DUAL-TASK EFFECTS ON SPEECH AND NON-VERBAL TASKS ACCORDING TO TASKS PROPERTIES

Michaela Pernon[1&2], Maryll Fournet[2&3], Cécile Fougeron[1], Marina Laganaro[4]

[1] Laboratoire de Phonétique et Phonologie, UMR7018, CNRS-Sorbonne Nouvelle (France); [2] Department of Clinical Neurosciences, Geneva University Hospital(Switzerland);[3] FAPSE, University of Geneva (Switzerland)

michaela.pernon@gmail.com ; Maryll.Fournet@unige.ch ; cecile.fougeron@sorbonne-nouvelle.fr ; Marina.Laganaro@unige.ch

ABSTRACT

Speaking while doing another task is frequent in everyday life. While the effect of speaking on performing another task has been often studied, little is known on the effect of dual-task on speech, or on the bidirectional interference of one task on the other. Here, we investigate dual-task effects on both speech rate and on performances in non-verbal attentional tasks with a bidirectional approach. Task properties are varied for the type of speech task: counting vs. sentence production, the type of non-verbal tasks in terms of attentional demand (go vs. go-nogo), and mode of presentation of the stimuli. Speech rate is found to decrease under dual-task conditions only in the counting task, and with most of the concurrent non-verbal tasks. Processing of the non-verbal tasks is also modified when speaking, but the direction of the effect depends on the type of speech tasks and of non-verbal tasks.

Keywords: dual-task, speech rate, type of speech task, attentional demand.

1. INTRODUCTION

Dual-task is frequent in everyday life, for instance when we talk while driving. Observations from dual-task paradigms in experimental settings or in clinical practice, show that the simultaneous execution of two tasks may induce interference of one task on the other, as compared to when the tasks are done in isolation.

Different theories provide explanations for the bidirectional effects of the dual-task condition on both tasks, in relation with the underlying mechanisms or strategies adopted by the subject to accomplish the two tasks. The Capacity sharing theory considers that people share processing capacity among tasks [11]. Since there is less capacity for each individual task when done simultaneously, performance on one or on both tasks may be decreased [18]. The central bottlenecks model [18], as well as other accounts such as task-switching or time-sharing hypotheses, links the dual-task cost explanation to the fact that attention can be given only to one task at the same time. In such accounts, if two simultaneous tasks need attention, one of them is suspended and delayed while the other one is carried out.

Different factors have been found to influence the interference between simultaneous tasks. Among them, the modality [24] and the mode of presentation of the stimuli to be processed [17] can affect the overlap in time of the two tasks [8]. The priority given to one task over the other, and the speed allowed for processing also modulate the dual-task effects. Finally, the degree of automaticity of the tasks [14, 19], their resource demands and complexity [16] are crucial for observing dual-task effects. When it comes to language, dual-task interference has been studied in particular to identify which utterance planning processes need attentional resources. Such studies have focused on abstract, linguistic processes such as lexical selection or phonological encoding [9, 24], whereas, little is known on the effect of dual-task on the speech itself. First, speaking has often been used as a secondary task in experiments focusing on the performances on another simultaneous task, walking for instance [2]. Second, results on dual-task effects on speech are controversial or difficult to generalise in particular because both the speech tasks and the concurrent tasks vary across studies. For the concurrent task, they include for instance visuo-motor tasks (e.g. placing objects on a board [6]), or other linguistic tasks (e.g. grammatically correct sentences generation [5]), or cognitive tasks (e.g. two-digit math subtractions [5]). As for the speech tasks, they include sentence repetition/production [3, 6], recitation of automatic series such as counting [10], semi-spontaneous speech [8, 10, 13, 15]. In addition to the variability in the content of speech tasks, different speech properties have been studied, spanning from voice intensity [5, 6, 10, 15], to temporal dimensions such as speech initiation time, pause time [10], speech rate [15], utterances durations [3] or disfluencies [4]. Regarding speech rate which will be of particular interest here, opposite results have been reported. Speech rate was not affected by a simultaneous visuo-motor tracking task in [10] or by a verbal working-memory task in [4]. On the other hand, speech rate decreased during walking, finger tapping and noise hearing [12] and increased with a simultaneous visuo-motor pegboard task [5].

