech plan prior to its articulation (Postma & Noordanus, 1996). The internal monitoring can also proceed through auditory monitoring (e.g., ‘listening’ to inner speech; Postma, 2000). Finally, there is also a *conceptual loop* (between the preverbal message and the conceptualizer) that checks for semantic appropriateness.

There is empirical evidence supporting the existence of internal monitoring. For instance, it has been found that some repairs in overt speech have a 0 ms cut-off to repair interval (Blackmer & Mitton, 1991). In other words, some speech errors are corrected immediately after having been produced, which indicates that the error must have been detected and repair processes had to be initiated before the word was completely pronounced. Similarly, there are also corrections made in speech that occur after the pronunciation of only the first phoneme of an incorrectly selected word, e.g., *v..horizontal* (Levelt, 1983). In such cases, it is hypothesized that internal monitoring detected the error before overt production, but too late to stop articulation of the initial phoneme.

Furthermore, the perceptual loop monitor is centrally regulated and requires controlled processing. It is generally accepted that controlled processes are capacity-limited and depend upon allocated resources (Shiffrin & Schneider, 1977). Therefore, it is plausible to assume that speech monitoring is a resource-limited process (Postma, 2000). In other words, if resources are allocated to other than monitoring activities, monitoring will not operate on an optimal level. Additionally, the perceptual loop theory maintains that speakers are usually aware of the monitoring process (i.e., monitoring is a conscious process).

In sum, in the perceptual-loop theory, actual error detection takes place at the level of conceptualization, where parsed speech is compared to the intention and linguistic standards and occurs as the speech comprehension system signals some kind of irregularity (Hartsuiker & Kolk, 2001; Oomen & Postma, 2002). This single monitor located within the conceptualizer handles appropriateness monitoring, inner speech monitoring, and external monitoring.

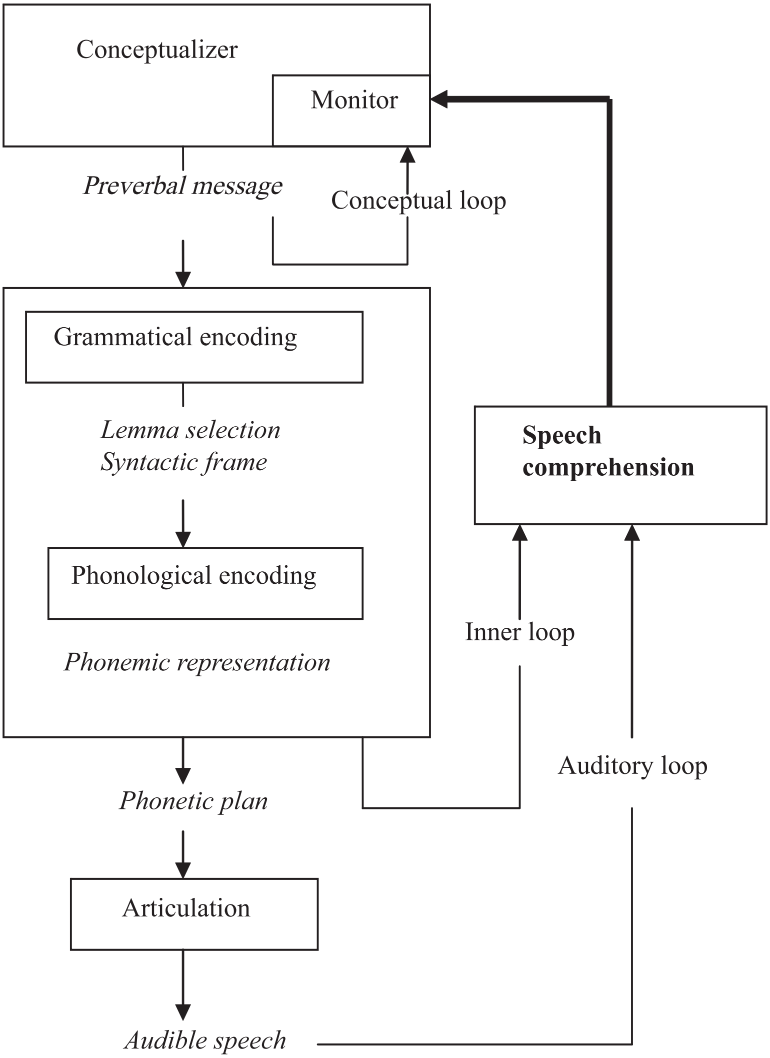

Figure 1. Graphical representation of Levelt's speech production model.

