

# ReSound ONE with M&RIE reduces listening effort

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## ABSTRACT

Everyone experiences listening effort that varies according to the specific situation. People with hearing loss must expend more effort to listen under similar conditions. The amplification provided by hearing aids as well as particular hearing aid technologies can reduce listening effort for wearers. The ReSound ONE™ features multiple noise-managing technologies which could provide this benefit. When fit with the unique Microphone & Receiver-In-Ear (M&RIE) receiver that collects sound with a microphone within the ear canal, the listening effort benefit may be further increased. This paper describes a study where hearing aid users wore ReSound ONE hearing aids fit with standard receivers and with M&RIE receivers. They participated in a listening effort task unaided and with each type of fitting. Results confirmed a listening effort benefit of ReSound ONE, and a clear trend of additional benefit with the M&RIE receiver unit.

Hearing is often talked about in terms of how a person's hearing thresholds compare to a normative group. People are then characterized as having hearing within normal limits or having a hearing loss. In fact, this information captures only one aspect of a person's auditory perceptual experience, and everyone's hearing is unique. Part of this distinctiveness comes from the way sound is shaped by the individual head, torso and pinnae of each person. In other words, everyone has their own acoustic cues. These cues help with localizing sound sources, segregating auditory scenes, determining sound quality, and perceiving auditory distance. In fact, hearing via the personalized filtering of one's own anatomy is the only way to truly experience immersive, natural sound.

Just as understanding a person's hearing involves more than measuring thresholds, understanding the potential benefits of wearing hearing aids involves more than assessing improved audibility for sounds. One aspect of hearing and wearing hearing aids that has received much attention in recent years is listening effort. An expert panel proposed a generally accepted definition of listening effort as "the deliberate allocation of mental resources to overcome obstacles in goal pursuit when carrying out a [listening] task".<sup>1</sup> If listeners are assumed to have a limited number of mental resources, then it follows that listening effort in any situation will affect the resources remaining for other cognitive tasks. In challenging conditions where there are competing signals and where the listener may want to attend to more than one signal, more effort will be required. Everyone experiences listening effort that varies depending on the situation. For example, imagine traveling with some family members. You decide to have a coffee at a café in the airport while waiting for a flight. There is generally a high amount of background noise at airports, as well as reverberation. In these adverse acous-

tic conditions, it is quite effortful to follow the conversation. At the same time you may want to monitor announcements regarding your flight – which may even be in a different language than your native one. While this situation may not be impossible to manage, it will likely be difficult. Today many people rely on flight status alerts sent via their smartphone rather than listening for broadcasted announcements. This is a way to reduce the listening burden and better enjoy the waiting time and whatever you might be doing.

For a person with hearing loss, the effort involved in listening is understandably greater. Not only is the signal degraded due to reduced audibility associated with hearing loss, there is also greater effort involved in deciphering and remembering what was heard.<sup>2,3</sup> The impact of this increase in perceived listening effort among adults with hearing loss is thought to contribute to listening-related fatigue<sup>4</sup> but may even extend to changes in the brain.<sup>5</sup> The use of amplification by people with hearing loss can reduce listening effort<sup>6</sup>, and there is evidence that noise management features may contribute further.<sup>7,8</sup>

The M&RIE (Microphone & Receiver-In-Ear) is also a hearing aid feature that may positively impact listening effort for people who wear ReSound ONE hearing aids. Inspired by the ReSound philosophy of Organic Hearing, M&RIE places a microphone in the ear canal along with the receiver. This remedies issues associated with microphone placement on top of or behind the pinna on the popular RIE style of hearing aid by preserving the hearing aid user's unique pinna-related acoustic cues. This information contributes to localization, sound segregation and sound quality. Compared to traditional microphone placement on the body of an RIE, it has been shown that the M&RIE results in better localization,<sup>9,10</sup> and preferred sound quality.

ty.<sup>11</sup> The M&RIE microphone placement has the additional advantage of protection from wind noise.<sup>12</sup> Because initial studies with M&RIE demonstrated that users were able to make use of their preserved pinna-related acoustic information, we wanted to investigate whether the improved perception of depth and direction of sound might also reduce listening effort.

