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Interactive applets on the Web for methods and statistics

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Interactive applets on the Web for methods and statistics

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Abstract

We present two web applications designed to optimally fulfill the criteria of parsimony, usability, and availability (platform independence) in the teaching of important concepts in research methods and statistics. Effects of confounded variables may bias results in within-subjects designs, and can be avoided or exaggerated by counterbalancing of order. The first web application seeks to illustrate underlying concepts and relationships between true effects, confound effects, and choice of counterbalancing schemes by letting the user continuously manipulate the relevant variables. In the second web application regression is conceptualized interactively by dragging the regression line to minimize continuously updated squares together representing the sum of squared errors. The sites can be viewed at http://www.bolderstats.com/within/index.html and http://www.bolderstats.com/regfit/index.html

1. Introduction

The advance of the Internet has changed the face and inner workings of both science and teaching (Reips, 2008; Wolfe, 2001). Internet-based teaching or i-teaching is fast becoming a new option at many educational institutions, and many teachers are looking for tools, methodologies and services that support their teaching. Such tools for Internet-based teaching are available wherever there is an Internet connection and a web browser. There are many educational web applications in statistics (e.g. Vassarstat, Lowry, 1998-2012; seeingstatistics.com, McClelland, 2000). However, relatively few can be found for concepts in research methods, and those for statistics are often based on texts and static displays. Furthermore, i-teaching is young and thus many sites suffer from usability problems and lack an adequate concept that combines technology and pedagogy.

Web services that might be used in Internet-based teaching of research methods include collections of web studies (e.g. the Psychological Research on the Net list by John Krantz and the web experiment list at http://wexlist.net/ ; Reips & Lengler, 2005) that may serve as examples, web experiment generators with features like visual displays of designs (e.g. WEXTOR at http://wextor.org ; see Reips & Neuhaus, 2002), and portals that link to related services (e.g. the iScience Server at http://iscience.eu). Web services for researchers can be used in teaching as well, e.g. to introduce the concept of and create visual analogue scales in measurement (Reips & Funke, 2008) or for exercising data mining in tweets, the short messages exchanged in the social network Twitter (Reips & Garaizar, 2011). Statistical web services became available for intercoder reliability calculation (Freelon, 2010) or for the calculation of effect size in a Student t test (Soper, 2012).

The present paper exemplifies optimal ways of designing web services for Internet-based teaching of research methods and statistics by describing two web applications. One aims at the understanding of a specific concept in research methodology: counterbalancing effects on confounds in within designs. The other one guides beginners to understanding a fundamental principle often used in statistics: regression. Both applications were designed to be easily available, usable, and parsimonious.

2. Design principles

To achieve availability, usability, and parsimony we derive a number of educational and technological principles for the design of web sites that are to be used in teaching of research methods and statistics. Our goal is always to have students understand fundamental concepts rather than arithmetic tricks (see McClelland, 2005). By bringing our content to the web, following guidelines for human-computer interaction (e.g. Dix & Shabir, 2011), and creating the content platform-independently, we achieve high availability.

Techno-educational concept

Static or even animated illustrations in which students just watch are not as effective in teaching statistics and especially research methods as web-based graphics that are truly interactive (Tversky, Morrison & Betrancourt, 2002). Java, HTML5, Flash, and Mathematica offer useful tools for providing interactive visualizations of important statistical and research methods concepts.

Even with interactive visualizations, not all interactions are equally useful. For example, entering choices in text boxes and then updating displays is not as effective as dragging lines and shapes resulting in immediate visualization with continuous updating (as opposed until after the return key is hit). Such interactivity is easy to provide using Java, HTML5, Flash, and Mathematica tools. Examples of the different methods and illustrations of the different types of interactivity will be provided below and on the applications' sites.

Important features we see as essential for an educationally valuable experience in a web application are:

- Interactive vs. static or animated display, so the user becomes more engaged instead of being in a mere spectator role (lean-forward versus lean-backward interaction);
- True interaction, i.e. the web application is continuously updating the display instead of providing a limited selection of preset scenes. True interaction includes dragging and immediate updating:
    - Dragging instead of text boxes for parameters. Variables need not be represented in an abstract way (by a formula), rather they are available in a visual format that can be manipulated physically.
    - Immediate updating: The causal relationship between action and result is reflected in the immediate display, rather than being interrupted by the pressing of buttons etc.
- Visualization with color coding. Concepts are colored in a consistent way. Different instantiations of the same concept have the same color, and those of different concepts have different colors. Careful coloring is aware of the needs of the color blind.
- Avoid "statistician's workbench"
    - A few obvious things to do rather than the ability, say, to do a multitude of different simulations with many manipulable parameter values.