The production-based approach is an alternative account for the self-monitoring process. According to this approach, self-repair processes have access to various stages of speech production (Laver, 1980). In other words, immediate aspects of speech planning, such as components *inside* the formulator, are accessible for monitoring. The production-based view does not limit itself to one monitor, on the contrary, it states that monitors are widely distributed throughout speech production levels. If an error has been detected, further processing is cancelled. This error interruption usually occurs within 150 ms (Oomen & Postma, 2002). The production-based approach, unlike the perceptual loop theory, argues that monitoring is not largely dependent on the resources allocated to it. It is possible that some of the production-based monitors possess their own specialized resources (Postma, 2000). Therefore, one would expect that resource limitations will not lead to a less accurate working of the self-monitor. Another crucial difference between the production-based approach and the perceptual loop theory is that the production-based view states that self-monitoring is an unconscious process.

In this section, two approaches to self-monitoring during speech production were described: the perceptual loop theory and the production-based theory. Both of these theories have been subject to criticism. For instance, the perceptual loop theory claims that all monitoring proceeds through the comprehension system. However, research with aphasic patients showed that some of the patients have an intact comprehension system but impaired monitoring, and the reversed was also found to be true (Marshall, Rapparport, & Garcia-Bunuel, 1985; Marshall, Robson, Pring, & Chiat, 1998; for overview see Oomen, Postma, & Kolk, 2001). This indicates that the comprehension system is not crucial for monitoring. Furthermore, Oomen and Postma (2001) showed that error detection and repair processes do not suffer from time pressure (i.e. speech has to be produced at higher than normal speed). This is not in accordance with one of the predictions of the perceptual loop theory, which holds that under time pressure less time will be available for inner loop monitoring. The production-based monitors can adjust their functioning based on speech rate. However, one of the main objections to the production-based approach is that it assumes the assistance of separate monitors working on each level of production. Such a system might not be economical, since for optimal functioning it would require several additional monitoring devices (Wheeldon & Levelt, 1995). Despite the differences in described theories, they both agree that if the monitor is not optimally functioning, then more errors will pass undetected and uncorrected. Therefore, under more challenging conditions when monitoring is impaired more errors will be committed.

## 1.2 Speech errors

Speech errors are generally assumed to occur during the construction of an internal representation of the utterance at a semantic, syntactic, phonological, or motor program level. Due to speech planning errors or the incorrect execution of correctly planned programs, for instance, speakers produce errors such as “laboratory in my own computer” instead of “computer in my own laboratory” (Fromkin, 1971; see also Garrett, 1975, 1980).

Errors in which segments, features, or clusters are disordered, deleted or added are related to processes that link phonological units with slots in phonological frames. Examples of such errors are “at the right tace” (intended utterance “at the right time and place”) or “a brun” (instead of “a bread bun”; these examples are taken from the Fromkin’s Speech Error Database from the Max Planck Institute for Psycholinguistics).

According to Baars (1992), speech errors arise from competition between alternative speech plans, time pressure, and momentary overloading of the conscious limited capacity system. Errors might occur when two or more output plans are active at the same time. Solving competition between these plans requires allocation of resources. If a wrong output plan is selected, an error will occur. One of the factors affecting the working of the verbal monitor is time pressure. Levelt (1989) states in his perceptual loop theory that the verbal self-monitor is a controlled process, and hence resource-limited. If there are insufficient resources available for verbal monitoring activities, then functioning of the monitor will not be optimal and lead to more errors. Time pressure adds an extra load on the central-capacity system (Baars, 1992). Hence, time pressure causes overload in the functioning of the verbal self-monitoring and prevents sorting out of the competing plans thus leading to more errors. Previous research showed that under time pressure conditions more errors were made (Oomen & Postma, 2001). In the same study, however, Oomen and Postma also showed that the same percentage of errors was corrected during a time pressure condition as during a control condition, indicating that most likely speech production mechanisms were affected by time pressure and verbal self-monitoring processes were able to adjust to the demands of the task.

In another study, Oomen and Postma (2002) asked participants to overtly describe visually presented networks and detect errors in the speech of others, in the absence or presence of randomly generated finger taps. The finger typing task continuously demands attention, which decreases the processing resources available for monitoring. Oomen and Postma showed that participants intercepted a small percentage of errors in the dual-task condition compared to the percentage of detected errors in the control condition, indicating that self-monitoring might indeed be a resource-limited process.