Surprisingly, only a few studies have looked at bidirectional effects in dual-task paradigm where one task is usually the focus and the other task is a way to

create interference. Analysing performance on both tasks might be of specific interest to better understand strategic effects in the allocation of attentional resources among tasks [22]. Among the studies which include a speech task in a dual-task paradigm, some find bidirectional effects [3, 8] while others don't find it systematically [12, 15]. Since the tasks' parameters, participants and speech dimension vary across studies, a clear comparison remains difficult. Moreover, the experiences often do not integrate the variable of the mode of presentation of the stimuli to be processed that the input and output modalities or instructions could generate. The goal of the present paper is to shed light on the attentional resources required for speech by investigating the bidirectional dual-task effects of producing overlearned speech utterances while doing a concurrent non-verbal task varying in mode (continuous versus discrete) and attentional demand (go versus go-nogo). We use overlearned speech sequences to minimise the linguistic planning processes and investigate the attentional resources required by motor speech planning. We conducted with the same participants two experiments differing in the mode of presentation of the stimuli in the non-verbal task (continuous versus discrete), each including two types of speech task (counting vs. sentence production) and two dual-task levels of attentional demand (go vs. go-nogo) and analysed the results in a bidirectional approach.

2. METHOD

Twenty-seven young adults (6 males, 21 females) were recruited at the Faculty of Psychology and Education Sciences in Geneva. They were aged between 19-29 years old (mean age: 22, SD: 2,8).
The experimental procedure is presented in Table 1, all tasks were done in single condition (SINGLE) either speech only or non-verbal task only; and in a dual-task condition (DUAL) with simultaneous speech and non-verbal tasks.
Speech tasks: two speech tasks were performed and audio recorded. The speech in the first task is rather automatic and involves a sequential rhythm since the speaker had to count from 1 to 20, digit by digit. In the second task, the production is more linguistically elaborated but overlearned as the speaker had to repeat continuously a 'meaningful' sentence: "papa et papi papotaient tout à coup", [papaepapipapɔtɛtutaku] (*Dad and grandpa were suddenly chatting*). All the syllables of the sentence have a CV structure, with unvoiced C to facilitate acoustic segmentation. For both speech tasks, the speech material (i.e. the 1-20 count (24 syllables) and the sentence (11 syllables) are repeated in a loop during 55 second.
The two speech tasks were produced in a speech-only condition at the beginning (SINGLE: counting task 1, sentence production task 1) and at the end (SINGLE:

counting task 2, sentence production task 2) of each experiment to control for a potential learning bias and were averaged.
Non-verbal tasks: for the non-verbal tasks, two modes of presentation of the stimuli to be processed are used in two separate experiments. In *Experiment 1*, visual stimuli (geometrical shapes) are presented one by one (hence, in a 'discrete' mode of presentation of the stimuli) on a computer screen and participants have to detect a target shape. Manual responses (accuracy and reaction times) are recorded by the keyboard. The non-verbal task in *Experiment 2* is a paper-and-pencil task, where rows of visual stimuli are all presented on a paper sheet and participants have to cross the target stimuli in a 'continuous' mode from left-to-right. In each of the two experiments, 2 types of non-verbal tasks varying in attentional demand are tested: a go task (GO) involving sustained and selective attention, and a go-nogo task (GONOGO) involving also inhibition.
For the GO task in *Experiment 1*, participants had to click when they saw a circle on the screen (with only circles appearing during the task), while for GONOGO task, they had to click only for "x" sign and not for the "+" sign. There were 24 target stimuli on the 55 s. period in the GO, and 16 in the GONOGO condition (along with 8 NOGO items). The experiment was programmed using PsychoPy® (version: 1.85.0) [20] and used pseudo-randomized interstimuli intervals (1500, 2000, 2500ms). Duration of each task was 55 s.
For the GO condition in *Experiment* 2, participants had to cross target shapes, i.e. triangles presented in rows with circles, while for the GONOGO, they had to cross circles only when preceded by a triangle. Duration of each task was 55''.

