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Sex differences in oral asymmetries during wordrepetition

MARKUS HAUSMANN,* SIMONE BEHRENDT-KÖRBITZ, HEIKE KAUTZ, CHRISTINA LAMM, FRAUKE RADELT and ONUR GÜNTÜRKÜN

AE Biopsychologie, Fakultät für Psychologie, Ruhr-Universität Bochum, D-44780 Bochum, Germany

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Abstract—During speech production the right side of the mouth is opened to a larger degree in most people. This facial asymmetry is thought to be related to a left hemisphere dominance in language processing and/or motor programming. We investigated asymmetrical lip separations during discrete or serial word productions in right handed persons. The results revealed a right sided lip separation bias in both genders during discrete word production in which the words had to be uttered once. As soon as the words had to be produced continuously, however, a clear sex difference appeared with males having the usual right bias but females now showing no clear asymmetry, with a tendency for larger lip separations on the left side. These results suggest the existence of two separate neural systems from which one controls the discrete task and which is left hemisphere dominant in both genders. The other is probably involved in serial word productions and shows a sex difference with regard to its asymmetry pattern. © 1998 Elsevier Science Ltd. All rights reserved.

Key Words: gender; motor programming; lateralization; apraxia; speech; hemispheric asymmetries.

Introduction

Speech is often accompanied by subtle asymmetries of facial muscles which mostly lead to larger mouth openings on the right. It is supposed that the left hemisphere dominance for speech and motor selection leads through the crossed pyramidal (voluntary movements) and extrapyramidal (involuntary movements) tracts [13] to a stronger contralateral activation of the lower face muscles on the right [9]. This activation hypothesis might also explain the more pronounced gesticulations on the right during speech [14]. Similar results are obtained in interference tasks: it is more difficult to balance a small wooden dowel on the forefinger of the right hand than on the left during speaking. If the same object is balanced with the hand located ipsilateral to the speech-dominant hemisphere, no interference appears [18]. In these tasks it is especially controlled rather than automatic speech which causes interferences with right hand performance [28].

Clinical data make it conceivable that the left hemisphere dominance for many aspects of language processing is causally linked to its prominent role in the programming of movements. Patients with left hemisphere lesions often show, besides aphasic symptoms, additional deficits in manual skills [17]. This common appearance of aphasic and apraxic disorders after left hemispheric damage has been first observed by Liepmann [19], who proposed that the left hemisphere plays an important role in the control of a number of different motor behaviors, of which speech is but one example. Kimura has recently extended this suggestion by arguing that, at least for oral movements, there are two anatomically distinct, yet functionally linked, systems within the left hemisphere that are involved in the production of the motor outputs. One is involved in the production of a single movement, while the other is involved in selecting movements and facilitating an efficient transition from one movement to another [4, 15]. With increasing complexity of oral movements during speech production, left hemisphere processes are increasingly involved [20] and right-sided oral motor asymmetry becomes more pronounced [4]. On the other hand, there is evidence from aphasic patients that highly automatized speech can even lead to a greater opening of the left side of the mouth controlled by the right hemisphere [7].

Sex differences are a further feature of cerebral asymmetries, with men generally shown to be more lateralized

* Corresponding author. AE Biopsychologie, Fakultät für Psychologie, Ruhr-Universität Bochum, 44780 Bochum, Germany. Tel.: 0049 2347004323; Fax: 0049 2347094377; E-mail: markus.hausmann@ruhr-uni-bochum.de

than women [21–23, 26], although counter-examples exist [1, 30]. In this context, Graves *et al.* [8] observed that males show stronger right-sided lip separations during continuous word production than females. Wolf and Goodale [29], however, observed just the opposite pattern. It is possible that these contradictions result from the interaction of the two variables of speech complexity and sex which have not yet been systematically studied. The present study looks at the effects of these variables in right-handed people.

Methods

Thirty-nine subjects (students of 19–42 years, 19 males, 20 females) participated in this experiment. Their right-handedness was determined with the Edinburgh Inventory [25]. All subjects were native German speakers and were told that the size of their pupils during the single or repeated production of neutral or emotional words was to be monitored. No subject had any previous injury to the face or jaw, or wore dental braces. All men were clean shaven.