## MEASURING LISTENING EFFORT

One reason it is of interest to quantify listening effort is that it can capture information about hearing aid benefit that is not reflected in measures of audibility or speech understanding. Figure 1 illustrates this point. Generally speaking, as signal-to-noise ratio (SNR) improves, speech intelligibility increases and listening effort decreases. However, listening effort continues to decrease where speech intelligibility has reached its maximum. This indicates that effort must still be put in to understand at the maximum level until SNR improves further. Therefore, measuring listening effort can add nuance to our understanding of what the listener is experiencing in a wide range of listening conditions.

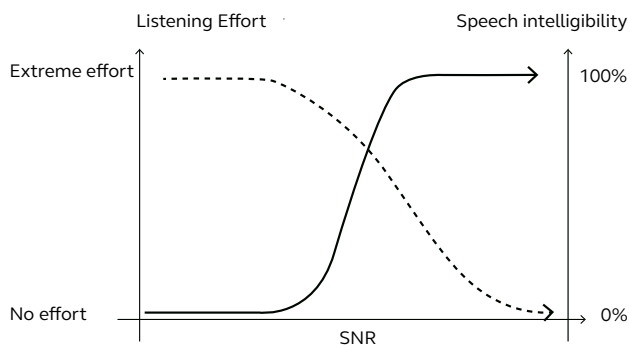


Figure 1. Listening effort and speech intelligibility as a function of SNR. Listening effort continues to decrease with improved SNR even as speech intelligibility has reached a maximum.<sup>13</sup>

Listening effort can be measured by physiological correlates such as pupil dilation, by neuroimaging such as EEG or fMRI, by behavioral techniques such as dual task paradigms, or by subjective means.<sup>14</sup> Each of these methods comes with its own challenges. For example, physiological and neuroimaging methods require specialized equipment and expertise, and involve varying degrees of inconvenience to the test participant as well as a carefully controlled lab environment. Behavioral techniques such as dual task methods typically involve asking participants to perform a speech intelligibility task while simultaneously doing another task, like pushing a button when a certain stimulus appears on a screen. By measuring reaction time on the second task, it is possible to assess the listening effort on the speech task because reaction time on the second task increases as effort increases. However, there are numerous types of dual task paradigms, which complicates interpretation and comparison of results across studies. In addition, test participants may switch their attention back and forth between the tasks or generally prefer to attend to the second task rather than the first. This can strongly affect the validity of the results. Subjective methods typically ask people to rate listening effort after the fact. This type of assessment has little

sensitivity to listening effort, as it is common to forget what the experience in a particular situation was.

To complicate matters further, the various methods for measuring listening effort may be not assessing the same thing. Alhanbali et al<sup>15</sup> compared different methods of measuring listening effort with 116 participants and found them to be reliable, but not strongly correlated. They pointed out that listening effort is multidimensional, and that different measures of listening effort are not interchangeable. While some may reflect mental load generally, others may tap into cognitive-auditory interactions more specifically.

## A subjective lab-based method

Krueger et al<sup>16</sup> took a pragmatic approach in developing a method for assessing listening effort. Requirements for this method were that it be fast and easy to use, that it use measurement equipment common in audiology research in a relatively simple test set up, that it capture the entire range of listening effort that could be experienced by each individual, and that participants be actively involved in the procedure. This latter requirement is important because the user's momentary experience of how much effort they are making to listen has obvious clinical relevance; subjective perception ultimately affects the decision of whether to use the hearing aids. The resulting psychoacoustic method, called Adaptive Categorical Listening Effort Scaling (ACALES) requires less than 5 minutes per condition. Listeners are presented with target speech in a noise background for 10 to 15 seconds and asked to rate how effortful it is to follow the speaker using a 13-point categorical scale ranging from "No effort" to "Extreme effort". Presentation levels are varied adaptively depending on the listening effort rating, which allows derivation of listening effort as a function of SNR. With this method, the responses reflect the listener's subjective perception of listening effort during the task.

