Phonological Facilitation of Object Naming in Agrammatic and Logopenic Primary Progressive Aphasia (PPA): Evidence for a Phonological Processing Deficit

Abstract

Naming is a pervasive deficit in primary progressive aphasia. However, the source of such deficits across PPA variants is little understood. In this study, individuals with agrammatic (PPA-G) and logopenic (PPA-L) PPA, along with age-matched controls, performed a picture-word interference task to test for online phonological processing deficits during naming. All groups exhibited phonological facilitation (PF) effects, i.e., speeded picture naming in the presence of phonologically-related words. However, the PPA participants exhibited abnormally large PF effects that also were protracted, compared to the control group. These results suggest that impaired phonological processing may contribute to anomia in PPA-G and PPA-L.

Introduction

Successful object naming requires both lexical-semantic and phonological processing, and impairment at either processing level can lead to naming difficulty. Individuals with PPA often show early and pervasive deficits in naming, however, relatively little is known about the online processing mechanisms underlying anomia in PPA and whether these mechanisms are differentially impaired in patients presenting with different PPA variants. Previous research indicates that individuals with agrammatic (PPA-G) and logopenic (PPA-L) tend to produce more phonological errors than people with semantic PPA (PPA-S), whereas the opposite pattern has been reported for semantic paraphasias (Clark, Charuvastra, Miller, Shapira, & Mendez, 2005). This suggests that phonological processing may be more prone to impairment in PPA-G and PPA-L. However, previous online studies show that lexical-semantic processing is disrupted during naming even in non-semantic variants of PPA (Rogalski, Rademaker, Mesulam, & Weintraub, 2008; Thompson et al., in press; Vandenberghe et al., 2005). It has not yet been demonstrated whether phonological processing deficits in PPA-G and PPA-L affect naming online.

The present study tested for online phonological processing deficits in PPA-G and PPA-L using the picture-word interference paradigm (PWIP; Rosinski, Michnick-Golinkoff, & Kukish, 1975). In the PWIP, participants are presented with a computer-generated picture of an object to be named along with a distractor word, which the participant is instructed to ignore. The dependent measure is naming latency. Picture naming can be speeded by distractor words that are phonologically related to the target (e.g. *radish* for target RABBIT), an effect called the *phonological facilitation* (PF) effect (Hashimoto & Thompson, 2010; Lupker, 1982; Schriefers, Meyer, & Levelt, 1990; Starreveld, 2000). In recent years, the PWIP has emerged as a tool to study the processing mechanisms underlying naming difficulty in patients with anomia (Hashimoto & Thompson, 2010; Wilshire, Keall, Stuart, & O'Donnell, 2007). PF effects of unusual magnitude and/or duration may reflect an online processing deficit.

Method

Participants. 13 individuals with PPA-L, 8 with PPA-G, and 17 age- and education-matched controls participated in the study. All participants underwent an extensive neuropsychological and neurolinguistic test battery. The PPA participants presented with progressive language

deficits with no evidence of other language or neurological deficits and were diagnosed with either PPA-G or PPA-L based on criteria presented by Mesulam et al. (2009).

Materials. The experimental stimuli consisted of 400 word-picture pairs (50 pictures each paired with 4 phonologically-related and 4 unrelated distractor words). Each stimulus pair was presented at one of four stimulus onset asynchronies (SOAs): 0 ms (i.e., simultaneous presentation of picture and word), +100 ms (i.e., presentation of word 100 ms after picture), +300 ms, and +500 ms.

Procedure. Participants were instructed to name pictures as they appeared but to ignore the distractor words to the extent possible. Each trial began with a 500 ms fixation cross, followed by presentation of the stimulus pair. Participants were given either 3500, 5000, or 7000 ms to name the picture, depending on their naming ability. The acoustic waveform of each response was recorded.

Data Analysis. Correct responses were analyzed for naming latency, measured from picture onset to production of the first phoneme of the target word. Mild phonological paraphasias were accepted as correct, and their distribution across conditions was analyzed to gain a better understanding of participants' offline phonological processing ability. PF effects (faster naming times in the presence of phonologically related words relative to unrelated words) were calculated for each participant at each SOA.

Results

Accuracy. All participants performed the task with at least 70% accuracy. The PPA-L group ($p < .01$), but not the PPA-G group, was significantly less accurate than the control group.