The experiment started by placing the forehead of a seated subject against a headmount which allowed free mouth and lower jaw movements. All subjects were instructed to keep their head and body still during the whole test. The lower face region was monitored by a video camera and the movements of the mouth were recorded for later analysis with a time lapse video system (JVC BR-S920E). A strong light source was located behind the camera to ensure clear contrast between the lips and the mouth opening. The experimenter spoke the stimulus words, to be repeated by the subjects. Three words, which all start with the bilabial phoneme "Ma" as initial syllable ("Marmor", "Massaker", "Mabopi"), were used as stimuli. The first is a neutral word, the second a non-neutral negative word, while the third is a non-word. The fourth stimulus was the syllable "Ma". The four stimuli were to be produced both in a discrete and in a serial condition. In the discrete condition the subjects had to speak each of the four words only once. In the serial task they had to repeat the word until the experimenter interrupted by saying "stop". This was always done after the tenth word. All subjects participated first in the discrete and then in the serial condition.

In the subsequent analysis the frame with the largest lip separation during production of the initial syllable "Ma" was selected by searching the video band in steps of 40 ms. In the discrete condition this frame was used for analysis. In the serial condition the initial syllable "Ma" of the first, third and sixth repetition of the word was analysed. "Ma" is a useful phoneme for this kind of analysis, since it starts with a complete closing of the lips and ends with a clear opening.

To define the two points of measurement on the left and the right side of the mouth in these still images, the two horizontal ends of the lips were marked and a line was drawn joining the two end points. The midpoint was determined and the mouth was thus divided into right and left sections with a line perpendicular to the horizontal. The height of the left- and the right-sided lip opening was then determined at the point of transition from the first to the second quarter (right side) and at the transition from the third to the fourth quarter (left side) of the horizontal line [11].

Wolf and Goodale [29] observed absolute larger mouth openings in males than in females. To avoid confounding variables of this kind, relative instead of absolute opening values were used. Thus, left-sided mouth openings were set with relation to right-sided ones. The asymmetry index (AI) was then calculated as $R-L/R+L$. All values of this index range between $+1$ and -1. Positive values indicate right-sided asymmetries, while left-sided asymmetries result in negative values.

Results

The measurements of the asymmetry index (AI) of all 39 subjects were used in the analysis. The general results are shown in Fig. 1a–d which represents the asymmetry indices of each stimulus differentiated for "sex" and "series". Positive values give larger right-sided lip openings. We found the same right-sided asymmetry patterns for the male group over all stimuli and the "series" condition. The female subjects evinced right-sided asymmetries only in the discrete condition, while in the serial (repeated) condition there were, on average, larger left-sided mouth openings.

The differences between the sex, word, or series specific AIs were analysed with a $2\times4\times4$ (sex $\times$ words ("Ma", "Mabopi", "Marmor", "Massaker") $\times$ series (discrete or 1, 3, 6 repetition)) ANOVA with repeated measurement. Over all conditions, the main effect of "sex" was only marginally significant ($F(1,37)=3.26$, $P<0.08$). In contrast, the main effect of "series" ($F(3,111)=4.36$, $P<0.01$) as well as the interaction between "series" and "sex" ($F(3,111)=3.26$, $P<0.025$) were significant. There was no significant difference on words ($F(12,444)=0.67$, n.s.).

Calculating an ANOVA separately for each individual series category (discrete and serial S1, S3, S6) revealed similar patterns of results for each word. Therefore the data from the four words were pooled in subsequent calculations (Fig. 2).

The ANOVA from the pooled conditions showed, that in the discrete condition the oral asymmetries were almost identical for both sexes ($F(1,37)=0.47$, n.s.). Thus in this case both groups produced a right-sided bias in their lip separations. However, the data set elicited important sex differences in the serial condition. Calculating a 2×3 (sex $\times$ 1, 3, 6 repetition) ANOVA for the serial condition revealed a significant effect for sex ($F(1,37)=4.18$, $P<0.05$), but no significance for "series" ($F(2,74)=1.18$, n.s.) and no significant interaction between sex and "series" ($F(2,74)=0.36$, n.s.). One way ANOVAs for each of the repetitions revealed that only the first (S1) repeated condition evinced a significant difference between sexes ($F(1,37)=6.09$, $P<0.02$), while the S3 ($F(1,37)=2.19$, $P>0.1$) and S6 ($F(1,37)=3.26$, $P<0.08$) conditions lacked significance. Additionally, female subjects evinced a marginally significant trend for decreasing asymmetries during word repetitions, as revealed by a planned comparison with linear polynomial contrasts ($F(1,37)=3.67$, $P=0.063$).