Figure 2 illustrates how ACALES can help to reveal individual differences in listening experiences that are not predictable on the basis of the audiogram, and how these differences can be quantified by SNR. In this example, three listeners with similar audiometric hearing losses completed the ACALES procedure. The resulting function in the right panel shows the mapping of their listening effort ratings to the SNR at which they made each rating. The function for Listener 3 showed the least amount of perceived listening effort, followed by Listener 1, while Listener 2 showed the most amount of perceived listening effort. At a rating of 7, corresponding to "moderate effort", the SNR for Listener 3 was about -10 dB. The 7 rating was given by Listener 1 at about -6 dB SNR, and by Listener 2 at about -5 dB SNR. This trend was observed across listening effort categories. It is reasonable to assume that these listening effort functions might be predicted by the speech recognition in noise performance of the individuals. Although some significant correlations for some effort categories have been shown depending on the competing signal used, there is not a clear relationship between speech recognition scores and listening effort ratings, which means that use of ACALES adds a unique perspective.<sup>3</sup>

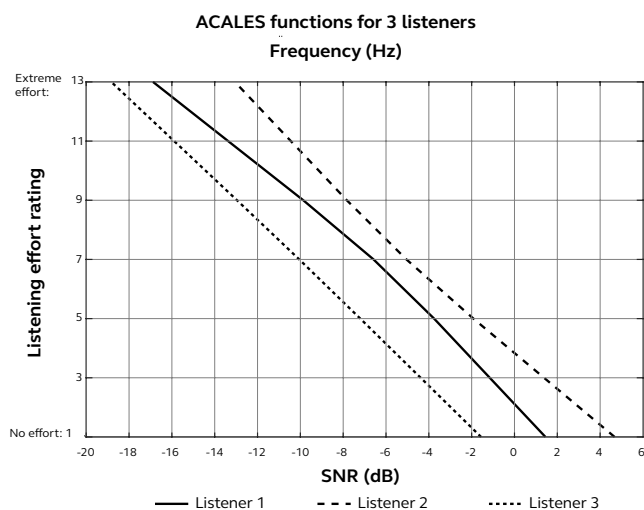
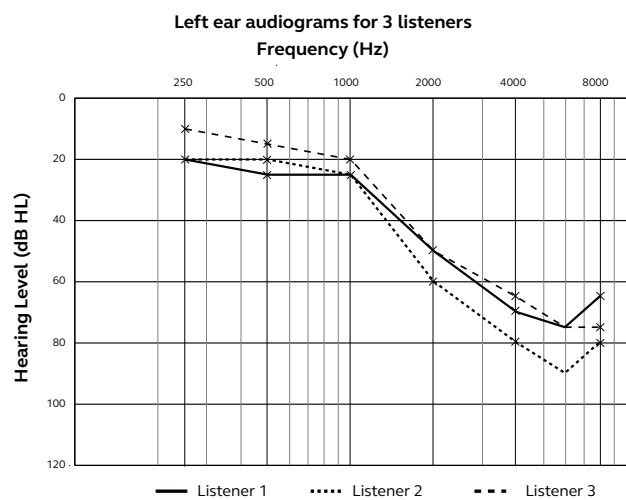
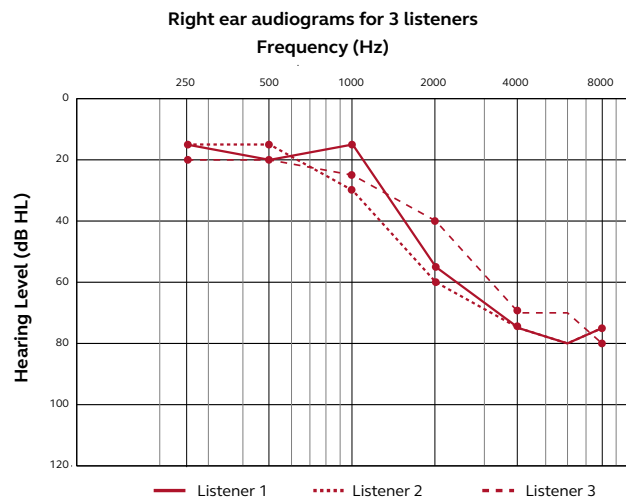


Figure 2. Example of ACALES functions for 3 individuals with similar hearing level thresholds.

In addition to showing individual differences in listening effort, ACALES is sensitive to the effect of wearing hearing aids, as well as to differences between hearing aids or hearing aid settings (Figure 3).

