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To understand human behavior, one cannot ignore the importance of speech perception to do so. Communication and other significant parts of our society are based on the way humans perceive and process language. Taking that into consideration, it is quite surprising that small components like phonemes, consonants, or vowels can have such a significant impact on language perception and are thus directly influencing our way of communicating or learning. Eager to learn more about how small language constituents affect our everyday life we choose to take a closer look at the paper "Brain Activation for Consonants and Vowels", written by Manuel Carreiras and Cathy J. Price. Realizing that speech perception and processing are far more complicated than the average native speaker might think, we also inspected the findings and statements from the annual Linguistics review "How Consonants and Vowels Shape Spoken-Language Recognition" composed by Thierry Nazzi and Anne Cutler.

To adequately evaluate the paper, we have to summarize it in reference to its background, prior hypotheses, key findings, figures, and supporting experiment. Correspondingly the method, procedure, and design of the experiment are going to be dealt with as well.

The background and inspiration for the utilized experiment were findings in behavioral and electrophysiological studies, which showed that there is a certain dissociation between consonants and vowels. In reaction to that, Price and Carreiras investigated the processing differences of vowels and consonants regarding neuronal activation patterns by using magnetic resonance imaging.

Which led Price and Carrieras to the hypothesis that there are differences between vowels and consonants within speech perception and processing (c.f. Price,Carreiras (2008) "Brain Activation for Consonants and Vowels": p. 1728). As a result of previous findings, Price and Carrieras specified their hypothesis, saying that changing vowels and consonants in a word would produce dissociation in brain activation. More specifically, stating that dissociations for consonants are greater in more anterior and/or left hemisphere regions while separations caused by changes of vowels are more significant in posterior and/or right hemisphere regions. Furthermore, the experiment led to conclude that the dissociation effect is more substantial if the vowels/consonants are transposed rather than replaced (c.f. Price,Carreiras (2008) "Brain Activation for Consonants and Vowels": p. 1727).

Coupled with these hypotheses are the key findings made during the in the following described experiment. The experiment was performed with thirteen women and seven men, all of which were right-handed, native Spanish speakers, and neurotypical, meaning that they did not have any neurological disorders or reading impairments. Additionally, all volunteers had a normal or corrected vision and were between the age of 22 and 46. The experiment is marked by its 2 × 2 × 2 factorial design. The first factor is describing the two given visual word processing tasks - lexical decision or reading aloud—. Consonant or Vowels are the differences which made up the second factor. The last and third factor is representing the change that was made on two non-adjacent letters -transposed or replaced-. (c.f. Price,Carreiras (2008) "Brain Activation for Consonants and Vowels": p. 1729).

In addition to this, the design included four pseudoword stimuli, by combining the two latter named factors, which were the non-adjacent transposed consonants/vowels and its corresponding control of replaced consonants/vowels. These resulting pseudowords were the object of both the lexical decision task and the reading aloud task. In the former, participants were instructed to identify whether or not a word is real by giving finger press responses, 1 to indicate a real word and two to indicate the opposite. However, in the reading aloud task, participants were asked to whisper the sounds of each given stimulus into a microphone. While the former measured both accuracy and response time, the latter only took the participant's accuracy into account. During the experiment, each trial started with a fixation point, followed by the stimuli, shown for 500 ms. After the participants saw the stimulus, a word or a non-word, they were instructed to choose either the lexical task or the reading aloud task. During both of these visual word processing tasks, dissociations of consonants and vowels were examined (c.f. Price,Carreiras (2008) "Brain Activation for Consonants and Vowels": p. 1729).

Henceforth the results of the experiment are going to be described. While observing the lexical task, one could see that words created by changed consonants had slower latencies than the ones formed by changed vowels. Furthermore, it can be seen that a pseudoword created by transposing two letters resulted in 84 ms slower responses than the pseudowords formed by replacing two letters. Taking into consideration both of those factors, being the type of change and the type of letter, which was changed, one can see that there was a difference in errors and reaction time for transpositions but not for replacement.

The reading aloud task on the other hand, which only considered accuracy, showed that pseudowords created by changed consonants resulted in more errors than the pseudowords created by transposed/replaced vowels. Moreover, there was a higher error rate for transposed-letter words than for replaced-letter words. Correspondingly to the lexical decision task, the reading aloud task also shows a significant difference between consonants and vowels in the transposed condition but not in the replaced condition (c.f. Price,Carreiras (2008) "Brain Activation for Consonants and Vowels": p. 1730).

