Journal of Communication Disorders 56 (2015) 1–7

Contents lists available at ScienceDirect

Journal of Communication Disorders

Ease of articulation: A replication

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ARTICLE INFO

Article history:
Received 22 September 2014
Received in revised form 14 May 2015
Accepted 15 May 2015
Available online 27 May 2015

Keywords:
Replication
Speech acquisition
Articulation

ABSTRACT

Researchers, as well as the lay public and the popular press, have become increasingly concerned about the lack of reproducibility of research findings. Despite this concern, research has shown that replications of previously published work comprise a very small proportion of published studies. Moreover, there are fewer published direct replications of research studies by independent investigators, and this type of replication is much less likely to confirm the results of the original research than are replications by the original investigator or conceptual replications. A search of the communication disorders research literature reveals that direct replications by independent investigators are virtually non-existent. The purpose of this project was to describe the major issues related to research reproducibility and report the results of a direct replication of a study by Locke (1972) regarding ease of articulation.

Two methods for rating ease of articulation were employed. We were able to reproduce the results of the original study for the first method, obtaining a moderate positive correlation between our rankings of phoneme difficulty and Locke's rankings. We obtained a very high positive correlation between our phoneme rankings and rankings obtained in the original study for the second method. Moreover, we found a higher correlation between difficulty rankings and order of speech sound acquisition for American English than was found in the original study. Direct replication is not necessary for all studies in communication disorders, but should be considered for high impact studies, treatment studies, and those that provide data to support models and theories.

Learning outcomes: The reader will be able to: (1) describe the major concerns related to the replicability of research findings; (2) describe the status of research replications in communication disorders; (3) describe how ease of articulation may relate to the order of speech sound acquisition in children; (4) list some types/areas of research that might be candidates for replication in the field of communication disorders.

1. Introduction

In 2012, Begley and Ellis reported that Amgen, a major American biopharmaceutical company, had attempted to replicate the findings of 53 published cancer research studies that it deemed "high profile." Amgen was able to reproduce the findings from only 6 of the 53 studies (11%). Concerns regarding reproducibility have been discussed among scientists for years, and increasingly more often in the popular press; however, the Amgen announcement led to increased interest and the creation of the Reproducibility Initiative, an effort to encourage authors of high profile research papers to allow independent

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http://dx.doi.org/10.1016/j.jcomdis.2015.05.004
0021-9924/

investigators to replicate their findings. Recently, the U.S. National Institutes of Health (NIH) described initiatives that they will undertake to enhance reproducibility (Collins & Tabak, 2014). Articles regarding the problem of reproducibility have appeared in journals such as *Nature*, and, in 2012, the journal *Perspectives on Psychological Science* devoted an entire issue to the topic of reproducibility in psychology research. In the Introduction to that issue, the editors provide an excellent overview of the problems, including an unwillingness or inability to share published data, fewer replications than in the past, and questionable research practices (Pashler & Wagenmakers, 2012). However, some investigators have argued that the significance of the reproducibility problem has been exaggerated. Their main arguments to support this position are that (1) investigators use statistical methods to control the rate of false positives, (2) conceptual replications are conducted frequently, and (3) science is self-correcting (Pashler & Harris, 2012). Unfortunately, upon further scrutiny, these arguments do not hold up.

The first argument (statistical controls) does not hold up because the .05 probability level for statistical significance that is typically used in investigations in the social science disciplines does not represent the number of false positives throughout the discipline's literature. In order to determine the number of literature-wide false positives, one must specify a post-study probability that an obtained effect is true, called the positive predictive value (PPV; Ioannidis, 2005). Based on the work of Ioannidis and other investigators and using a PPV of 10%, Pashler and Harris (2012) estimated that with an alpha of 5% and a power level of 80%, approximately 36% of published studies in psychology would be false positives. In that same journal, however, Bakker, van Dijk, and Wicherts (2012) estimated that the power level that is more typical of psychological studies is .35. Using the same procedure with a power level of .35, Pashler and Harris estimated a false positive rate that is considerably higher, approximately 56%.

The second argument (many conceptual replications) also does not hold up to scrutiny. A study of replications in psychology by Makel, Plucker, and Hegarty (2012) revealed that reproducibility was affected by the nature of the replication. If the replication was a direct replication by the original investigator(s) or a conceptual replication, the vast majority of studies reported findings that were similar to those of the original studies. A conceptual replication is one in which the rigor of the hypothesis is tested by employing different experimental methods. If, however, a direct replication (based on the methods reported in the original paper) was conducted by investigators who had no overlap with the original investigators, the study was significantly less likely to be successful in replicating the results of the original study.

The third argument (self correction) is also problematic. The argument in favor of self-correction is that because science is performed by making empirical observations, these observations can be confirmed or refuted by subsequent investigations. Those that are confirmed will stand, and those that are refuted will disappear from the literature. However, Ioannidis (2012) identified several impediments to self-correction in psychological and other sciences. These include publication bias (e.g., difficulties in getting negative results published), underpowered studies, lack of direct replications by independent investigators (due to bias toward direct replication inherent in the review process), and selective reporting bias. He argued that unless these biases are recognized and addressed, self-correction may not happen.

As noted above, in examining the top 100 journals in psychology, Makel et al. (2012) found few published reports involving direct replications. Based on a search of the literature, it seems that the same is true for journals related to communication sciences and disorders (CSD; Muma, 1993). Muma performed an analysis of the number of replications that had been published in the *Journal of Speech and Hearing Disorders* and the *Journal of Speech and Hearing Research* during the decade from 1979 to 1989. The combined data for both journals revealed only 9 direct replications out of a total of 271 studies. Based on these data, he estimated approximately 108 or 544 false findings, depending on the confidence interval employed. He also suggested that the rates of false positives might differ across the different communication disorders ("subpopulations"). Muma summarized the paper by arguing that: "there is an urgent need for more replications in the field of speech-language pathology and audiology (p. 929)."

The purpose of this paper is twofold. One purpose is to draw attention to the need for replication within the field of communication disorders. The second is to describe the replication of a study that was reported in one of the journals evaluated by Muma (1993), the *Journal of Speech and Hearing Research*. In particular, we felt that a study performed by Locke (1972) regarding the relationship between ease of articulation and order of speech sound acquisition by children was worthy of replication. One reason was because of his experimental approach. Speech production is the most elegant and complicated motor behavior that humans produce (Kent, 2004). To explore motoric factors in speech sound acquisition, Locke examined the ease of articulation of American English speech sounds by exploiting the insight of mature speakers of the language to address the question of why children generally seem to acquire speech sounds in a particular order. He asked adults to rate how easy or difficult 20 consonants sounds were to produce. We found this to be an intriguing approach for assessing speech sound production difficulty. There are multiple technologies for studying the physiology of speech production, and, as Kent (1997) noted, they "permit the examination of even the most hidden aspects of speech (p. 306)." But there are no technologies that can observe the complex contribution of all of the speech subsystems simultaneously. As speakers, we experience the entire process of normal speech production, including respiratory, phonatory, resonatory, and articulatory aspects, as well as the demands for coordinating all of these aspects and the perceptual consequences of the movements. However, speech is a behavior that is acquired in an implicit, unconscious manner, so the validity of a task in which we try to gain conscious insight into this process is uncertain.

Another reason for replicating the Locke study was that it was designed to inform models and theories of speech sound acquisition in children. Locke found that the participants in his study rated certain sounds as being more difficult to produce than others. Moreover, he found that ease of articulation had a strong positive correlation with order of speech sound acquisition in children. Sounds that adults judged to be easier to produce were acquired earlier by children, and those judged