- Not too many choices. In Internet-based education of complicated issues, e.g. statistics, it is particularly important to keep things simple. Otherwise, users may drop from using the web application. Too many choices will increase the burden, require consultation of complex instructions elsewhere, and will make it difficult for the user to focus on the key concepts.

We now turn to two examples of interactive methodological and statistical applets that illustrate these design principles.

3. Two examples: The sites

To illustrate how our design principles can be used to create web applications in teaching of research methods and statistics, we will present one from each of the two domains. The first one was created to teach correct counterbalancing as a way to control for confounding effects in within-subjects experimental designs. The second was created to support understanding of the principle of regression in statistics.

Research methods: Confounding in within designs

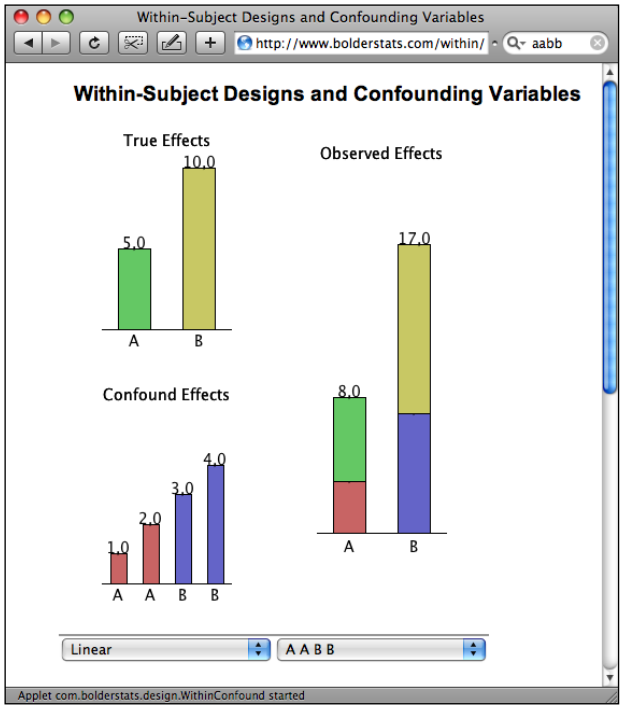
A variable that is confounded with the independent variable in a within-subjects experiment, for example training or fatigue, can be controlled via counterbalancing. Possible counterbalancing designs of order of levels A and B of the independent variable include ABBA, ABAB and AABB. Generally, an effect resulting from a within-subjects experiment can be expressed as follows.

$$Y_{it} = b_{0i} + b_1 X_i + b_2 Z_t + e_{it}$$

Technically, a Java applet was embedded in HTML code and can be viewed at http://www.bolderstats.com/within/. Figure 1 shows the Web page with the embedded applet.

Figure 1

Display of the site in a browser window. The present display shows effects of a linearly confounded variable when choosing an (incorrect) AABB counterbalancing strategy

