Did I Hear You Right? A Question of Selective Attention and Language

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Introduction

In the past, many studies have examined the human capacity to attend to sounds and enhance information from relevant sources while suppressing information from other, irrelevant sources (e.g., Coch, Sanders, & Neville, 2005; Hillyard, 1981; Bentin, Kutas & Hillyard, 1995). Research is typically done through dichotic listening tasks in which participants are asked to attend to one stream of sounds while ignoring a separate stream of distracting sounds.

One approach to the dichotic listening paradigm is to use two different story tellers, one male and one female, who read separate sets of stories, one played on the left side of the participant and the other on the right (Coch, Sanders, & Neville, 2005; Stevens, Lauinger & Neville, 2009; Isbell, Karns, & Neville, in prep). Implanted within the stories are two types of distracter probe sounds: a computerized /ba/, used as the linguistic probe, and a computerized /buzz/ or static sound, used as the non-linguistic probe.

This paradigm is effective in the examination of event-related brain potentials (ERPs) obtained through an EEG recorded while a participant is listening to the stories and time-locked to the onset of the different probes. Findings from ERPs have revealed that the brain response to the probes is enhanced by attention, with the effect occurring as early as 100 ms after probe onset (Coch, Sanders, & Neville, 2005). Adults displayed an early positive response (P1) followed by a negative response around 100 ms (N1), while studies involving children have also noted that probes presented on the attended side elicit larger amplitude ERPs relative to probes presented on the unattended side (Stevens, Sanders, & Neville, 2006; Stevens, Lauinger, & Neville, 2009).

Recent research suggests that linguistic probes have a more pronounced distraction effect than non-linguistic probes (Isbell, Karns, & Neville, in prep). The ERP data for these conditions showed an earlier attention effect for the linguistic probes than for the non-linguistic probes. More specifically, linguistic probes elicit an attention effect at the P1, while non-linguistic probes elicit an attention effect roughly 100 ms later at the N1 (Isbell, Karns, & Neville, in prep). However, these results have given rise to new questions. It is possible, for example, that the results are due to the linguistic probes standing out more from the story-telling environment than the non-linguistic probes. It is also possible that the effects are present because of the probe's linguistic nature, and the human brain's inherent capacity to detect language.

The current project answers these questions by using multiple linguistic probes, one for each narrator. As in the Isbell, Karns, and Neville experiment (in prep), the linguistic probes were the syllable /ba/, but unlike those previous studies, the linguistic probes were not computer generated. Rather, two spoken linguistic probes were used: one in the same spectral envelope of the speakers reading the stories and one outside that spectral envelope. Meanwhile, one non-linguistic probe was retained, a computerized /buzz/, identical to the non-linguistic probe used in previous studies (Stevens, Lauinger, & Neville, 2009).

The proposed set of probes allows for two possible testing outcomes. The first tests whether the earlier attention effect for the linguistic probe is due to spectral match, while the second tests whether it is the linguistic nature of the probe that drives the earlier attention effect. If the earlier attention effect reported by Isbell, Karns, & Neville (in prep) is due to the /ba/ syllable standing out more from the attended narrative, then the linguistic probe that does not match the narrator, the incongruent probe, will produce an earlier effect than the other probes. This would support the idea that the early attention effect is the result of a low-level pop-out effect. A pop-out effect is caused by the linguistic probe being louder or more pronounced than the story during which it is presented, causing the brain to respond not so much to language itself as to a distracting sound that stood out significantly from the rest of the story. However, if the congruent probe, the linguistic probe matching the attended narrator, elicits an earlier and larger magnitude effect, the result would provide strong evidence that the attention system of the human brain is specialized for language processing. Such an early language-related effect would be expected for the congruent linguistic probe and would be consistent with previous research suggesting that attending to language involves tuning in to the spectral envelope of the speaker being heard (Kerlin, Shahin, & Miller, 2010). Within this paradigm, however, the possibility exists that both of the linguistic probes show the same early effect. That result would support the idea that it is simply the linguistic nature of the probe that is significant. The final two scenarios would provide support for the idea that human brains have an inherent ability to attend to language.

Literature Review

Evidence suggests that linguistic distracters elicit an earlier attention effect on the evoked response from the brain, compared to non-linguistic distracters (Isbell, Karns, & Neville, in prep). Linguistic probes, presented on the attended side, elicit larger amplitude ERPs than the same probes presented on the unattended side. With adults this is observed as an increase in positive voltage 50 ms after the onset of the probe. In the case of non-linguistic probes, however, the increase in ERP amplitude for the attended versus the unattended probe is seen at later stages of processing, from 100-200 ms after the onset of the probe. The objective of the current research is to examine the possible factors that lead to this earlier ERP response for the linguistic probes.

These findings will have important implications for our understanding of the factors impacting the development of selective attention. For example, Stevens, Lauinger, and Neville (2009) found that the brain response to probes in this paradigm appears to be reflective of a child's socioeconomic status (SES). In their study, children from low SES backgrounds showed less difference in their ERPs between attended and unattended channels of the stories, while those with a higher SES background showed a greater difference between attended and unattended ERPs. In this instance, the lack of attention effect observed in low SES children was due to a lack of distracter suppression as evidenced by larger amplitude ERPs to unattended probes. In a related vein, this paradigm is also important for examining the role of attention in language impairments (Stevens, Sanders, & Neville, 2006). Children with selective language impairments (SLI) also fail to show an attention effect, but in contrast to low SES children, children with SLI have a deficit in enhancing attended information, seen as a lack of amplitude increase for attended probes.

