What are the active ingredients in anomia therapy? A random forest analysis of anomia research from 2009-2018

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Introduction
Anomia often occurs in adults with spoken expressive aphasia (Murdoch, 1990). Despite the wealth of research, the precise ingredients that explain successful word-finding outcomes in spoken anomia therapy remain unclear. Often, different combinations of therapy components are applied in research and clinical practice, masking the active ingredient(s) responsible for treatment efficacy. For example, to treat an impairment in accessing the phonological output lexicon, researchers have suggested having participants generate phonological cues (e.g., Leonard, Rochon, & Laird, 2008). Others have proposed the use of progressive cues, primarily either phonological or orthographic information (e.g., Hickin, Best, Herbert, Howard, & Osbourne, 2001). This diversity in treatment methods can unfortunately be confusing for a speech and language therapist. This study therefore adopts a novel approach: It systematically searched and combined individual data (obtained from group studies, case series or case studies), before employing random forest to determine the active ingredients in spoken single-word therapy.

Methods
Systematic search
A comprehensive search was conducted using 17 electronic databases, including general search engines (e.g., PubMed, PsychINFO) and more speech-therapy related ones (e.g., AMED for allied health professionals). After removing duplicated entries, the first and third authors independently reviewed and screened over 3,900 entries, based on pre-specified criteria. The primary selection criteria include: (1) Studies must be spoken single-word naming therapies; (2) participants are adults with word-finding difficulties as part of aphasia after stroke; (3) therapies are language-based approaches, i.e., semantic, orthographical and/or phonological approaches; (4) the reports must also be written in English and (5) include original data. We did not include studies investigating total communication and therapies beyond single-word naming, like the use of phrases to exchange information (e.g., Pulvermüller et al., 2001).

From the suitable studies, individual data were obtained. The final dataset was made up of data from just over 220 individuals. Information on therapy components as well as four outcome measures (short-term outcome for treated and untreated items respectively, long-term outcome for treated and untreated items respectively) were extracted. Short-term is defined as three weeks or less. Long-term is defined as more than three weeks after intervention. We sought to be comprehensive when accounting for the information on therapy components. The therapy components are thus divided into four groups: (1) Information on the therapy regimen (e.g., frequency of sessions per week); (2) Information on the words used in treatment (e.g., how many items were treated across sessions); (3) Information about the techniques (e.g., Were phonological cues used? Were semantic tasks used?); and (4) Information about the application of techniques (e.g., Were the cues applied in an increasing or decreasing order?). All these pieces of information were then entered as variables into the meta-analysis.

Meta-analysis
Random forest was used to compute the meta-analysis. Random forest is an established ensemble learning method useful for determining variables and has been fruitfully applied across

various disciplines (e.g., de Aguiar, Bastiaanse, & Miceli, 2016; Stephan, Stegle, & Beyer, 2015). It does so by imputing classification and regression decision trees (Breiman, 2000). Random forest is appropriate due to the mixture of categorical and continuous variables-of-interest, the 'large-*p* small-*n*' characteristic of our data, as well as its versatility in managing data derived from small-*n* design studies.

Results

Concordance statistics and the "Out Of Bag" (OOB) errors obtained for the random forests suggested that the imputed random forest models were accurate (i.e., concordance indices were greater than '0.83' and OOB rates were less than '0.18' for all imputed models). The primary results were based on the variables' order of importance when predicting a particular outcome. For the successful naming of treated items in the short term, the results suggested that providing the written form of the target word, explicit application of orthographic part-word cues, and applying cues based on responses were important variables. For successful naming of treated items in the long-term phase, feedback on naming accuracy, providing written form of the target word and explicit application of orthographic part-word cues were important variables. As for the naming of untreated items in the short term, providing the written word form of the target word was also important.

Discussion

From data extracted from over 220 individuals with aphasia, the role of orthography appeared to be important across the three outcome measures, whether the use of orthography was operationalized in terms of the provision of written target word or as orthographic part-word cues. We will discuss the clinical implications of maximising ingredients that drive successful naming rehabilitation, particularly in relation to the application of orthography. We will also briefly discuss the importance of using advanced statistical approaches to integrate findings from small-n research data, in order to advance the field.

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