The recorded fMRI data delivered a more robust activation of the right superior temporal sulcus area (STS) during tasks with transposed or replaced vowels, compared to consonants. An even strengthened effect is observed during the speaking aloud task.

The right STS is very close to an area that is observed as being involved in auditory speech processing, concerning vowels and nonspeech sounds. This area also includes the processing of prosody properties in auditory speech processing. Vowels influence melody and rhythm, which are prosodic features of a word, and therefore their changes alter the prosodic information. Given that it is quite apparent why prosodic processing during speech processing and vowel processing, even in written tasks, is quite similar. In contrast to that, the right middle frontal cortex depicted a significant impact in the lexical decision task, especially with transposed vowels.

In summary, it can be said that the activation of the STS and the right middle frontal cortex depends on the various task types (speaking aloud or lexical decision task) and the type of the transposed or replaced letter (vowel or consonant). The effect can also be seen in Figure 1 and Figure 2.

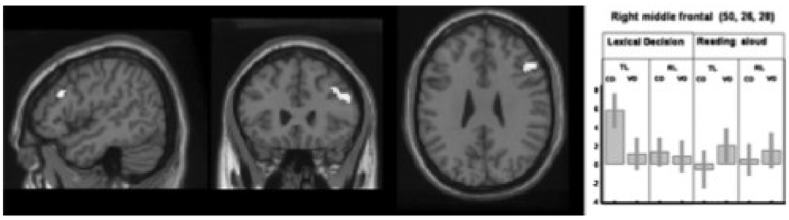

Figure 2 *Left part*: Axial, coronal, and sagittal sections for the contrast consonants > vowels for transposed letters in the lexical decision task. All contrasts depicted at $P < 0.001$ uncorrected. *Right part*: Graphs of contrast estimates and 90% confidence intervals for a right frontal middle area. TL, transposed letters; RL, replaced letters; CO, consonants; VO, vowels.

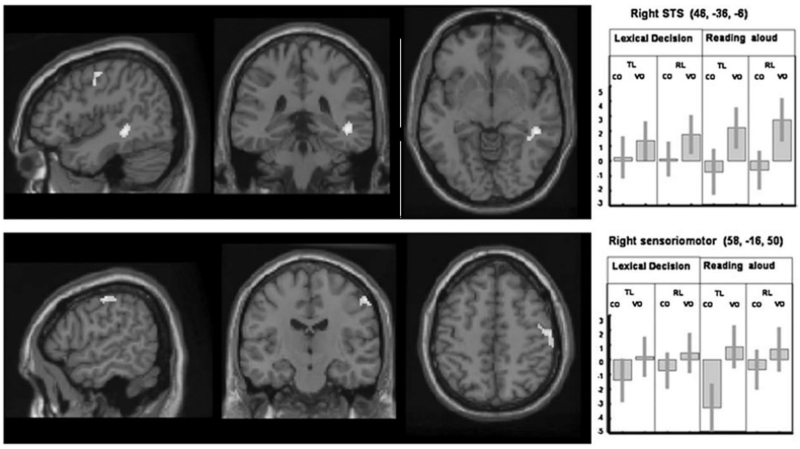

Figure 1 *Left part*: Axial, coronal, and sagittal sections (left part) for the contrast vowels > consonants in the right STS. All contrasts depicted at $P < 0.001$ uncorrected. *Right part*: Graphs of contrast estimates and 90% confidence intervals. TL, transposed letters; RL, replaced letters; CO, consonants; VO, vowels.

Since the results of the experiment are illustrated, revealing relations between these results and results from this type of experiment in other literature seems to be appropriate.

First of all, as discussed above, the experiment reveals that vowels and consonants have different standards concerning prosodic/lexico-semantic processing. Nespor offers a compatible approach stating consonants concerns the lexicon, and vowels concerns grammatical, plus prosodic information (c.f. Thierry, Cutler(2019) "How Consonants and Vowels Shape Spoken-Language Recognitions." p.35). This overlap lets us suggest that the result is more credible since the experiment is not the only one presenting this result.

Next to that, the observed similarity in the effects of vowel and prosody processing is consistent with the statement that vowels increase prosodic processing [Nespor et al. 2003] (c.f. Price,Carreiras (2008) "Brain Activation for Consonants and Vowels": p. 1730). Considering both results, one can go so far and state that one result ensues from the other one, and clarification is provided.

