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Using Online Tutorials to Introduce Psychology Undergrads to R: Student Experiences, Knowledge, and Attitudes

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Statistical literacy, comprising both conceptual knowledge and practical skills using statistical software, is foundational to undergraduate psychology education. However, consensus is lacking for how to best incorporate software instruction into introductory statistics courses. In this investigation, we evaluated the effectiveness of three online tutorials introducing undergraduates to R. We recruited 273 students across seven sections of an introductory statistics course in psychology. Using quantitative and qualitative approaches, we assessed students' experiences with the tutorials. We also compared students' attitudes toward statistics and statistical software before and after they completed the tutorials and tested their knowledge of R after they completed the tutorials. Overall, students had positive experiences with the tutorials and demonstrated adequate knowledge of R following the tutorials. Students' attitudes about statistics and statistical software remained stable and neutral to positive before and after completing the tutorials. Although students perceived more effort was needed to learn statistics after having completed the tutorials, they also perceived themselves as being more able to use statistical software, regardless of whether direct instruction in non-R software was included in the course design beyond the tutorials. Results suggest brief online tutorials can effectively scaffold undergraduate psychology students' learning of basic R skills. Furthermore, by increasing students' confidence with using statistical software, positively impacting students' experiences, and maintaining their attitudes toward statistics, online tutorials may increase students' motivation to continue developing their statistical skills.

Keywords: statistical literacy, e-learning, statistical software, psychology, online learning

Supplemental materials: https://doi.org/10.1037/stl0000350.supp

Teaching introductory statistics involves a focus on both conceptual knowledge of statistics theory and applied skills using statistical software to analyze data and interpret results (Guidelines for assessment and instruction in statistics education [GAISE]; Carver et al., 2016). However, research shows that only 59% of Canadian (Davidson et al., 2019) and 69% of American (Bartz & Sabolik, 2001) undergraduate psychology programs include the teaching of statistical software in introductory statistics courses. Moreover, these researchers note that when software is used, it is most often "point-and-click" software (e.g., SPSS; IBM Corporation, 2021), rather than syntax-based software such as R (R Core Team, 2021). One explanation for instructors' preference for point-and-click software is that these programs are perceived as easier to learn relative to syntax-based software. This perception is especially relevant when considering the learning context of an introductory statistics course, where students are usually learning both statistical theory and software skills for the first time (e.g., Anglim, 2013). Many psychology undergraduate students lack prior instruction in programming (Dempster &

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McCorry, 2009; Rode & Ringel, 2019), and they may experience a steep learning curve when first introduced to syntax-based software like R. A second explanation for psychology instructors' preference for teaching point-and-click software is that it takes longer to teach syntax-based software like R (see Li, 2021). However, R is increasingly common in graduate schools' instruction of statistics (Davidson et al., 2019), and skills in R (or other syntax-based software) are highly desired in today's workforce (Muenchen, 2013). Thus, it is becoming increasingly advantageous to start students' learning of R early on in their psychology education. However, the best method to integrate the teaching of R into introductory statistics courses in a way that does not sacrifice students' performance or experience, or take up too much time from other course content, remains up for debate.

Despite extensive research supporting the benefits of teaching statistical software in other disciplines (e.g., Baumer et al., 2014; Ciftci et al., 2014; Doğan, 2009; McCulloch, 2017), limited research focuses on psychology specifically. Furthermore, the research that does exist has yielded mixed results.

One study investigated the effects of incorporating SPSS instruction into an introductory statistics course on psychology students' attitudes toward statistics, their statistics anxiety, and their attitudes toward statistical software (Brezavšček et al., 2016). At the end of the course, students reported neutral to positive attitudes toward statistics (i.e., statistics' usefulness, value), relatively low statistics anxiety, and moderately positive perceptions of their abilities to use statistical software. Moreover, the researchers found that positive attitudes toward statistics and statistical software were related to a greater motivation to continue developing these skills. This was particularly true if the experience with learning the software was not anxiety provoking for the students. Overall, these results suggest that the teaching of software in introductory statistics courses can have some positive impact for psychology students. However, the authors warn that the implementation of software instruction should be carefully tailored to students' learning needs to ensure that their experience does not stimulate anxiety about the course.

Another study involving psychology students yielded somewhat contradictory evidence. Jatnika (2015) studied changes in undergraduate psychology students' attitudes toward statistics both before and after adding a module including instruction in SPSS, as well as the module's impact on students' academic achievement. Although students' perceptions of their statistical competence increased after the instructor implemented the SPSS module, their performance in the course decreased once mastery of SPSS was required in graded components. Results from Jatnika (2015) offer a mixed view of the effects of incorporating software when teaching psychology students statistics for the first time. In particular, the results suggest that requiring students to master software skills in exchange for grades may hinder their ability to perform well in the course.

To our knowledge, only one published study has investigated the effect of teaching R in introductory statistics courses in psychology. Counsell and Cribbie (2020) quantitatively examined students' attitudes toward statistics, statistical software, and R, and qualitatively assessed students' experiences learning R. These students reported poorer attitudes toward statistics and statistical software compared to both upper-year undergraduates and graduate students, both at the beginning and the end of the course, though the valence of their attitudes was neutral (means at the midpoint of the response scale) rather than overtly negative. The authors were unable to make statistical comparisons pre–post due to large amounts of missing data across time points, so there is a need for further statistical comparison of undergraduate students' attitudes before and after learning R. With respect to students' learning experiences, a substantial portion of students indicated that they had a negative experience learning statistics using R, and that learning both R and statistics had been quite difficult for them. A positive learning experience is important as it may affect students' motivation and learning outcomes (Brezavšček et al., 2016; Onwuegbuzie & Wilson, 2003; Primi et al., 2018).