Table 1: Experimental design for both *Experiment 1* and *Experiment 2*.

condition	speech task	non-verbal task	duration
SINGLE	counting task 1	-	55''
SINGLE	sentence production task 1	-	55''
SINGLE	-	GO	55''
DUAL	counting task	GO	55''
DUAL	sentence production task	GO	55''
SINGLE	-	GONOGO	55''
DUAL	counting task	GONOGO	55''
DUAL	sentence production task	GONOGO	55''
SINGLE	counting task 2	-	55''
SINGLE	sentence production task 2	-	55''

The order of the experiments (1 or 2), of the tasks for the non-verbal GO and GONOGO, and for the speech tasks (counting and sentence production) were counterbalanced across the 24 participants. The participants were instructed to speak at their usual speech rate and could breathe anytime needed. For the computerized visuo-manual task in *Experiment 1*, they had to press space bar as soon and as accurately as possible for the targets. For the paper-and-pencil visuo-motor task in Experiment 2, they had to

proceed line by line without going back to correct themselves. During the dual-task condition, they had no instruction about task prioritization and were asked to perform both tasks at the same speed and accuracy as in single condition.

The effect of dual-tasking on speech is measured on speech rate, computed as the number of syllables per second for each of the two speech tasks in each condition. For non-verbal tasks, performance is assessed via mean reaction time for correctly processed target stimuli in *Experiment 1* and number of correctly processed stimuli in 55'' in *Experiment 2*. In both experiments, the effect of dual-tasking on speech and on the non-verbal task is tested with repeated-measures ANOVAs with conditions (3 levels: SINGLE, DUAL-GO, DUAL-GONOGO) as a within subject factor separately for each speech task and non-verbal task. Posthoc pairwise comparisons were performed using Tukey's HSD. Critical significance was set at $p < .05$. The effect size is indicated by partial eta-squared.

3. RESULTS

3.1. Experiment 1

Figure 1: mean speech rate (nb of syll/ s.) averaged across participants (N=27) and standard deviations for counting and sentence production tasks in *Experiment 1* according to 3 conditions: SINGLE, DUAL-GO, DUAL-GONOGO.
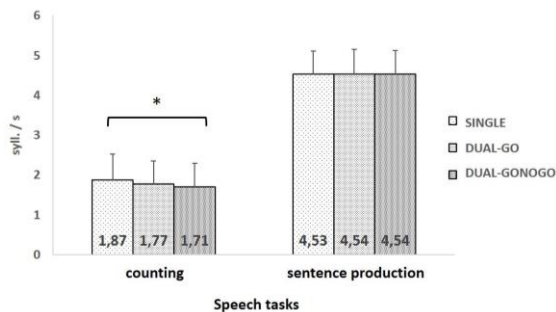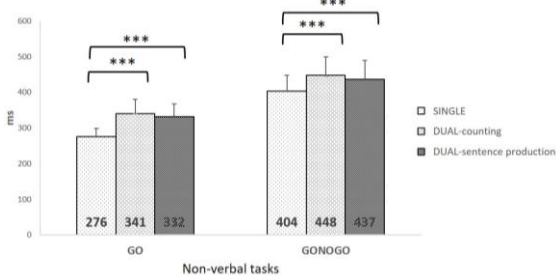

Figure 2: mean reaction times (ms) averaged across participants (N=27) and standard deviations in the GO and GONOGO non-verbal tasks in *Experiment 1* according to 3 conditions: SINGLE, DUAL-counting, DUAL-sentence production.

Rate in the speech tasks: as shown in Figure 1, speech rate was significantly affected by the condition, but only for the counting speech task (F (2, 52) = 3.93, p<.05; partial η^2= .13). This effect was due to the dual-GONOGO condition where counting was produced with a slower rate than in SINGLE condition (p<.05).