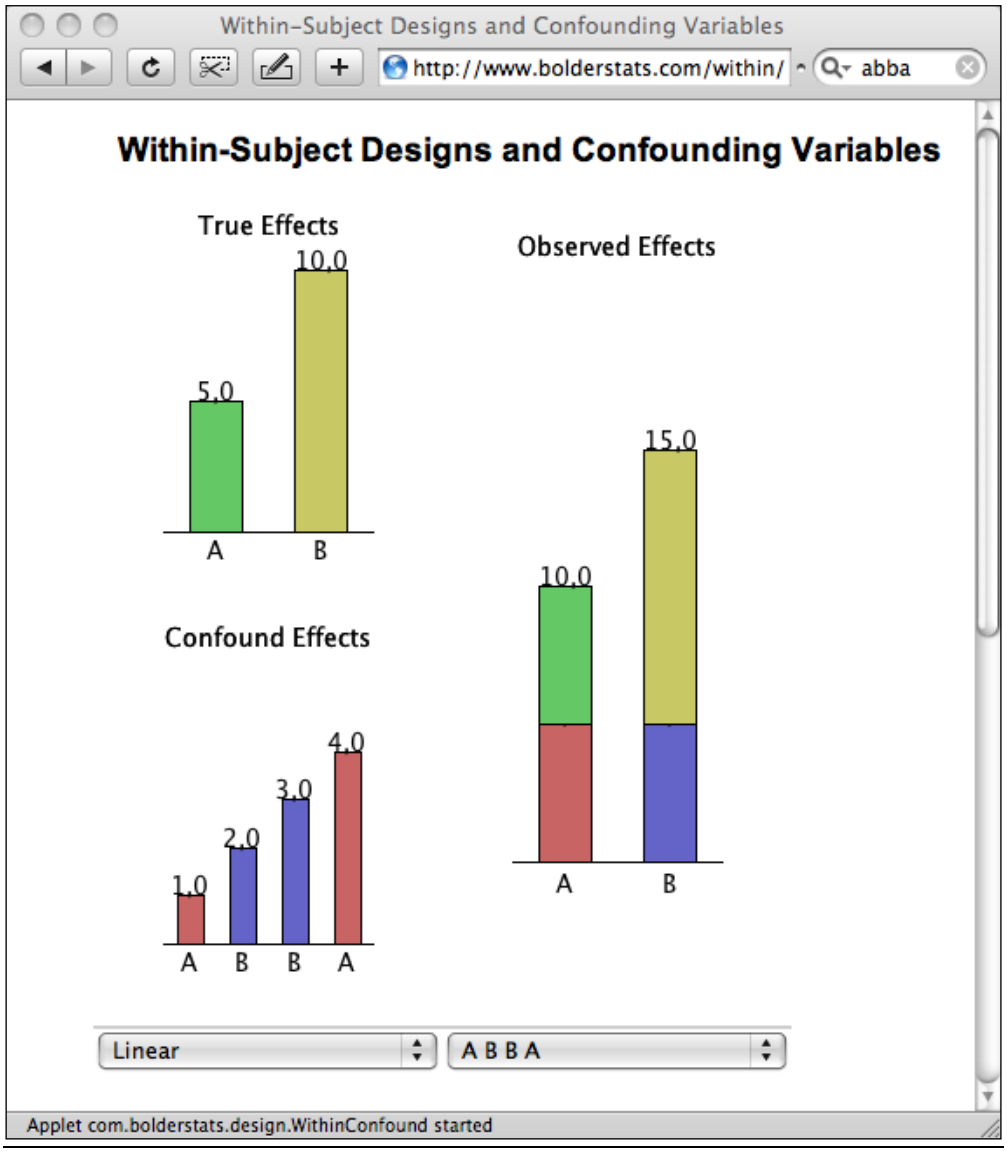


The instructions below the applet read as follows: "Use the menu on the bottom left to select the confounding function. One of the options in that menu is 'Drag to set', which allows the user to drag the columns in the Confounding Effects window to whatever values and patterns desired. Use the mouse to drag any of the effects, either true or confounding, on the left side of the graph. The resulting net observed effect is displayed on the right. Use the menu on the bottom right to select the order of the treatments to the two groups. The combined effects on immediately updated in the right-hand graph."

Figure 2 presents the situation after the correct counterbalancing strategy was chosen in the bottom right menu. The true effect (difference between the two bars on the upper left) is reflected in the observed effect.

