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Motor preparation in picture naming tasks

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ABSTRACT

In certain circumstances, words can be uttered as an involuntary action. We hypothesize that, once pronunciation of a word is fully prepared it can be triggered as a reflex with no need for cortical processing. We used modified protocols of picture naming tasks, with different levels of cognitive demands, to measure reaction time to word pronunciation (RTWP). In test trials, picture presentation was accompanied by a startling auditory stimulus (SAS). When one and the same picture was repeatedly shown, SAS shortened RTWP by about 30% (StartReact effect), which did not occur when random pictures were shown. If subjects were led to learn which picture was to appear after repeated presentation of three pictures in sequence, they exhibited again the StartReact effect. We conclude that word pronunciation may be fully prepared for execution in absence of cognitive demands. However, the StartReact effect is inhibited during cognitive tasks.

1. Introduction

Preparation to perform a simple motor task implies enhancement of excitability in the structures required for its execution. In simple reaction time (RT) tasks, the more ready the subject is for task execution, the lesser should be the requirement for cognitive processing (Henderson & Dittrich, 1998). It is under these conditions that the StartReact effect may appear (Valls-Solé, Rothwell, Goulart, Cossu, & Muñoz, 1999; Carlsen, Chua, Inglis, Sanderson, & Franks, 2004), i.e., a significant shortening of RT when a startling auditory stimulus (SAS) is presented together with the imperative signal (IS).

A task undoubtedly involving cognitive activity is speech (Pulvermüller et al., 2006; Tremblay, Shiller, & Ostry, 2003). In one of their experiments, Stevenson et al. (2014) showed that the StartReact effect was present in vocalization of a syllable, using this observation to support cortical involvement in the physiology of the StartReact effect. Indeed, speech is a motor task requiring more cognitive processing than moving a limb segment (Grimme, Fuchs, Perrier, & Schöner, 2011). However, the relationship between cortical processes and speech production is not straightforward. There are examples conditions in health or disease in which utterance of a word may be an automated action. This is the case with recurring utterances in aphasia patients (Rodrigues & Castro-Caldas, 2014), some phonic tics in patients with Gilles de la Tourette syndrome (Worbe, Lehericy, & Hartmann, 2015), mantra-type practices (Berkovich-Ohana, Wilf, Kahana, Arieli, & Malach, 2015) or swearing in response to pain (Robertson, Robinson, & Stephens, 2017). In all these examples, words can be uttered without intervention of cognitive processes or dedicated thinking.

We reasoned that, by experimental manipulation, it would be possible to diminish the cognitive processing needed for speech production to a minimum and allow, in this way, subjects to prepare beforehand the articulatory channels for word pronunciation up to the extent that the StartRact effect is made evident. We used the Snodgrass and Vanderwart (1980) picture naming set to arrange for word pronunciation tasks with varying requirements of cognitive processing. In this type of test, when pictures are presented randomly, subjects require a high degree of cognitive processing to retrieve from memory the word corresponding to the object represented in the picture (Schuhmann, Schiller, Goebel, & Sack, 2009; Turken & Dronkers, 2011). Consequently, we should not expect a StartReact effect since execution

Abbreviations: LW, Learned Word; IS, Imperative Signal; RW, Random Word; SAS, Startling Auditory Stimulus; SW, Same Word

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circuits cannot be prepared beforehand. However, we predicted that, if we allowed subjects to know what picture to expect, then, they could prepare the articulatory mechanisms corresponding to the selected word beforehand. If this is the case, the StartReact effect would be fully expressed.

Our aim was to improve our understanding of the relationship between cognitive and executive aspects of word pronunciation, considering the StartReact effect as a probe for the degree of preparation. We further checked the influence of preparation in word utterances by presenting the subjects repeatedly with a set pattern of three subsequent images and, therefore, allowing them to learn what picture to expect after a few repetitions. We hypothesized that, as described for limb movements (Maslovat, Hodges, Chua, & Franks, 2011), the StartReact effect would appear only when subjects have learned the sequence and are able to fully prepare the task-specific execution channel in advance.

2. Methods

A group of 27 healthy, right-handed subjects participated in the study (aged 25–66 years, 10 women, 34 ± 12 years old - mean age ± standard deviation). The Ethics Committee of the Hospital Clinic of Barcelona approved the study protocol and all subjects signed an informed consent prior to inclusion in the study.

2.1. Recording word pronunciation

We attached an accelerometer (i.e., piezo crystal sensor Pro-Tech, U.S.A.) over the cricothyroid cartilage. Accelerometric signals were recorded with a conventional electromyograph (KeyPoint Net, Alpine Medical, Natus, U.S.A.) at a sampling rate of 2000 Hz with filter settings between 0.1 Hz and 200 Hz, time resolution of 2 s per division and gain of 1 mV per division. With this device, word vocalization was recorded as a series of reproducible and word-specific oscillations derived from vibration generated by the passage of air in the vocal cords (Leote et al., 2017; Vermula, 1979; Vitikainen, Mäkelä, Lioumis, Jousmäki, & Mäkelä, 2015).