Phonological paraphasias. Both PPA groups produced significantly more phonological paraphasias than the control group (p's $< .01$). In the PPA-L group, phonological paraphasias were more common in unrelated than related trials across SOAs (main effect of relatedness: $F(1,12) = 7.6558$, $p < .05$). In the PPA-G group, this same pattern held only at 0 and +100 ms (interaction between relatedness and SOA: $F(3, 21) = 3.0189$, $p = .053$).

Naming latency and PF effects. Both PPA groups had longer naming latencies than the control group (p's $< .001$). Figure 1 summarizes the PF effects found for the three groups at each SOA. For healthy controls, significant PF effects were found at SOAs of 0 and +100 ms (p's $< .05$), but not at +300 or +500 ms. For the PPA-L group significant PF effects were found at 0, +100, and +300 ms (p's $< .05$), but not at +500 ms. The PPA-G group exhibited significant PF effects at 0 and +100 ms (p's $< .01$) and a trend towards PF at +300 ms ($p = .081$), but not at +500 ms. Of the PPA-G group, 6 of 8 participants exhibited PF effects at +300 ms. In addition, the magnitude of PF effects (i.e., the percent difference in RT between related and unrelated trials) was greater for both PPA groups than for controls (see Figure 2).

Discussion

The present study used the PWIP to test for impaired phonological processing during naming in PPA-G and PPA-L. The participants with PPA exhibited naming difficulty during the task, as reflected by lower accuracy and longer naming latencies relative to the control group. In

addition, members of both PPA groups produced more phonological paraphasias than controls, indicating difficulty with phonological encoding during naming (cf. Clark et al., 2005).

The PF results are consistent with the hypothesis that phonological processing deficits contribute to naming difficulty in PPA-G and PPA-L. Both PPA groups exhibited larger PF effects than the control group, which may be due to abnormal levels of lexical activation (cf. Hashimoto & Thompson, 2010). In addition, the PPA-L group and some individuals with PPA-G exhibited PF effects at the late SOA of +300 ms, in contrast with the control group. This suggests that phonological encoding may be slowed in PPA-L and some people with PPA-G. It may also be the case that the nature of phonological processing deficits differs in PPA-G and PPA-L. This possibility is supported by the different distribution of phonological paraphasias in the two groups.

Impaired phonological processing during naming in PPA-G and PPA-L likely stems from atrophy in the cortical regions that support phonological processes. Both PPA-G and PPA-L are associated with atrophy in brain regions that have consistently been linked to phonological processing, namely the left inferior frontal gyrus (IFG) in PPA-G and the left posterior temporal cortex in PPA-L (Gorno-Tempini et al., 2004, 2011; Mesulam et al., 2009). Both regions are at the heart of the network claimed by Indefrey and Levelt (2004) to support phonological processing during word production.

Taken together with previous studies demonstrating abnormal semantic processing during naming (Rogalski et al., 2008; Thompson et al., in press; Vandenberghe et al., 2005), the results suggest that semantic and phonological processing deficits may both contribute to anomia in PPA-G and PPA-L.

References

Clark, D. G., Charuvastra, A., Miller, B. L., Shapira, J. S., & Mendez, M. F. (2005). Fluent versus nonfluent primary progressive aphasia: A comparison of clinical and functional neuroimaging features. *Brain and Language, 94,* 54-60.

Gorno-Tempini, M. L., Dronkers, N. F., Rankin, K. P., Ogar, J. M., Phengrasamy, L., Rosen, H. J., Johnson, J. K., Weiner, M. W., & Miller, B. L. (2004). Cognition and anatomy in three variants of primary progressive aphasia. *Annals of Neurology, 55,* 335-346.

Gorno-Tempini, M. L., Hillis, A.E., Weintraub, S., Kertesz, A., Mendez, M., Cappa, S. F., Ogar, J. M., Rohrer, J. D., Black, S., Boeve, B. F., Manes, F., Dronkers, N. F., Vandenberghe, R., Rascovsky, K., Patterson, K., Miller, B. L., Knopman, D. S., Hodges, J.R., Mesulam, M.-M., Grossman, M. (2011). Classification of primary progressive aphasia and its variants. *Neurology, 76,* 1006-1014.

