1. Introduction

J. D. Brown's (1991) classic paper in *TESOL Quarterly*, titled "Statistics as a Foreign Language," demonstrated that teachers and even researchers in the field were not well versed in statistics. Likewise, Meara (1995) wrote, "[When I was in graduate school], anyone who could explain the difference between a one-tailed and two-tailed test of significance was regarded as a dangerous intellectual; admitting to a knowledge of one-way analyses of variance was practically the same as admitting to witchcraft in 18th century Massachusetts" (p. 341). Since then, a large body of quantitative research in TESOL has been conducted, employing a range of techniques (e.g., Loewen and Gass, 2009; Plonsky, 2013). In this sense, statistics is no longer "a foreign language," but rather it is a communicative and analytical tool for conducting and reporting our research practice. At the same time, however, Loewen et al.'s (2014) replication of Lazaraton et al.'s (1987) survey of researchers' knowledge of statistics revealed that statistical literacy of researchers in the field has not changed much in the last two decades.

A number of recent works have sought to address this weakness and to move researchers in applied linguistics toward more appropriate analyses. In many cases, the reporting of effect sizes and confidence intervals, for example, seek to align L2 research with what is considered best practice in other social sciences such as education and psychology (Cumming, 2012). In other cases, novel techniques such as bootstrapping and mixed effects modeling have also been introduced as a means to advance and potentially improve quantitative data analysis in the field (Baayen, 2008; Cunnings, 2012; Larson-Hall, 2015; Larson-Hall and Herrington, 2010; Plonsky, Egbert and LaFlair, 2014).

In an effort to keep abreast with and apply these and other recent statistical advances, we argue in this paper in favor of the use of R, a statistical software environment, for quantitative

applied linguistics research. In order to facilitate the use of R, we also introduce an R-based web application recently developed by the first author. Throughout the paper, we advocate the use of R as a lingua franca (communication tool) for applied linguists. However, it is not our intention to "sell" this particular software to the readers of *Applied Linguistics* or to anyone, for that matter. Rather, we seek to inform a general applied linguistics audience of how recent advances in quantitative data analyses have been driven by—and can be fruitfully utilized using—R. We are also pragmatic in our approach, and we recognize that R, like any program, has its weaknesses. Therefore, our goal is achieved if, after reading this article, readers make more informed decisions concerning statistical software depending on their research foci and needs.

2. Advantages of Using R

R is a free, open-source computer language and software environment for statistical computing and graphics (R Core Team 2014). Compared with SPSS, it is not used by many researchers in applied linguistics (Loewen *et al*. 2014). In Loewen *et al*.'s (2014: 372) survey, SPSS was found to be used by 69% of the respondents. In contrast, R was used by only 15% of the respondents, even less than the 17% who conducted their analyses "by hand." Despite its lack of popularity in our own field, the use of R in other disciplines has been rapidly gaining in popularity and, according to Muenchen (2014), R recently "became the most widely used analytics software for [all] scholarly articles." We first outline the reasons why R is popular among researchers in other fields and why we recommend its use for analyses in quantitative applied linguistics research as well.

The reproducibility of data analysis is perhaps the most compelling advantage provided by R. As applied linguistics continues to mature, more attention will likely continue to be paid to

research synthesis/meta-analysis as well as replication research (Oswald and Plonsky 2010; Porte 2012). Further momentum in this area is found in the IRIS (Instruments for Research Into Second Language Learning and Teaching) database launched in 2012 as "a free, searchable, up- and downloadable collection of instruments, materials and stimuli that are used to elicit data for research into second and foreign languages" (IRIS n.d.) to which many international journals in applied linguistics, including *Applied Linguistics*, have pledged their support. These are all signs of the field's maturity and emphasis on reproducibility of research.

In order to examine the reproducibility of primary studies and further promote replication, however, the data itself and data analytic procedures must also be shared. And in fact, journals and funding agencies increasingly require data to be made publicly available after publication. In addition to data sharing, open access to R codes will facilitate reproduction and replication of data analysis. This is possible because R is a command line driven program. With R, you only need to run the code to replicate the analyses and produce the exact same results obtained by the original study. This feature of R also enables researchers to experiment with and learn from alternate analytical approaches based on the same dataset.