In addition to that, the event-related potential findings by Carreiras, highlighting that the specific processing of vowels is more posterior than the consonant ones, reveals a relation to the result that the location of the vowel effect can be located in the posterior STS and therefore explaining more extensive the context of vowel processing (c.f. Price, Carreiras (2008) "Brain Activation for Consonants and Vowels": p. 1730).

Nevertheless, there are some inconsistencies too. As revealed, the lexical decision activated the right hemisphere area linked to the response inhibition and did not activate an area correlated with lexical processing. A spoken study by Carreiras states that in using preserved consonant information, words are evoked better than in using preserved vowel information.

Additionally, the vowel and consonant prime types cause different brain response patterns (c.f. Thierry, Cutler (2019) "How Consonants and Vowels Shape Spoken-Language Recognitions." p.32). Findings by Lupker and Perea & Acha lead to the knowledge that C frames, in contrast to V sequences, can be jumbled up with little effect on lexical access (c.f. Thierry, Cutler (2019) "How Consonants and Vowels Shape Spoken-Language Recognitions." p.32). Taking these two results into consideration, you can say that the results of the experiment are inconsistent with the spoken study findings.

All things considered, most of the results are consistent with other results from similar studies making them more credible or broadening the topic's horizons, but eventually, we revealed one clear inconsistency. Nevertheless, the annual review of Linguistics, "How Consonants and Vowels Shape Spoken-Language Recognitions" by Nazzi Thierry and Anne Cutler, provides a plausible but also hypothetical explanation for this inconsistency: Seemingly, there is no need for printed-word recognition to engage mechanisms that are bound to the strong consonant/vowel asymmetries in lexical processing. As a result, consonants and vowels are considered as acoustic rather than written entities (Nazzi, Cutler (2019) "How Consonants and Vowels Shape Spoken-Language Recognitions." p 33). In trying to connect the named results, a more linked view on the topic is made and the emphasis is laid on the relation between the particular findings.

Henceforth, we will critically evaluate the essential findings and the concluded thesis based on the design of the experiment. Starting with the core of the paper, the experiment, and its design. As previously stated, the experiment combined multiple factors resulting in a variety of tested conditions and possible comparative values to investigate the stated hypothesis further. The 2 × 2 × 2 factorial design allowed more specific observations than experiments that only took one factor at a time into account. The factorial design also enabled combinations of different elements (for example, transposed consonants in the lexical task or replaced consonants in the reading aloud task), which helped to estimate the effects of a factor at several factors of the other elements. While a multilayered view on a particular factor can be quite interesting, it also sets limitations on the experiment with regard to the readers' comprehensibility. Adding factors results in an exponential growth of possible variations, thus making it harder to distinguish whether or not the experimental units are homogeneous if there are larger numbers of treatments.

Additionally, it is not easy to interpret the large size of factorial experiments, especially when the interaction between factors exists. Correspondingly, the example lacked detailed documentation of time measurement with respect to the differences between vowels and consonants, only presenting comparative rather than sole values. On the contrary, the experiment had an understandable way of determining the function of the STS. Also, exposing patients who have a lesion in the STS to the experiment to not only examine whether or not those patients are able to fulfill the reading aloud task but also test if the deactivation of the STS for vowels will decrease and thus presenting evidence for prosodic processing of the STS. Moreover, the exposed findings are process-specific since the activation patterns of consonants and vowels were task-specific. As a result, only restricted statements are possible. For instance, referring to the visual word processing study, the left hemisphere activation was not characterized by significant consonant versus vowel changes. In different tasks, like auditory word repetition or spelling, left hemisphere differences could possibly be observed for consonants contrary to vowels related. However, the given findings do not exclude such possibilities.

Another point is that the given task dependency concerning consonant versus vowel processing inside of visual processing tasks does not cover the possibility of consonant versus vowel discrepancies being independent of a task in the auditory domain.

To conclude, the paper has proper documentation of the set-up. It includes detailed information about the scanner and the intention of the author. Likewise, it also brought new knowledge into the research field of consonants versus vowels, namely that vowels have a link to the prosodic processing area in the brain.

References

Nazzi Thierry and Anne Cutler. "How Consonants and Vowels Shape Spoken-Language Recognitions." Annual Review of Linguistics, 2019.

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