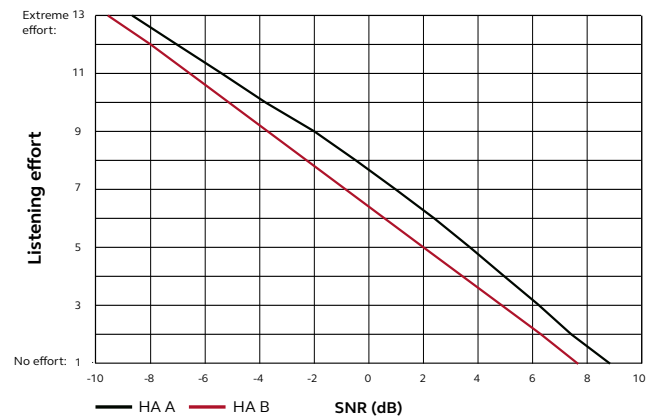


Figure 3. ACALES results for a group of participants who rated listening effort with different hearing aids. ACALES revealed that "Hearing aid B" resulted in less listening effort than when participants were wearing "Hearing aid A".

As discussed, ReSound ONE with M&RIE may reduce listening effort due to the natural microphone location in the ear canal and the individual acoustic cues that are made accessible to the hearing aid wearer. In this experiment, the ACALES method was applied to investigate whether a listening effort benefit of ReSound ONE with M&RIE could be quantified.

## METHODS

### Participants and hearing aid fitting

Twenty-four adults (age range 54-84 yrs) with mild-to-moderate symmetric hearing losses participated in this study, which was carried out at Hörzentrum Oldenburg in Germany. All were experienced with amplification.

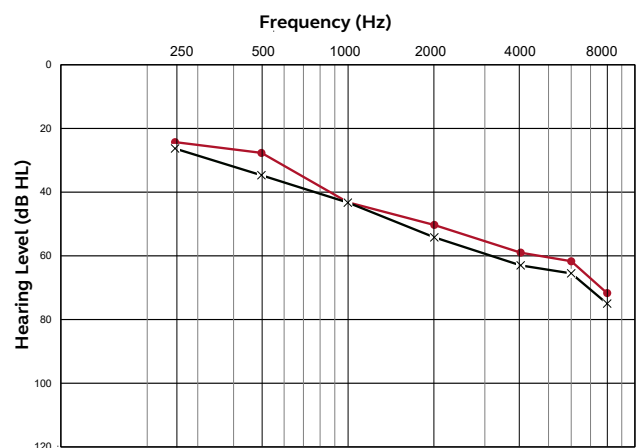


Figure 4. Mean hearing threshold levels for right and left ears.

Participants were fit bilaterally with ReSound ONE 964 RIE hearing aids according to the ReSound proprietary fitting prescription. All were programmed to the manufacturer's default settings, which includes All Access Directionality as the primary listening program. This program uses environmentally based control of microphone modes to support native listening strategies.<sup>18</sup> All Access

Directionality activates binaural beamforming in complex environments with high noise levels, and attempts to preserve spatial hearing cues in quiet and moderately complex environments by activating the canal microphone in the M&RIE module or by using a pinna compensation algorithm based on the device microphone inputs if the fitting uses a standard receiver. For most users, this latter mode will be active 60-80% of their wear time depending on their typically encountered listening environments.

Participants wore the hearing aids in their daily lives for at least 4 weeks in total divided into two periods of two weeks. Half of the group wore the hearing aids with standard medium power level receivers initially, while the other half wore the hearing aids fit with the M&RIE receiver modules. After the initial wear period and laboratory testing, the receiver type each person wore was switched and they acclimated to the new fitting before returning for the final laboratory testing.

Procedures

Participants were tested unaided, aided with the standard receivers, and aided with the M&RIE receivers with ACALES as well as the Göttingen Sentence Test (GÖSA).<sup>19</sup>

ACALES

Participants were seated in a quiet test room with speech presented from 0 degrees azimuth and noise from 135 degrees azimuth as shown in Figure 5. The competing noise was spectrally shaped to match the target speech and presented at 65 dB SPL. Three sentences from the Oldenburg Sentence Test (OLSA)<sup>20,21,22</sup> were presented and the participant then rated their perceived listening effort using the 13-category scale. The noise was kept constant, and the level of the target speech was varied according to the listening effort rating (see Krueger et al<sup>3</sup> for further test procedure detail).

