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Predicting language therapy outcomes in bilinguals with aphasia (BWA) remains challenging due to the multiple pre- and poststroke factors that determine the deficits and recovery of their two languages. Computational models that simulate language impairment and treatment outcomes in BWA can help predict therapy response and identify the optimal language for treatment. Here we used the BiLex computational model to simulate the behavioral profile of language deficits and treatment response of a retrospective sample of 13 Spanish-English BWA who received therapy in one of their languages. Specifically, we simulated their prestroke naming ability and poststroke naming impairment in each language, and their treatment response in the treated and the untreated language. BiLex predicted treatment effects accurately and robustly in the treated language and captured different degrees of cross-language generalization in the untreated language in BWA. Our cross-validation approach further demonstrated that BiLex generalizes to predict treatment response for patients whose data were not used in model training. These findings support the potential of BiLex to predict therapy outcomes for BWA and suggest that computational modeling may be helpful to guide individually tailored rehabilitation plans for this population.