2.2. SAS

The SAS was obtained by discharging the magnetic coil of a magnetic stimulator (MagStim, London, UK) over a metallic platform at an intensity of 100% of the stimulator's capacity. This delivered an auditory stimulus of 130 dB (sound-pressure level), suitable for eliciting the auditory startle response (Valls-Solé et al., 1995; Valls-Solé, Valldeoriola, Tolosa, & Nobbe, 1997; Valls-Sole et al., 1999). This was monitored by surface EMG recording from orbicularis oculi and sternocleidomastoid muscles, with pairs of silver cup electrodes (2 Hz–5 kHz). We chose these muscles because their activation indicates that the subject has normal startle responses (Maslovat et al., 2015).

2.3. Experimental procedure and study conditions

Subjects were sitting on a comfortable chair, with their hands resting on armrests, facing a computer screen (15 in. wide) placed at 1 m from the subject's eyes. The experimental setup was construed with Presentation® (Neurobehavioral systems, U.S.A.). The study conditions are schematically presented in Fig. 1. Briefly, there were control trials, containing only the IS, and test trials, in which the presentation of the IS was accompanied by the delivery of a SAS. We created blocks of thirty trials presented with an intertrial time of 20 s (from trial onset to trial onset). For each trial, a black background screen was presented first, containing a centered white "X" letter, as an attention fixation cue. After 4 s, the "X" disappeared as a forewarning sign and, 2 s later, the IS was presented as a visual stimulus consisting of a full-screen white frame with a picture of 8 × 8 inches on it. The picture was shown for 3 s and, therefore, the whole trial lasted 9 s, allowing for 11 s of rest from the end of one trial to the beginning of the next one. We divided the study in three consecutive sessions in different days (at least one day apart). The set up and experimental settings were the same in all three sessions. We ensured the quality and similarity of the recordings through measuring and comparing the electrodes impedance at the beginning of each session.

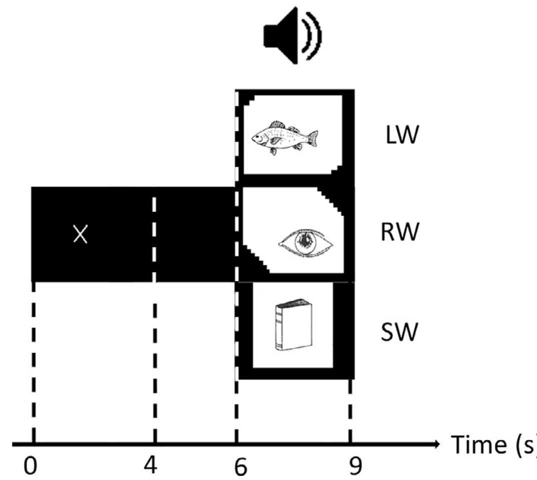

Fig. 1. Schematic representation of the experimental procedures. Subjects were instructed to utter as soon as possible, the word defining the picture that was shown as imperative signal (IS) in the computer's screen. Trials commenced with subjects fixating their gaze on the letter 'X' in the center of a black background. Disappearance of this symbol was the forewarning for the IS to be shown 2 s later. There were three different conditions: presentation of the same picture, requiring pronunciation of the same word in all trials (SW), randomly presented pictures, requiring pronunciation of words that subjects had to retrieve from memory at random (RW), and a perfect sequence of pictures, leading to learning the word to pronounce (LW). A startling auditory stimulus (SAS) was semi-randomly applied together with the IS in 6 out of 30 trials for each condition.

As stimuli, we used the pictures of the Snodgrass and Vanderwart collection for picture naming task (Snodgrass & Vanderwart, 1980). We selected only pictures whose names are either one or two syllables long in the language used for the study (Spanish). Subjects were asked to inspect the set of 24 selected pictures before starting the experiment in order to check the picture-name agreement, so as to ensure that it reached 100% before the experiment was carried out. Subjects were requested to pronounce aloud the word as early as possible at presentation of the picture. In every condition, test trials containing a SAS were presented simultaneously with the IS in 6 out of the 30 trials. Presentation was semi-random, as no SAS were presented in any of the first 3 trials, nor after another test trial.

2.3.1. First session

For the first condition in the first session, subjects were asked to select one out of the 24 pictures and memorize the word defining the selected picture. This picture was used as the IS for all 30 trials. Therefore, subjects were expected to fully prepare beforehand the motor structures needed for pronunciation of the expected same word in all trials (SW condition). In the second condition, which we ran after a period of rest of 20 min after ending the SW experiment, we used the same paradigm but subjects were presented with the whole collection of 24 pictures shown randomly, with no possibility to prepare the word to pronounce (RW condition). Subjects were often reminded that they had to pronounce the word defining the object shown in the picture as fast as possible along the test.

2.3.2. Second session

Subjects were presented with the images for the picture-naming