Performances in the non-verbal tasks: reaction times for GO (F (2, 52) = 69.5; p < .001; partial η^2= 0.73) and for GONOGO (F (2, 52) = 12.3; p<.001; partial η^2= 0.32) tasks were affected by conditions. As shown in Figure 2, both the GO and GONOGO non-verbal tasks had longer reaction times in the Dual settings, either when participants simultaneously counted or produced sentences, as compared to the SINGLE condition (all: p<.001).

3.2. Experiment 2

Rate in the speech tasks: in this experiment, speech rate, shown in Figure 3, was also affected by condition only in the counting speech tasks (F (2, 52) = 5.37; p<.01; partial η^2= 0.17). Counting was slower in dual-task settings with both the GO (p<.05) and GONOGO (p<.01) tasks compared to when done with no other tasks (SINGLE).

Figure 3: mean speech rate (nb of syll/s.) averaged across participants (N=27) and standard deviation for counting and sentence production tasks in *Experiment 2* according to 3 conditions: SINGLE, DUAL-GO, DUAL-GONOGO.
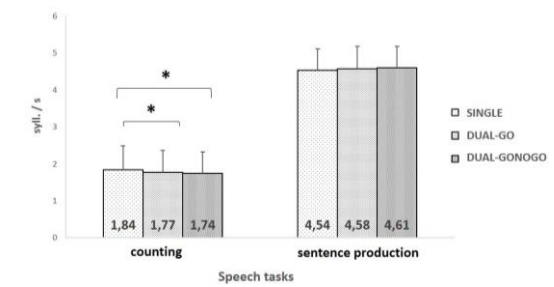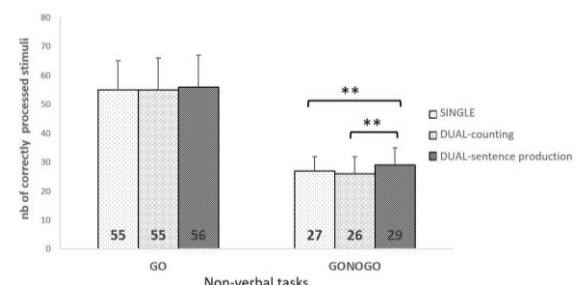

Figure 4: mean number of correctly processed stimuli averaged across participants (N=27) and standard deviation in the GO and GONOGO non-verbal tasks in *Experiment 2* according to 3 conditions: SINGLE, DUAL-counting, DUAL-sentence production.

Performances in the non-verbal tasks: the number of correctly processed stimuli (Figure 4) depended on condition for the GONOGO task (F (2,52) = 7,15; p < .01; partial η^2= 0.22), but not for GO task. Surprisingly, in this GONOGO task, more stimuli were correctly processed in the dual condition with concomitant sentence production, compared to both

the SINGLE condition (p <.001), and the dual condition where the participant had to count (p<.01).

3. DISCUSSION AND CONCLUSION

Here, we investigated the influence of the type of speech tasks, attentional demand of concomitant tasks and mode of presentation of the stimuli. Modification of speech rate is interpreted as a cue to attentional demand of speech production. The bidirectional analysis of the effects of one task on the other is a way to estimate the underlying mechanisms and global strategies adopted by the speakers when dual-tasking. Our results first show that dual-task effects are not similar across speech tasks. A dual-task effect on speech rate was found for the counting task in both experiments. This result is opposite to [10]'s results, who found a constant rate in counting during a visuo-motor tracking task. In contrast, we did not find a dual-task effect on speech rate of the sentence repetition task, which is similar to what was found by [5] and [3] with other concurrent non-verbal tasks. Differences in dual-task effects according to the type of speech task could be due to the fact that the attentional resources to be shared with the other non-verbal tasks are recruited only in counting, which is an automatic speech task but which may require inhibition when it is done in a loop. Subsequent analyses will be done to analyse if the slowing of speech rate is more important close to the end of the 1-to-20 series where speakers need to inhibit the next digits and reset a new loop. For the sentence repetition task, the absence of dual-task effects could be due to the fact that the sentence had to be repeated again and again and therefore becomes quite automatic and overlearned with no or very little linguistic planning. This learning effect was also found by [5] for the speech measures of a repetition task with visuo-motor task and linked to the practice of the speech task in the single condition done before. It could be relevant to analyse another parameter of speech fluency like disfluencies that could be more sensitive to dual task effect than speech rate.