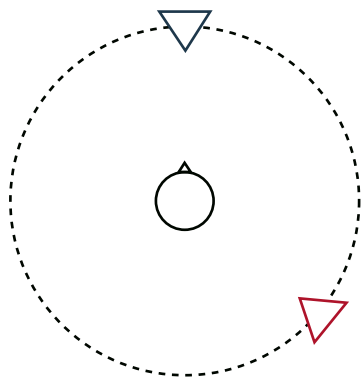


Figure 5. The target speech signal was presented from 0 degrees azimuth (blue triangle), with competing noise from 135 degrees (red triangle).

GÖSA

GÖSA is a speech test with everyday sentences presented in background noise. An example sentence is “Many people dislike flying.” No training is required for this test. The speaker arrangement was the same as with ACALES with speech from 0° azimuth and noise from 135° azimuth. The result of this adaptive test is the Speech Reception

Threshold (SRT), which indicates the SNR at which the participant achieved 50% speech recognition.

RESULTS AND DISCUSSION  
GÖSA

As shown in Figure 6, participants showed improvement over unaided when wearing ReSound ONE regardless of which receiver was fitted. When fit with M&RIE, the average SRT was 0.9 dB (p=.003) better than with traditional microphone placement. This statistically significant improvement illustrates an advantage of picking up the sound in the ear canal, which is much closer to the way sound naturally enters the ear. Sound entering the ear is shaped by the pinna depending on the direction of arrival and frequency of the sound. For sound in the horizontal plane, high frequencies arising from behind are deflected while those from in front are enhanced. This is a monaural effect that complements the binaural spatial release from masking that occurs when the target sound and competing sounds are spatially separated, and therefore helps account for the small difference seen between traditional microphone placement and M&RIE.

Hearing with individualized pinna cues is also important. This was illustrated in a study where the investigators manipulated the position of the pinnae by placing an elastic band around normal-hearing listeners’ heads to make their pinna protrude.<sup>23</sup> Speech recognition in noise testing with natural pinna position versus protruding position showed about 1 dB better average performance for the natural position, which is similar to the difference in performance between traditional microphone placement and M&RIE in the current study. The investigators speculated that protruding pinnae may be worse for speech recognition but an alternative explanation is simply that changing natural pinna cues puts listeners at a disadvantage. In other words, listening with your own ears with their individual shape and placement on your head is optimal.

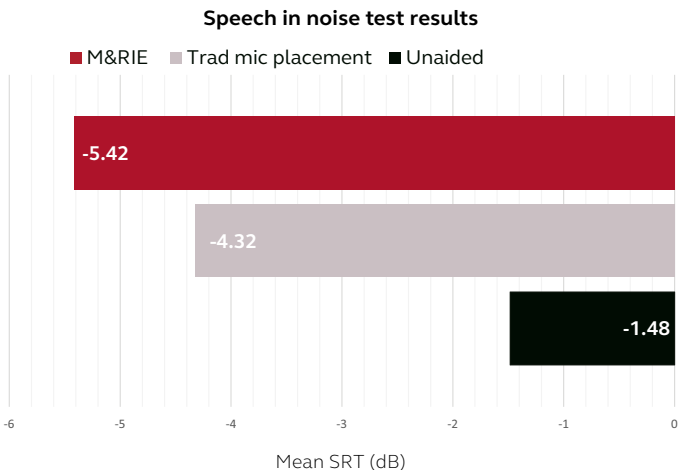


Figure 6. Mean SRT for each condition. Performance was significantly better in the aided than unaided conditions. Performance with M&RIE was better than with traditional microphone placement. A lower score indicates better performance.

## ACALES

The mean listening effort functions for the aided and unaided conditions are plotted in Figure 7 in the same way as the examples shown in Figures 2 and 3. They show the relationship between the SNR and the listening effort category that the listening condition was mapped to. The further to the left the function is on the graph, the less the listening effort is. When listening with ReSound ONE, participants rated listening effort as less than when listening unaided across all listening effort categories. Listening effort benefit can be derived by comparing the SNRs for different conditions. When collapsed across all listening effort categories, the mean listening effort benefit for ReSound ONE fit with traditional microphone placement was 1.8 dB, while it was 2.6 dB for ReSound ONE fit with M&RIE ( $p=.002$ ). These results confirm how hearing aids – and ReSound ONE specifically – reduce listening effort. In addition, the ACALES method shows how this benefit persists even at positive SNRs where speech intelligibility will have reached its maximum.