Our next point is also related to the reproducibility of data analysis. Statisticians and computer scientists have developed thousands of R packages. These packages can be used for conducting nearly any analysis imaginable. User-friendly R manuals and textbooks, three of which have been written by linguists, of course also come with R codes (Baayen 2008; Gries, 2013; Larson-Hall 2015). In applied linguistics, more advanced statistical analyses and modeling have been introduced in recent years such as:

- bootstrapping (Larson-Hall and Herrington 2010; Plonsky *et al*. 2014);

- hierarchical linear modeling / multilevel modeling / mixed-effect modeling (e.g., Baayen, Davidson and Bates 2008; Cunnings and Finlayson in press; Gries 2015);
- Bayesian analysis (Gudmestad, House and Geeslin 2013); and
- quantile regression (Chen and Chalhoub-Deville 2014).

These were all conducted with R, enabling codes and packages to be provided or cited. When R codes are provided, they are usually accompanied by the dataset, which enables researchers to re-run the analyses themselves. This hitherto unprecedented type of communication of data analysis is greatly facilitated with R, and it is precisely for this reason that we regard R as a (potential) lingua franca for quantitative data analysis in applied linguistics.

Yet another benefit of R is its ability to produce high-quality graphics. Because R is a command line driven language, the researcher specifies graphic elements with code. This is challenging for beginners, but learning how to make a plot with R provides the researcher with the autonomy to go beyond program defaults to produce more effective data visualizations, a perennial problem in applied linguistics (e.g., Larson-Hall and Plonsky 2015).

Figure 1 shows an example of R's superiority in producing graphics even for simple purposes. The same data are used to plot four types of graphs with the amount of information increasing from (A) to (D). Specifically, in (A) (made in Excel), the barplot contains only the means, while barplot (B, SPSS) has the means and error bars. The boxplot (C, SPSS) is an improvement on these graphs in that it includes more information (i.e., quartiles, median, minimum and maximum scores, and outliers) than the barplot with error bars (B). Finally, though, the boxplot (D), created in R, is superior to all others in that it allows the researcher to show not only all the information provided by the SPSS graph but also individual data points (beeswarm plot), their means, and error bars.

[FIGURE 1 NEAR HERE]

A final advantage of R over other analytical options is tied to the fact that R is a programming language, rendering the range of possible uses and functions nearly unlimited. Its flexibility enables ideas suggested by a community of professional statisticians and computer scientists to be integrated almost instantaneously. R can also be used with MYSQL database and Apache web-server, which facilitates the development of innovative online programs or platforms. One such program, "Concerto" (http://www.psychometrics.cam.ac.uk/newconcerto), is an online R-based adaptive testing platform. Concerto can be used for free to create your own CAT (computer adaptive test) and administer it online.

R can also be used to analyze corpus data (see Gries, 2009) using natural language processing packages (e.g., tm: Text Mining Package). Various indices have been developed in recent years, for example, that enable learner corpus researchers to automatically score learner writing (or speaking) and to measure readability, lexical diversity (see Koizumi and In'nami 2012 for a review), and discourse-level representations of a text (e.g., Coh-Metrix; Graesser, McNamara and Kulikowich 2011). The R package "koRpus" (Michalke 2014), for example, can compute a number of reliability and lexical diversity indices, and the author of the package has created a web application to illustrate the kinds of text analyses users can conduct (http://ripley.psycho.hhu.de/koRpus/). These and other flexible features are possible because,

unlike any other statistical software package, R is also, as we have noted, a programming language.

3. The "langtest" Web Application

So far we have highlighted only strengths of the R statistical package. The major downside of R is its command line interface (CLI; although *R Commander* makes it possible to use R with a Graphical User Interface). For those who want to utilize R more immediately, we recommend a web application (http://langtest.jp/) developed by the first author using Shiny (http://shiny.rstudio.com/), a web application framework for R.

The web application "langtest" is very easy and intuitive to use. The user simply copies and pastes his/her data from a spreadsheet as shown in screenshots from the website in Figure 2. S/he can then conduct a wide range of statistical analyses. Furthermore, all analyses on the website provide sample data and output with which users can compare their own.