The other factor found to influence dual-task effects in our study relates to the difference between experiment 1 and 2 and the attentional demands of the non-verbal tasks. Indeed, counting is slower when the stimuli of the secondary task are presented in a discrete mode (in experiment 1), but only for the condition requiring enhanced attentional demand, i.e. inhibition in the GONOGO conditions. In experiment 2, where the processing of the non-verbal task can be done in a continuous way by the participant (all the stimuli to be processed are in front of the participant and proceed at his/her own pace), the counting is slower with both concurrent GO and GONOGO tasks.

Regarding the non-verbal tasks, a dual-task effect is also found when they were performed while speaking. However, the effect goes in opposite directions in the two experiments. In experiment 1, a negative dual-task effect is observed with longer reaction times for correct answers. In experiment 2, a positive dual-task effect is found with an increase of stimuli processed when participant had to produce sentences simultaneously (but not while counting). It is difficult to compare performances based on two different measures, reaction time in the computerized experiment 1 and number of correctly processed stimuli in the paper-and-pencil experiment 2. Reaction times may be more sensitive to task demand and can reflect the slowing down of the processing of the non-verbal task when participants had to count simultaneously. It is also possible that the attentional demand for the non-verbal tasks is stronger in experiment 1 than in experiment 2. Assuming that processing capacity are shared among the two tasks [11, 18], the bidirectional interference between the non-verbal task and the speech task is thus stronger for the more demanding tasks: the non-verbal task in experiment 1 and the counting speech tasks, showing both a slowing down (in reaction time and speech rate) when done simultaneously. The limit in capacity hypothesis thus do not explain the positive dual-task effects found in experiment 2 for the non-verbal go-nogo task (increased number of processed stimuli in the sentence production condition). We can see here the interest of analysing both speech and secondary task's performances because another type of processing might take place. While speech is slowed in dual-condition, number of processed visual stimuli rises. This could reflect a ''magnet effect'', which is the tendency of biological oscillator to attract each other [7]. As also found by [5] and [21], the shared motor modality of processing (writing for the non-verbal task and speaking) could facilitate the attraction of the rhythmic pattern adopted in the two tasks and create a positive "energizing effect", as the one found for Parkinson's disease patients who increase voice intensity when dual-tasking [1, 15].

The present findings confirm the recruitment of attentional resources in speech production but only for specific speech tasks. The underlying mechanisms or strategies used by healthy subjects to achieve dual-task depend on the type of speech task, the attentional demand of the non-verbal tasks and the mode of presentation of the stimuli. Further analyses of the data will include time point analyses of non-verbal tasks and more refined analysis of speech rate and speech rhythm.

4. AKNOWLEDGMENTS

5. REFERENCES

[1] Adams, S. G., Winnell, J., Jog, M. 2010. Effects of interlocutor distance, multi-talker background noise, and a concurrent manual task on speech intensity in Parkinson's disease. *Journal of Medical Speech-Language Pathology*, *18*(4), 1-9.

[2] Armieri, A., Holmes, J. D., Spaulding, S. J., Jenkins, M. E., Johnson, A. M. 2009. Dual-task performance in a healthy young adult population: Results from a symmetric manipulation of task complexity and articulation. *Gait & posture*, *29*(2), 346-348.

[3] Bailey, D. J., Dromey, C. 2015. Bidirectional interference between speech and nonspeech tasks in younger, middle-aged, and older adults. *Journal of Speech, Language, and Hearing Research*, *58*(6), 1637-1653.

[4] Bosshardt, H. G. 2002. Effects of concurrent cognitive processing on the fluency of word repetition: Comparison between persons who do and do not stutter. *Journal of Fluency Disorders*, *27*(2), 93-114.