## 1.3 Electrophysiological correlates of error processing

The recording of electroencephalography (EEG) is a non-invasive technique that provides an excellent way to investigate online information processing in the brain with milliseconds precision (Fabiani et al., 2000; Luck, 2005). EEG reflects information arising from synchronous activation of neuronal populations in the brain. The neural currents resulting from this activation generate an external electric potential that can be measured with EEG. EEG can be used to examine event-related and ongoing brain activity. Event-related potentials (ERPs) are voltage differences that can be measured by EEG before, during or after a sensory, motor or psychological event. Thus, ERPs reflect electrical activity of the brain time-locked to ongoing information processes of a particular event, e.g., presentation of stimuli or a response to a stimulus (Hillyard & Kutas, 1983; Luck, 2005)

Event-related potentials have been an important tool in investigating neural systems involved in different aspects of behavior, including those related to the processing of an error. Over a decade ago an error-related negativity (ERN) was observed in EEG recordings when participants made an error in a task (e.g. Gehring, Goss, Coles, Meyer, & Donchin, 1993; Falkeinstein, Hohnsbein, Hoorman & Blanke, 1991). Since then it has been found that the ERN is generated about 100 ms after the onset of the electromyographic activity preceding the actual overt response and it peaks approximately 100 ms thereafter (see Figure 2; Scheffers, Coles, Bernstein, Gehring, & Donchin, 1996; Holroyd, & Yeung, 2003). The generation of the ERN is localized in the anterior cingulate cortex (ACC; Holroyd, & Coles, 2002). It has been proposed that the ACC has a monitoring function and initiates other systems to adjust their processing as needed (Holroyd & Coles, 2002).

It has been hypothesized that the ERN is generated as a result of a mismatch between representation of anticipated and actual stimuli/response (Bernstein et al., 1995). This hypothesis was supported by the fact that the ERN occurs only after slips and not after mistakes[1] (Dehaene, Posner, & Tucker, 1994). More recently it was suggested that the ERN is an output of an error-detection system. This error-detection system is hypothesized to be comprised of two main components. The first component is system monitoring, function of which is a detection of errors. The monitoring system includes a so-called *comparator* that compares correct response to the actual response. The second component is *remedial action system* (Coles, Scheffers, & Holroyd, 2001). It receives a signal from the comparator if a mismatch is detected, and starts on corrective actions. The ERN is generated when the error signal arrives at the remedial action system (Coles et al., 2001). This theory is in line with the neurophysiological view, which states that when participants err, the mesencephalic dopamine system (i.e. comparator) sends a negative reinforcement signal to the frontal cortex (anterior cingulate sulcus; i.e. remedial action system), where it generates the ERN by disinhibiting the apical dendrites of motor neurons in the ACC (Holroyd, & Coles, 2002). Support for the importance of the mesencephalic dopamine system (i.e. basal ganglia) comes from studies done with Parkinson's patients, who show a decrease in amplitude of the ERN during error trials (i.e. reduction in error detection; Falkenstein, Hoormann, Christ, & Hohnsbein, 2000).

Another theory of the ERN is a conflict-monitoring theory (Botvick, Carter, Braver, Barch, & Cohen, 2001). According to this theory, the ACC monitors for response conflict and then send this information to brain regions that are responsible for cognitive control (e.g. lateral prefrontal cortex).

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[1] In cognitive psychology there is a difference made between slips and mistakes. Slips are the incorrect executions of correct planned programs. Mistakes are correct execution of the inappropriate programs (Dehaene et al.,1994).

The ERN is generated during continued stimulus processing, after the error causes activation of the correct response, which in turn results in post-error conflict.

The ERN has the following characteristics: the amplitude of the ERN depends on the degree of a mismatch (Bernstein et al., 1995; Holroyd, & Coles, 2002; Falkenstein et al., 2000). The more deviant is the anticipated stimuli/response from the actual stimuli/response the higher the amplitude of the ERN. Furthermore, the amplitude of the ERN largely depends on the motivation of the participants (e.g., the amplitude of the ERN increases when participants concentrate more on the accuracy in the performance than speed; Dehaene et al., 1994). Next, the amplitude of the ERN depends on the confidence that an error had occurred, independently of whether they actually committed an error or not (Scheffers & Coles, 2000). Another characteristic of the ERN is that it can be elicited unconsciously, i.e. when the participants where not aware that they made an error (de Bruijn, Hulstijn, Meulenbroek, & van Galen, 2003; Nieuwenhuis, Ridderinkhof, Blom, Band, & Kok, 2001; but see Dehaene et al., 1994, Luu, Flaisch, & Tucker, 2000).