As its name "langtest" suggests, analyses of particular interest to researchers in language testing can also be conducted, such as item analysis (based on norm-referenced and criterion-referenced testing), generalizability theory, and item response theory (IRT).

Because "langtest" utilizes the power and flexibility of R, it produces output that includes effect sizes such as Cohen's *d* (which is not produced by SPSS), confidence intervals, and other valuable indices. The application also provides superior functionality in data visualization. In many analyses, the user can produce boxplots as suggested by Larson-Hall and Herrington (2010) instead of bar graphs with error bars. The web application "langtest" is also, of course, free, and all codes are available on the website, so interested users can modify the code as needed; they can also study the code as an example or to assist in producing their own.

[FIGURE 2 NEAR HERE]

The web application "langtest" was created for three main reasons. First, it frees us from the need to purchase software such as SPSS. Second, it provides users with clear examples of each analysis (as an educational purpose). And third, it is our hope that by engaging with "langtest," learners will want to learn how to use R as well. That is, though "langtest" is more than adequate for the vast majority of analyses in our field, it also has limitations (e.g., users can check the R codes used in "langtest," but they are not recorded in a reproducible command line format). And as users become more experienced, addressing relationships that require more sophisticated or flexible analytical approaches, they may require the full range of functionality available in R to meet their research needs.

4. Conclusion

R may someday be the de facto standard software for quantitative data analysis in applied linguistics. Statistics used to be regarded "as a foreign language" (Brown 1991), but we hope R will someday be considered "as a lingua franca." The hands-on approach to statistics embodied by R helps researchers gain a deeper understanding of the data analytic process, rather than relying on SPSS defaults. We concede that the learning curve of R can be steep. However, considering the advantages described above, we feel it is worth undertaking. If you want to learn

another language, you devote your time and effort to learning it. You choose an economical option to learn it. You learn from others who have been successful and in a supportive community of practice. Learning R is very much the same.

Finally, we hope that the web application we have introduced here, “langtest,” will introduce quantitative researchers in applied linguistics to the possibility of how R, the preferred package of researchers in the 21st century, can contribute to improved data analysis and reporting practices.

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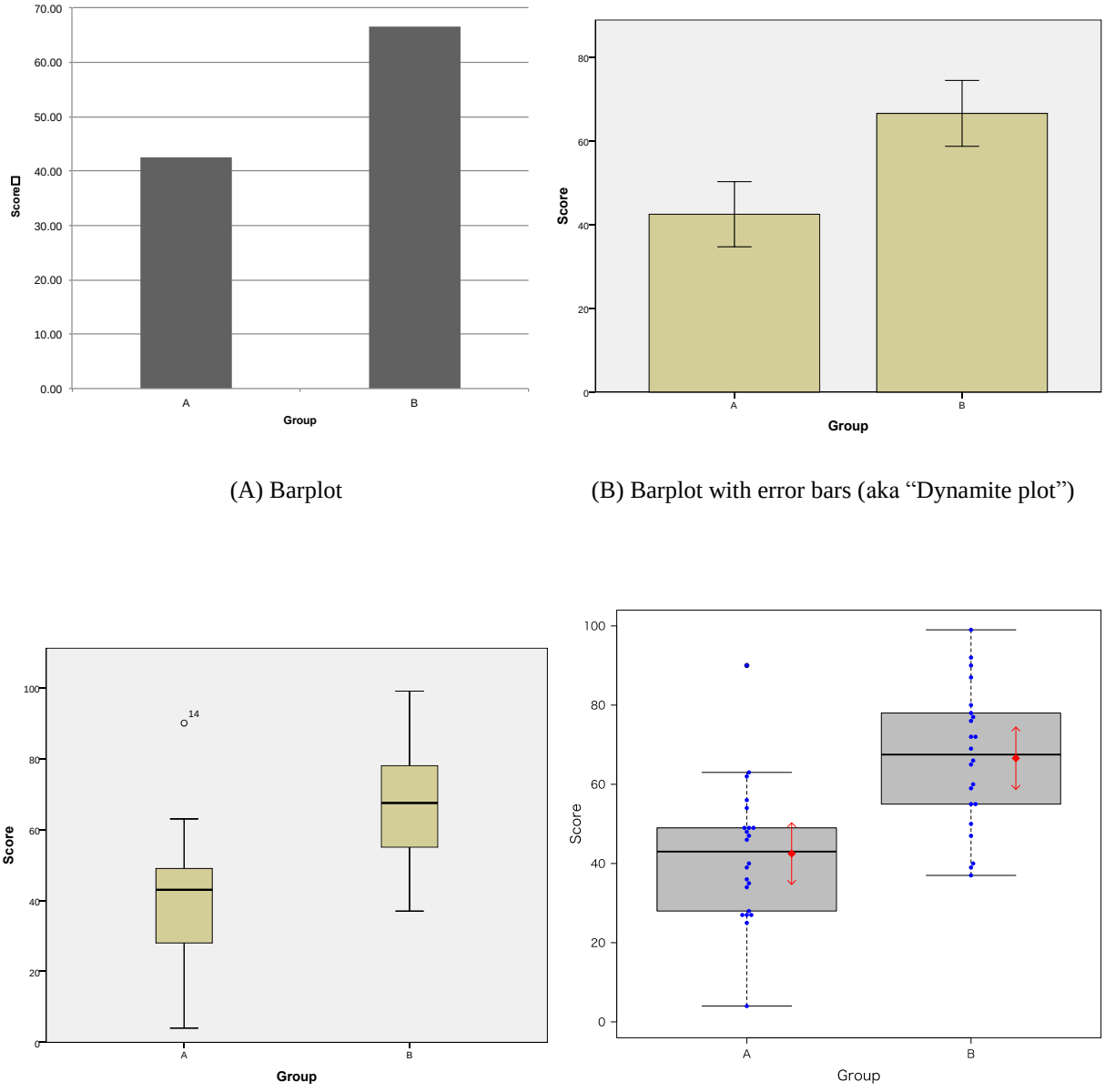