The previous analyses reported sex effects, analysed with respect to the different experimental conditions. In the following analyses, strength of oral asymmetries were analysed to reveal conditions which produced lateralized

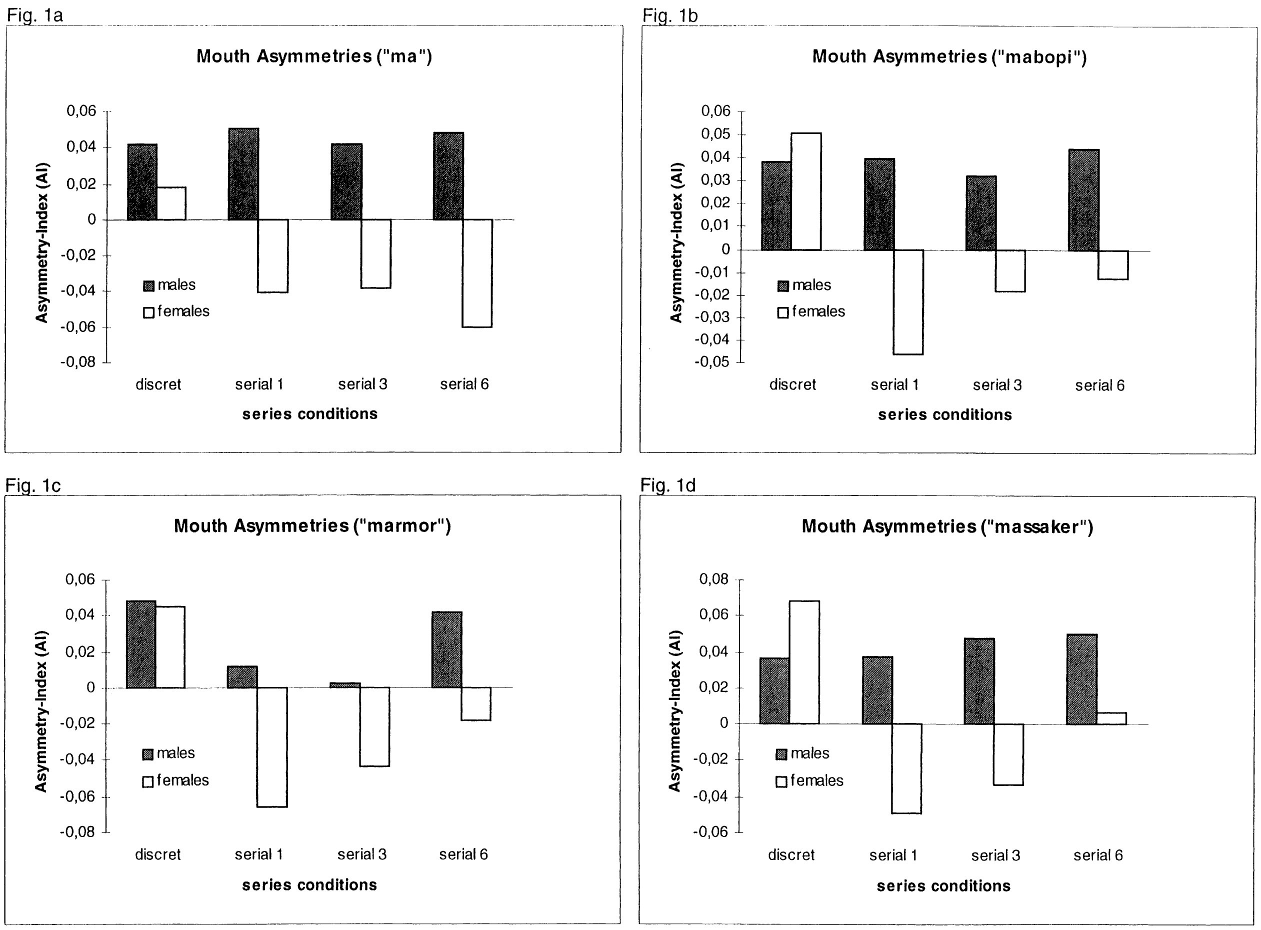

Fig. 1. (a–d). Asymmetry indices (AIs) in the discrete and serial conditions of each stimulus. Positive values give larger right-sided lip openings.