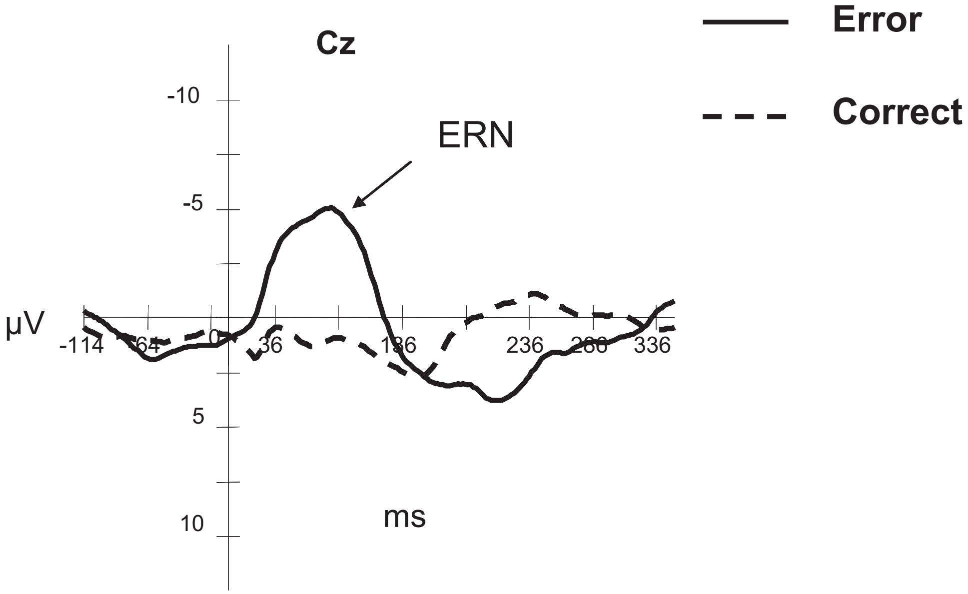

Figure 2. Response-locked ERPs on correct trials (dashed lines) and error trials (solid lines) at Cz. Error trials show a prominent error-related negativity (ERN).

To summarize, the ERN relies on an internal monitoring system (de Bruijn, et al., 2003) and should be indifferent to modality of the error information (Holroyd, & Coles, 2002). Indeed, the ERN was observed in a variety of different areas of research. Note, however, that the majority of the findings reported in this section come from the studies that used action/motor monitoring tasks and not related to the linguistics. There are only few studies that used the ERN after verbal errors (see Masaki et al., 2001; Sebastián-Gallés, Rodríguez-Fornells, Diego-Balaguer, & Díaz, 2006), which we will briefly review below.

Masaki and colleagues (2001) examined whether or not the ERN occurs in relation to speech errors in the Stroop color-word task. Participants in their study were instructed to overtly name the color of each stimulus as quickly and accurately as possible. As a result, Masaki and colleagues found an ERN-like response after speech errors, e.g. when participants named the wrong color.

Sebastián-Gallés and colleagues (2006) assessed Spanish-dominant and Catalan-dominant bilinguals using a lexical decision task in Catalan. In the experimental stimuli, the vowel change involved a Catalan-specific /e – ɛ/ contrast, which is absent in Spanish. The authors showed that Spanish-dominant bilinguals had great difficulty in rejecting experimental non-words, and did not show an ERN in their erroneous non-word decisions either. According to Sebastián-Gallés et al. this suggests that Spanish-dominant bilinguals activated the same lexical entry from experimental words and non-words and therefore showed no differences between correct and erroneous responses. In contrast, Catalan-dominant bilinguals had a clear ERN.

Recently, Möller, Jansma, Rodriguez-Fornells, and Münte (2007) used a laboratory task known to elicit speech errors. In this task, participants are presented with inductor word pairs such as '*ball doze*', '*bash door*', and '*bean deck*', which are followed by a target word pair such as '*darn bore*' (see Motley et al., 1982). The reversal of initial phonemes in the target pair compared to the inductor pairs is supposed to lead to speech errors such as '*barn door*'. Möller and colleagues asked their participants to covertly read the inductor word pairs and vocalize the target word pair immediately preceding a response cue. Möller and colleagues found a negative deflection on error trials, as compared to correct trials, preceding the response cue. They proposed that this activity reflects the simultaneous activation of competing speech plans. However, the authors do not make an explicit link between the negativity they found in their study and the ERN.If the ERN can be observed after speech errors does this mean that the verbal monitor works in a similar way as an action monitor? It seems plausible that different types of monitoring have analogues mechanisms to monitor different kinds of behavioral output. In such a way, an action monitor may monitor for motor slips by checking for possible mismatches between representations of actual and desired motor behavior. A verbal monitor, on the other hand, may monitor some internal representation as it is produced during speech planning by checking potential mismatches between intended and actual verbal production. By investigating the relationship between verbal self-monitoring and the ERN a better understanding of working of verbal monitor may be reached. Additionally, the ERN can provide researchers with a new useful tool for psycholinguistic research. For example, one of the major problems with studying covert errors in language production is that one can never be sure about compliance of the participants. By using the ERN as an electrophysiological marker, this problem can be eliminated.

As stated in the beginning of this general introduction the verbal self-monitoring is a crucial part of speech production processes. However, essential knowledge concerning the precise working of the monitor is still lacking. Investigations of the factors that effect the working of the verbal monitor and relating verbal monitoring to known electrophysiological correlates of error processing will shed a light on processes underlying verbal self-monitoring in speech production. These are the main aims of the present dissertation. The remaining chapters concern experimental studies of verbal-monitoring. As the chapters are based on separate manuscripts they may be read independently of each other. Therefore, there is unavoidably an overlap between chapters.

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