Figure 2

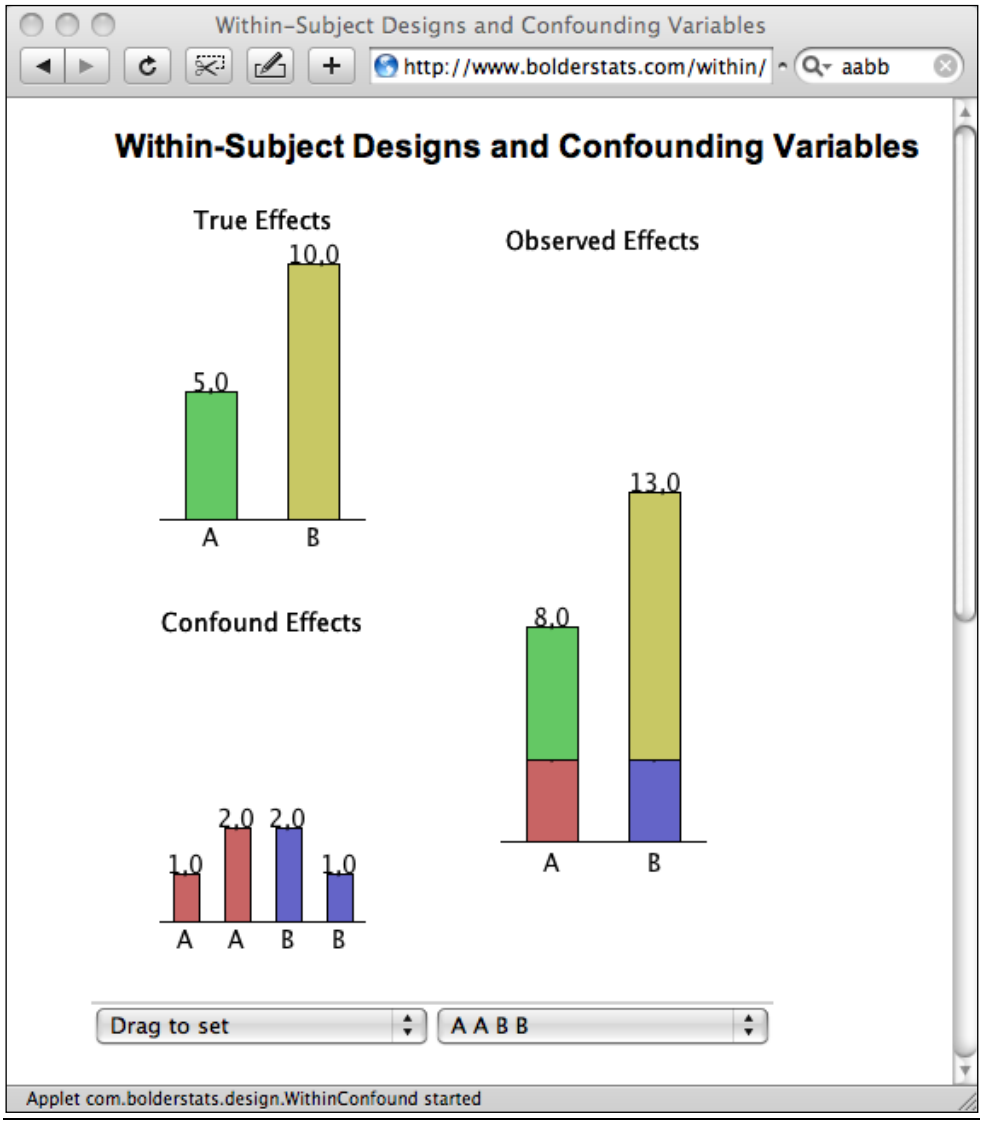
A display showing effects of a linearly confounded variable when choosing an ABBA counterbalancing strategy.



Understanding the concept: continuous flow. Using Java as the basis for the Web service allows the direct manipulation of processes with continuous updating of results. As a user drags bars with the mouse arrow (in "drag to set" on the bottom left menu, see Figure 3), all corresponding effects are changed instantaneously. The continuity of the relationship is thus matched in the user's experience: one's movement in manipulating a variable and the perception of changes in the related variables correlate – as specified by the construct. The full spectrum of possible relations between the variables can thus be experienced in one flow of action and its resulting changes.

Figure 3

Drag to set: In drag to set mode all bars can be adjusted freely by using the mouse arrow. The current display shows effects of an inverted-U confounded variable (e.g. combined effects of fatigue and learning/testing) when (correctly) choosing an AABB counterbalancing strategy.



Importantly, frequent instances of types of confounds (e.g. linear like growing fatigue) and of counterbalancing strategies (e.g. ABBA) still become salient via quickly accessible preset options in drop-down menus.