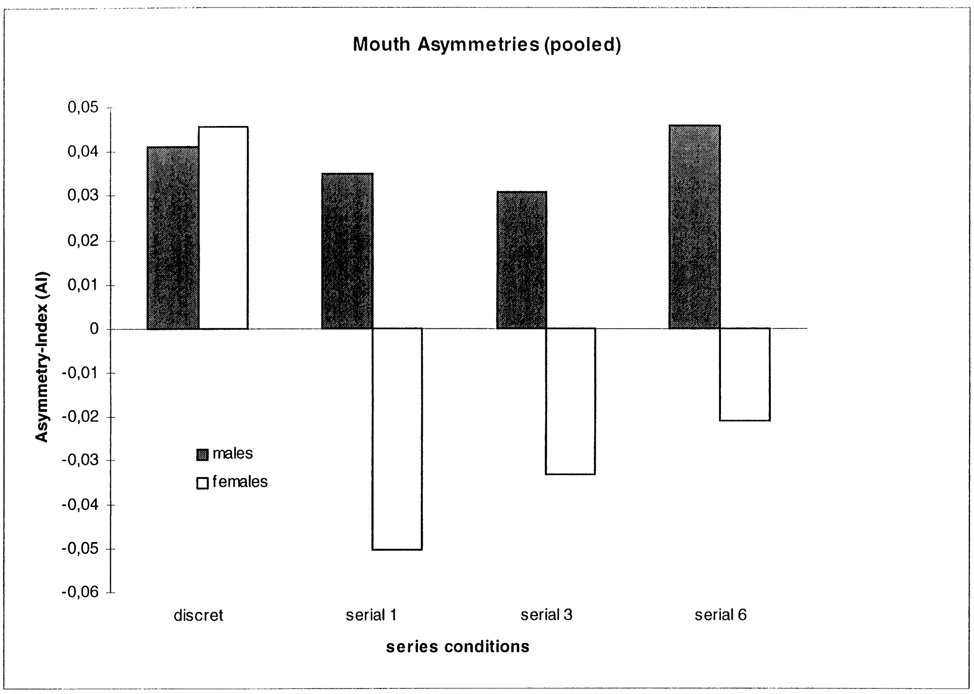

Fig. 2. Asymmetry indices (AIs) in the discrete and serial conditions of the pooled stimuli. Positive values give larger right-sided lip openings.

lip openings significantly deviating from symmetry. For this we computed one-sample *t*-tests which compared the AI ratios with the virtual symmetry score 0. For the males, all conditions exhibited significant right-sided asymmetries (discrete condition: $t(1,18) = 4.93$, $P < 0.001$; serial conditions (S1, S3, S6): S1: $t(1,18) = 5.58$, $P < 0.05$; S3: $t(1,18) = 2.31$, $P < 0.05$; S6: $t(1,18) = 5.21$, $P < 0.001$). The female group showed a significant right-sided asymmetry only in the discrete condition ($t(1,18) = 2.48$, $P < 0.05$). In the serial condition their oral asymmetries shifted in the direction of a larger left-sided lip separation, but this effect was not significant in any of the serial conditions (all *t*s $(1,19) < -1.63$, n.s.). Thus statistically, female subjects evinced symmetrical mouth openings throughout the serial condition.

Men's faces are larger, with heavier jaws and bigger muscles in the lower portion [2, 3]. To control the possible influence of mouth size on the mechanical and dynamical aspects of speech movements, we calculated the range of mouth size of our subjects. Within each sex, we then dichotomized the subjects into large or small mouthed individuals. There was no significant influence of mouth size on asymmetry in either group (females: $F(1,18) = 0.37$, n.s.; males: $F(1,17) = 1.77$, n.s.). Additionally there was no obvious difference in speech rate between males and females. Thus only sex could be the relevant mediator for the described effects.