The current paradigm has proven to be a robust measure of selective attention for both adults and children (Coch, Sanders, & Neville, 2005). Although the morphology of the ERPs differs between children and adults, attention effects are observed in both groups, suggesting that attention networks are formed early in life, yet continue to develop. For both children and adults, ERPs provide a more sensitive measure of attention than behavioral measurements; the ERPs can identify differences in signal enhancement and suppress distracters.

Methodology

To answer questions remaining from previous research, this research continued to use those earlier paradigms, while adding modifications. Previously the probes used for both the linguistic and non-linguistic probes utilized computerized sounds. In an effort to minimize the spectral mismatch, the linguistic and non-linguistic probes were created from the narrators' own voices, both male and female. Each probe was a 100 ms clip of the /ba/ sounds from both narrators' voices taken directly from the narrations and converted to both left and right channel auditory clips. For the /buzz/ sounds, the 100 ms clips were rearranged randomly to create the effect of static or white noise. The non-linguistic sounds were also converted to the left and right channels, to be superimposed on both the attended and unattended narratives.

Participants were recruited through fliers placed around a university campus. All participants received monetary compensation for their time in the lab. At the time of testing, all participants received, signed, and returned consent forms before they participated in the tests. To measure the extent to which the human brain responds to all types of probes, each participant was fitted with a 32-electrode cap and had additional electrodes placed below the right eye, to the sides of both eyes and on both mastoids behind the ears. These additional electrodes helped to compensate for EEG signal artifact due to eye movement, blinks, and muscle noise.

After fitting the cap and connecting all of the electrodes, researchers led the participants into a sound-attenuated booth. Each participant was seated between two speakers, on the left and right, and two to three feet from a computer monitor that displayed pictures from the attended story. Over an intercom, participants received oral instructions to remain as still as possible and to pay close attention to the story on the attended side. After those preliminary instructions the paradigm began. Each story was approximately 2.5-3.5 minutes in length, and at the end of each story participants were asked three comprehension questions from the attended story to ensure that they had attended to the appropriate story. A total of eight stories were played for each participant, varying the attended side in the pattern of LRRLRLLR. After the EEG was collected, subsequent processing stages helped to extract data around the times of the probe onset, from 100 ms before to 500 ms after the probes.

Results

Results of the data collected for participants (n=22) suggest that it is not simply the linguistic nature of the probes that elicits a response from the brain, but that the spectral envelope plays a role. Results show an early P1 effect elicited from probes that match the male attended narrator in the unattended ear, 50 to 100 ms after onset of the stimulus. This is contrasted with the later P2 response from the non-linguistic probes which displayed a response 50-150 ms later than the male linguistic probes. The female narrator did not produce the same responses as those from the male narrator. In keeping with previous research, it was found that hemispheric asymmetries exist, showing a right ear/left hemisphere advantage for the male narrator.

Discussion

The ability to selectively attend to relevant information is critically important for educational achievement and overall life success. The inability to suppress irrelevant information can hinder learning in an academic environment. Many questions related to the subject of language and dichotic listening remain to be answered. In this study, the use of the dichotic listening paradigm with slight alterations allowed us to take into consideration not only the mechanics of the brain itself, but also the role that language plays in those mechanics.

In the past, this listening paradigm has utilized a computer generated /ba/ sound superimposed over the story that participants hear. The use of a computer generated sound left open the possibility that previous research was confounded by a pop-out effect, in which the brain was responding simply to a distracting sound that stood out significantly from the rest of the story. The current research has eliminated those confounding elements from the study.

The results from the current study suggest that there is, in fact, a response to linguistic probes presented during the stories that is earlier and greater in magnitude than the response to non-linguistic probes. Linguistic probes created from the voice of the male narrator showed an early P1 effect displayed at 50-100 ms after the onset of the stimuli, compared to non-linguistic responses from 150-200 ms. These results also replicated past research showing a right ear/left hemisphere advantage. This right ear advantage proved to elicit even earlier and larger magnitude responses than the same probe presented in the left ear. However, these results were not seen with all linguistic probes, suggesting there is a need for further research.

Participants showed no response to female probes at any time after the onset of stimuli. These results seemed to contradict past research as well as results from the male narrator in this current study. After a reexamination of the probes used throughout this study, a possible explanation is that the formant signature—the peaks of the spectral sound—of the female probe may be dissimilar from the male linguistic probe as well as the non-linguistic probe, in that the response to the female linguistic probe has a later onset. This later onset could be detracting from the effect of the probe and therefore diminishing the effect it has on the listener.

In the future it will be imperative that the probes be normalized not only on volume and type of sound but also on sound quality and the timed onset of the sound. Although in this study the male linguistic probe presented an earlier and greater magnitude response from the brain, it is difficult to say definitively that the language quality of the sound produced these effects. These results would have been more convincing had the second narrator produced the same effects. It remains reasonable to conclude that the brain responds to language much differently than other sounds in our environment. It is now the task of future research to determine what exactly causes these differences.

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