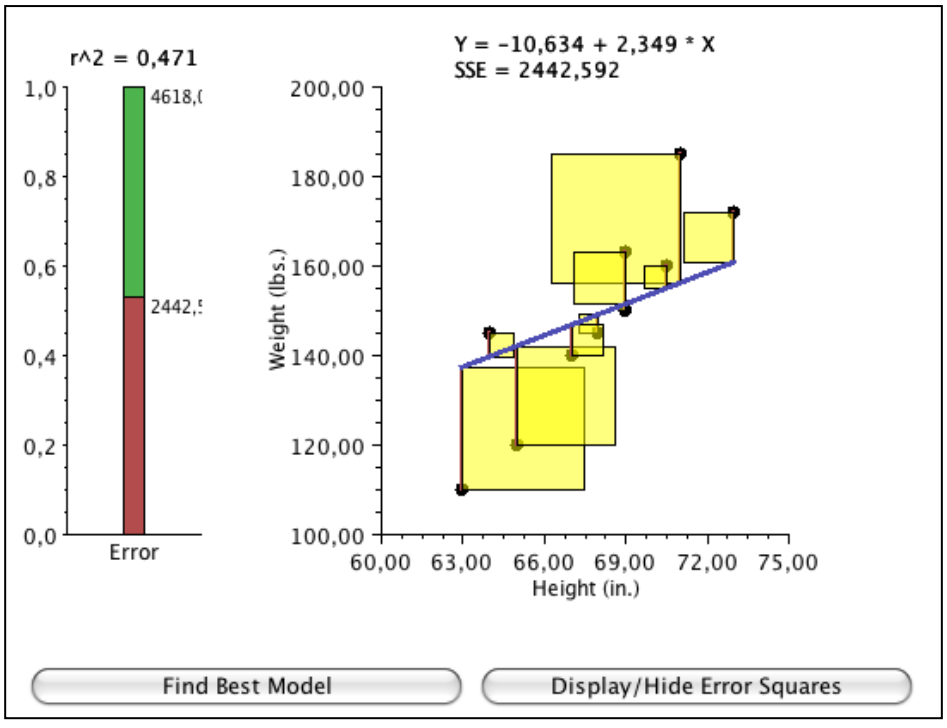
Statistics: Understanding regression

The second Web application we choose to illustrate our design principles is taken from the realm of statistics. At the applications web site, http://www.bolderstats.com/regfit/index.html, the user is asked to fit a regression line – by directly dragging the line. With an optional click on a button "Display/Hide Error Squares" (Figure 4, bottom) the Web application illustrates how minimizing the sum of squared errors yields a regression line. The squared errors for each point are displayed and change size immediately when the blue regression line is dragged so as to reduce the sum of squared errors. A meter on the left of the Web application keeps track of the user's progress and provides aggregated feedback. The part of the original sum of squared errors that is reduced turns green and the proportion of the error meter that turns green is equivalent to r-sq. By clicking on a "Find Best Model" button one may confirm via a shortcut that one has found the best-fitting regression line.

As a link to the world of formulas, the Web application always displays the regression formula that describes the current state of the display. The formula is continuously updated, as are R square and the numerical value of the sum of squared errors (SSE). Furthermore, the Web application offers a comparison of two groups via regression, the same principles apply.

Figure 4

An interactive applet to teach the concept of regression.



4. Conclusion and outlook

The direct manipulation of processes with continuous updating of results that seems particularly important in understanding complex concepts in research methods and statistics could successfully be implemented using Java and basic HTML in the presented web sites for teaching regression and the concept of counterbalancing effects on the impact of confounds in within-subjects experimental designs.

All techniques that are suited to create easily available and usable sites featuring continuous flow on the Internet (HTML5, Java, Flash, and Mathematica) include automated tools for monitoring user actions, freeing the developer of interactive visualizations to focus on the substance of the concepts.

Time and place and other detailed information about actions (mouse clicks, movements, slider drags, etc.) are delivered to the developer's code, which can then process it or ignore it as appropriate. The drudgery of writing code to monitor user actions is eliminated. Furthermore, the user action data can be used in finding typical patterns that may indicate misconceptions in users or groups of users. Such data will help in further improving the teaching of important concepts in research methods and statistics.

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04-27 Female income, the ego effect and the divorce decision: evidence from micro data
March 2004 - Randy Kesselring (Professor of Economics at Arkansas State University, USA) was guest at AIAS in April and May 2003

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Januari 2004 - Joop Hartog & Aslan Zorlu

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