In each of the experimental conditions females showed larger variances in their oral asymmetries than males. To analyse this effect, a *t*-test of the variances of males and females in all 16 conditions (4 words $\times$ 4 series) was calculated. This calculation revealed that females produced significantly larger variances in their experimental results ($t(1,15) = -5.91$, $P < 0.001$).

Discussion

The results of the present study reveal that males show consistent right-sided oral asymmetries both in the discrete and the serial condition. Females evince this pattern only in the discrete contingency while they display a left-sided tendency in the serial condition (Fig. 3). The switch between a right-biased lip opening to a more symmetrical pattern at the transition from the discrete to the serial condition is, in women, most obvious during first word production. This pattern might indicate that discrete and serial word productions are controlled by two dissociable neural systems whose asymmetry is moderated by sex.

The right-sided oral asymmetry for both sexes during single word production accords perfectly with a large number of reported studies pursued up to now [5, 7, 8, 10, 12, 29]. The result of the present study, in addition, shows that a sex difference is absent in simple discrete verbal tasks, but appears in the complex serial condition. Contrary to our data, Wolf and Goodale [29] reported stronger right-sided oral asymmetries in the female group, which were particularly pronounced when the bilabial phonemes were embedded in a series of other phonemes. One explanation for this might be that Wolf and Goodale [29] only tested a small and unrepresentative sample. This is especially likely since, in our and several other studies [e.g. 21], the female data had a considerably higher variance than those of males, even when analysing conditions separately.

It should be noted that in the production of connected speech, in multisyllabic utterances for instance, the position of the articulators at any point in time is a function not only of the phoneme target currently being uttered but also of those produced and those about to be produced. These coarticulations possibly play a role in determining mouth opening at the peak position. Although these speech phenomena could possibly have contributed to some of the data patterning, it is unlikely that they produced the asymmetries to a significant extent. Otherwise we would expect the different target words with their differing coarticulation patterns to exert varying effects on lateralized mouth opening. This was not the case.

Graves *et al.* [8] and Graves and Landis [6] indicated that, during a picture description task, right-handed males show greater oral asymmetries than did right-handed females. The authors concluded that this result might be due to an additional involvement of emotional or visuospatial factors during this task which primarily occurred in women. Purely verbal tasks were reported not to produce sex-variant mouth asymmetries [8]. The results of the present study make a more parsimonious hypothesis likely. Our data were invariant on the emotional meaning of the uttered words. Additionally, no visuospatial processes were needed to master the task and the subjects did not display any obvious prosodic variations. Therefore, the present data set can be explained by proposing the existence of two separate neural systems for motor programming. One of them controls the discrete task while the other one is involved in a serial condition with its multiple word-to-word transitions. In males both systems are located in the left hemisphere. Females show left dominance only in the discrete condition while a bilateral or even right hemisphere based neural system is activated during the serial task. This hypothesis accords with several different lines of evidence. Based on a large sample of unilaterally lesioned patients, Kimura [15] has suggested the existence of two functionally linked motor systems within the left hemisphere. One of them controls the production of single movements while the other one is involved in selecting motor outputs and in facilitating an efficient transition from one movement to another. Likewise, Nicholson and Kimura [24] found sexual variation in the neural organization of motor programming systems which was investigated in single vs speeded repetition of speech and manual movements. Males tended to have a basic motor-speed advantage while women differed in being faster at programming a sequence of movements. Combined with