Hashimoto, N., & Thompson, C. K. (2010). The use of picture-word interference to examine naming abilities in aphasic individuals. *Aphasiology, 24,* 580-611.

Indefrey, P., & Levelt, W. J. M. (2004). The spatial and temporal signatures of word production components. *Cognition, 92,* 101-144.

Lupker, S. J. (1982). The role of phonetic and orthographic similarity in picture–word interference. *Canadian Journal of Psychology, 36,* 349–367.

Mesulam, M., Wieneke, C., Rogalski, E., Cobia, D., Thompson, C., & Weintraub, S.

(2009). Quantitative template for subtyping primary progressive aphasia. *Archives of Neurology*, *66*, 1545-1551.
Rogalski, E., Rademaker, A, Mesulam, M-M., & Weintraub, S. (2008). Covert processing of words and pictures in nonsemantic variants of primary progressive aphasia. *Alzheimers Disease and Associated Disorders*, *22,* 343-351.
Rosinski, R. R., Michnick-Golinkoff, R., & Kukish, K. S. (1975). Automatic semantic processing in a picture-word interference task. *Child Development, 46,* 247-253.
Schriefers, H., Meyer, A. S., & Levelt, W.J.M. (1990). Exploring the time course of lexical access in language production: Picture-word interference studies. *Journal of Memory and Langauge, 21*, 686-698.
Starreveld, P. A. (2000). On the interpretation of onsets of auditory context effects in word production. *Journal of Memory and Language*, 42, 497-525.
Thompson, C. K., Cho, S., Price, C., Wieneke, C., Bonakdarpour, B., Rogalski, E., Weintraub, W., & Mesulam, M.-M. (in press). Semantic interference during object naming in agrammatic and logopenic Primary Progressive Aphasia (PPA). *Brain and Language.*
Vandenberghe, R., Vandenbulcke, M., Weintraub, S., Johnson, N., Porke, K., Thompson, C. K., & Mesulam, M-M. (2005). Paradoxical features of word finding difficulty in primary progressive aphasia. *Annals of Neurology*, 57, 204-209.
Wilshire, C. E., Keall, L. M., Stuart, E. J., & O'Donnell, D. J. (2007). Exploring the dynamics of aphasic word production using the picture–word interference task: A case study. *Neuropsychologia*, *45*, 939–953.

Figure 1. Phonological facilitation effects at each SOA for the control, agrammatic (PPA-G) and logopenic (PPA-L) groups (* = $p < .05$; ** = $p < .01$; *** = $p < .001$).

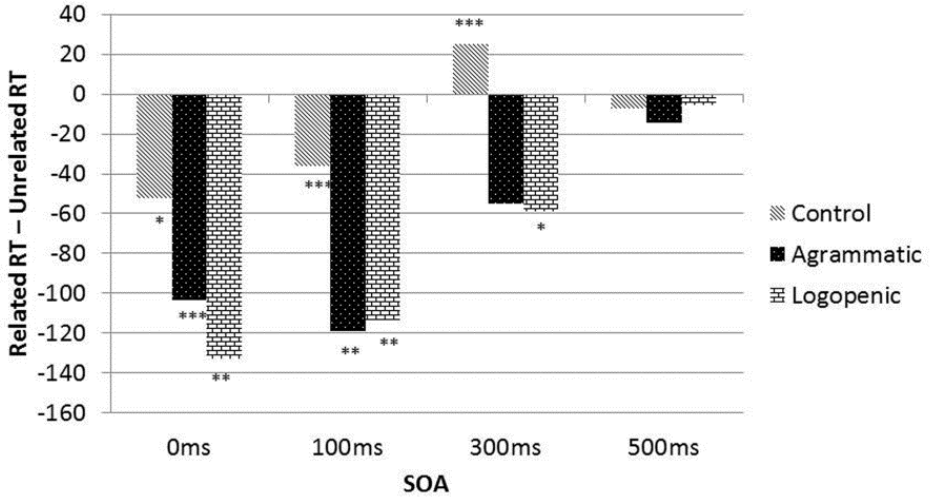

Figure 2. Magnitude of phonological facilitation effects for control, agrammatic (PPA-G) and logopenic (PPA-L) groups at each SOA.