[5] Dromey, C., Bates, E. 2005. Speech interactions with linguistic, cognitive, and visuomotor tasks. *Journal of Speech, Language, and Hearing Research*, *48*(2), 295-305.

[6] Dromey, C., Shim, E. 2008. The effects of divided attention on speech motor, verbal fluency, and manual task performance. *Journal of Speech, Language, and Hearing Research*, *51*(5), 1171-1182.

[7] Ebersbach, G., Dimitrijevic, M. R., Poewe, W. 1995. Influence of concurrent tasks on gait: a dual-task approach. *Perceptual and motor skills*, *81*(1), 107-113.

[8] Eichorn, N., Marton, K., Schwartz, R. G., Melara, R. D., Pirutinsky, S. 2016. Does working memory enhance or interfere with speech fluency in adults who do and do not stutter? Evidence from a dual-task paradigm. *Journal of Speech, Language, and Hearing Research*, *59*(3), 415-429.

[9] Ferreira, V. S., Pashler, H. 2002. Central bottleneck influences on the processing stages of word production. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *28*(6), 1187-1199.

[10] Ho, A. K., Iansek, R., Bradshaw, J. L. 2002. The effect of a concurrent task on Parkinsonian speech. *Journal of Clinical and Experimental Neuropsychology*, *24*(1), 36-47.

[11] Kahneman, D. 1973. *Attention and effort* (Vol. 1063). Englewood Cliffs, NJ: Prentice-Hall.

[12] Kemper, S., Herman, R. E., Lian, C. H. 2003. The costs of doing two things at once for young and older adults: Talking while walking, finger tapping, and ignoring speech of noise. *Psychology and aging*, *18*(2), 181-192.

[13] Kemper, S., Schmalzried, R., Hoffman, L., Herman, R. 2010. Aging and the vulnerability of speech to dual-task demands. *Psychology and aging*, *25*(4), 949-962.

[14] Maquestiaux, F., Ruthruff, E., Defer, A., Ibrahime, S. 2018. Dual-task automatization: The key role of sensory–motor modality compatibility. *Attention, Perception, & Psychophysics*, *80*(3), 752-772.

[15] McCaig, C. M., Adams, S. G., Dykstra, A. D., Jog, M. 2016. Effect of concurrent walking and interlocutor distance on conversational speech intensity and rate in Parkinson's disease. *Gait & posture*, *43*, 132-136.

[16] Norman, D. A., Bobrow, D. G. 1975. On data-limited and resource-limited processes. *Cognitive psychology*, *7*(1), 44-64.

[17] Pashler, H., Johnston, J. C. 1989. Chronometric evidence for central postponement in temporally overlapping tasks. *The Quarterly Journal of Experimental Psychology Section A*, *41*(1), 19-45.

[18] Pashler, H. 1994. Dual-task interference in simple tasks: data and theory. *Psychological bulletin*, *116*(2), 220-244.

[19] Pashler, H., Johnston, J. C., Ruthruff, E. 2001. Attention and performance. *Annual review of psychology*, *52*(1), 629-651.

[20] Peirce, J. W. 2007. PsychoPy—psychophysics software in Python. *Journal of neuroscience methods*, *162*(1-2), 8-13.

[21] Pernon, M., Trocello, J. M., Vaissière, J., Cousin, C., Chevaillier, G., Rémy, P., Fougeron, C., Kidri-Osmani, K., Woimant, F. 2013. Le débit de parole du patient wilsonien dysarthrique peut-il être amélioré en condition de double tâche? *Revue neurologique*, *169*(6-7), 502-509.

[22] Plummer, P., Eskes, G. 2015. Measuring treatment effects on dual-task performance: a framework for research and clinical practice. *Frontiers in human neuroscience, 9*, 225.

[23] Roelofs, A. 2008. Attention, gaze shifting, and dual-task interference from phonological encoding in spoken word planning. *Journal of Experimental Psychology: Human Perception and Performance*, *34*(6), 1580-1598.

[24] Wickens, C. D. 2008. Multiple resources and mental workload. *Human factors*, *50*(3), 449-455.