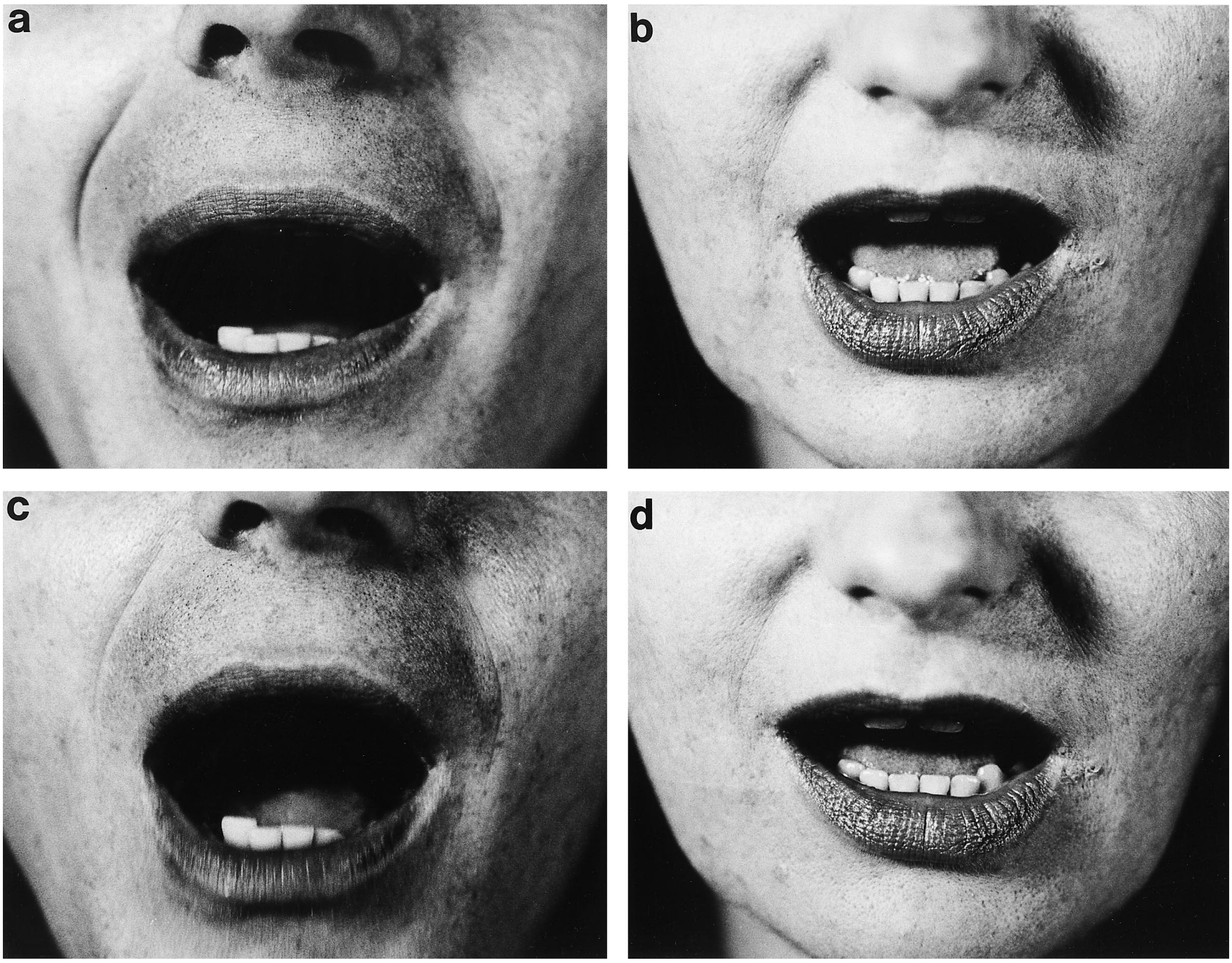

Fig. 3. Illustration of the lip separations during the production of the initial syllable "Ma" in the sequence "Mabopi" in males (a, c) and females (b, d) during the discrete (a, b) and serial condition S1 (c, d).

our study, this could indicate that these two systems are differently organized with respect to sex as well as hemisphere.

One open question is the smallest unit of motor programming. According to Kimura [16] the left anterior cortex is paramount for the reproduction of single oral movements like a single syllable, while the posterior cortex is critical for mediating multisyllabic speech like in words or phrases. If the distinction apparent in our data taps the same functional division, the smallest motor programming unit is not necessarily a syllable, but an entity which is defined by the person according to the instructions of the task. This is exemplified in the discrete condition of the present experiment in which the syllable "Ma" gave the same right-sided bias as the word "Mabopi" or "Massaker", although the latter were multisyllabic. However, the syllable "Ma" produced, in the first production of the repeated condition, a left-sided bias in women when the instruction was to repeat the stimuli over and over. Thus the functional division between a single- and a multi-unit programming system seems not to be built around syllables as elements but around units as defined by the persons relative to the task. This is in line with studies in cognitive psychology, which show that people need a longer time to initiate an utterance proportional to the number of words, irrespective of the number of syllables in these words [27]. Thus advance motor programming uses entities like words or even short phrases and not necessarily syllables.

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