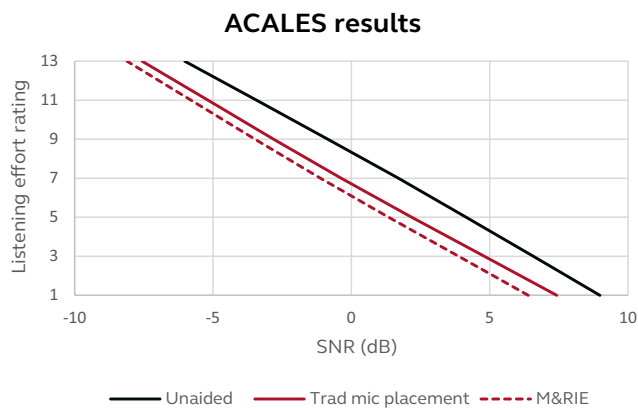


Figure 7. Mean listening effort functions for listening unaided and listening with ReSound ONE fit with M&RIE and standard receivers that use traditional microphone placement. On the y-axis, “1” corresponds to “no effort” and “13” corresponds to “extreme effort”

When examining the results for the two aided conditions, listening effort was rated lowest (best) for the M&RIE fitting. However, the difference between this condition and the condition with traditional microphone placement was not significant. Figure 8 replots the results comparing the listening effort benefit per listening effort category. A clear and consistent trend of less listening effort with M&RIE is observable. One factor that might affect the magnitude of benefit between M&RIE and the traditional microphone placement is acclimatization. The participants in this study were experienced with RIE hearing aids that used traditional microphone placement. Although they

wore the ReSound ONE hearing aids in each condition for weeks prior to testing, it is plausible that additional benefit of M&RIE might have been apparent with even longer wear time. Jespersen et al<sup>10</sup> reported on an ongoing study where people fit with ReSound ONE with M&RIE are being followed over an 18-month period. Among other outcome measures, they tracked localization performance at the initial fitting and at 4-month intervals. They found improved results after both 4 and 8 months of wear time. Because localization continued to improve with long-term experience with M&RIE, it could be anticipated that this acclimatization effect could extend to other benefits such as listening effort.

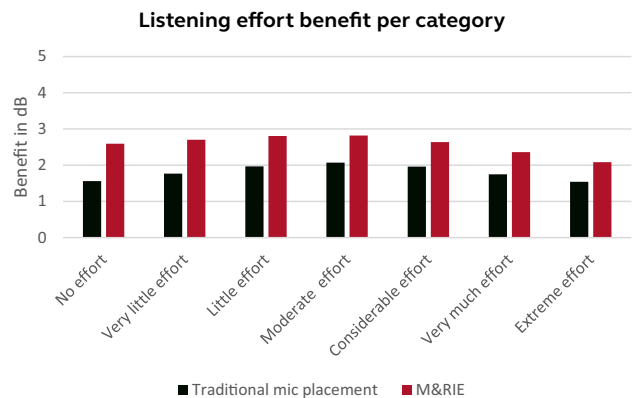


Figure 8. Mean listening effort benefit compared to unaided for ReSound ONE fit with M&RIE versus ReSound ONE fit with standard receivers using traditional microphone placement. A consistent trend of less listening effort with M&RIE was observed.

## SUMMARY

Everyone experiences listening effort to varying degrees in their daily lives. People with hearing loss experience greater listening effort than those with normal hearing. Listening effort occurs even when speech intelligibility is high. Hearing aids and specific hearing aid features have the potential to decrease listening effort for hearing aid users. This study used ACALES to look at the effects of the ReSound ONE with M&RIE on the listening effort experienced by people with mild-to-moderate hearing loss. ACALES results showed a significant listening effort benefit of 1.8 dB and 2.6 dB for ReSound ONE fit with standard receivers and M&RIE, respectively. A long-term study with ReSound ONE and M&RIE suggests that the additional small benefit provided by M&RIE compared to traditional microphone placement might be enhanced with longer acclimatization to the fitting. A small but significant improvement in speech recognition in noise performance for the M&RIE fitting compared to the fitting with traditional microphone placement also points to multifaceted advantages associated with the natural sound pick-up location provided by M&RIE.

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