(A) Barplot

(B) Barplot with error bars (aka "Dynamite plot")

(C) Boxplot

(D) Boxplot with more information

Figure 1. Comparisons of different plots with the same data.

Basic Statistics Calculator

Data input:

44
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32
51

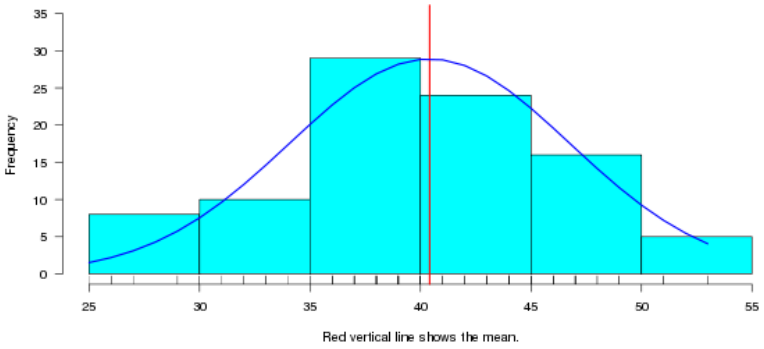
Input values can be separated by newlines, spaces, commas, or tabs.

Main About

Basic statistics

n	mean	sd	median	trimmed	mad	min	max	range	skew	kurtosis	se
92	40.41	6.35	40	40.69	5.93	25	53	28	-0.36	-0.34	0.66

Histogram



Box plot with individual data points

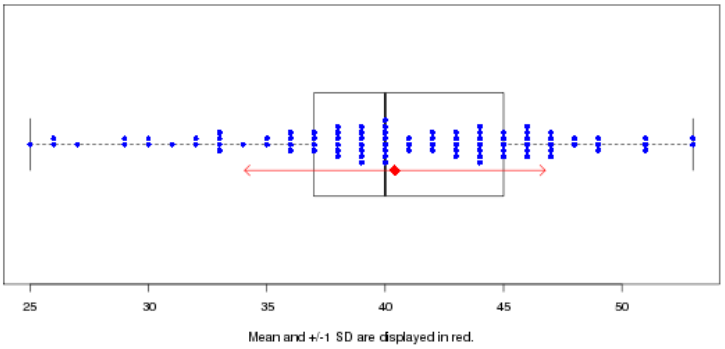


Figure 2. Screenshot of data entry and automatically produced graphics from "langtest."