Overall, the results from Counsell and Cribbie (2020) suggest that students' attitudes toward statistics, statistical software, and their experiences learning R were not positive. These results are perhaps due to the inherent difficulty of being introduced to both challenging statistical concepts and R's steep learning curve at the same time, needing to conquer both in order to achieve learning objectives and perform well in the course. Indeed, students in Counsell and Cribbie's sample were required to use R in labs and on assignments, so mastery of R skills was directly tied to their course performance. Given that students may start their statistics courses with anxiety or low motivation to learn (e.g., Brezavšček et al., 2016; Druggeri et al., 2008; Onwuegbuzie, 2004; Rajecki et al., 2005), exposing them to potentially negative learning experiences in the course curriculum may further reduce their willingness and ability to learn statistics. As mentioned above, some psychology students may be at particular risk of negative learning experiences in statistics courses given their tendencies to lack strong math and programming backgrounds (Dempster & McCorry, 2009).

Taken together, existing research suggests that teaching software in introductory statistics courses may benefit students' attitudes toward statistics. However, given the presence of contradictory evidence regarding the effects of teaching software and students' performance in statistics courses, and the limited evidence specific to the effects of teaching R in psychology programs, incorporating software like R should be carefully implemented. In particular, pedagogical strategies for introducing statistical software in introductory-level courses should aim to maximize benefits while minimizing risks to student learning and experience. Similarly, the effectiveness of pedagogical approaches for teaching statistical software in introductory statistics courses should be thoughtfully evaluated prior to implementation. In other words, instructors should have some evidence that an approach for introducing students to R is effective prior to requiring mastery of R for high-stakes graded course assessments. Such evaluation ought to consider students' learning experience, the impact on student knowledge, and the effect on students' attitudes toward statistics and statistical software, which in turn can affect their motivation to learn more about statistics in the future.

The Present Study

This study evaluated the effectiveness of three brief (∼15 min each) online tutorials introducing R to undergraduate psychology students in introductory statistics courses. Importantly, these tutorials can be presented in parallel to course materials, exposing students to R in a guided, scaffolded manner without requiring them to master and perform in R to earn substantive course grades. Moreover, the tutorials can be used as a complement to existing course design without the instructor having to alter an existing course design. We examined students' experiences of learning R through these tutorials, their knowledge of R after completing the tutorials, and differences in students' attitudes toward statistics and statistical software before and after completing the tutorials. Four research questions guided this research:

1. What are students' experiences learning R through the online tutorials?
2. Do students demonstrate basic knowledge of R after completing the online tutorials?
3. Did students' attitudes about statistics in general differ before and after completing the online R tutorials?
4. Did students' attitudes about statistical software differ before and after completing the online R tutorials?

We did not specify hypotheses regarding students' experiences with the tutorials as we wanted to observe and understand students' experiences in the absence of a particular expectation. We predicted that students would demonstrate basic knowledge of R after completing the online tutorials as evidenced by their scores on a post-tutorial knowledge test. We further anticipated that students' attitudes toward statistics and statistical software would improve after completing the online R tutorials, given the relatively risk-free learning environment the tutorials present to students.

Method

Participants

We recruited participants from seven sections of introductory statistics for psychology courses at a large Canadian university. Four hundred forty-six students consented to participate. Of these, we removed 165 cases for not completing all study components and eight additional cases for failing at minimum two of five attention checks (e.g., "Please respond 'disagree' to this question"), resulting in a final analytic sample of 273 participants.

The sample was 21.56 years old on average ($SD = 5.85$), and the majority of the sample was identified as female (75.8%; 22.3% male; 0.4%

nonbinary; 1.5% prefer not to say/other). The sample was ethnically diverse (31.1% White; 19.8% South Asian; 12.5% East Asian; 7.7% Black; 5.9% Hispanic; 4.0% Arab; 1.1% First Nation; 1.1% West African; 0.4% Native Hawaiian; 11.0% other; 5.5% did not respond), roughly reflecting the racial composition of the overall department and university. Most participants were full-time students (94.1%), enrolled in a statistics course for the first time (88.6%), and reported the course was a program requirement (94.9%). The majority of participants (78.0%) were enrolled in a section of statistics that incorporated a non-R statistical software (jamovi) in the course curriculum. Participants had a mean cumulative grade point average (GPA) of 6.07 on a 9-point scale (SD = 1.66, letter grade equivalent = B) at the start of the course. Participants' GPAs did not differ across the seven sections, $F(6, 239) = 1.28$, $p = .086$, nor across instructors, $F(2, 243) = 1.18$, $p = .180$.

Measures

Demographic Information

Participant demographic details were measured in the pretutorial survey. Demographic information collected included students' age, gender, race, whether it was their first time taking the course, whether they were required to take the course, international student status, enrollment and employment status, course section, their program/major, year of study, self-reported current GPA, and their anticipated performance in the course.

Attitudes Toward Statistics

The Survey on Attitudes Toward Statistics (SATS; Schau, 2003) was included in both the pretutorial and posttutorial surveys to measure participants' baseline and posttutorial statistical anxiety and attitudes toward statistics in general. This 36-item survey assesses six dimensions: (a) *affect:* student feelings concerning statistics (six items), (b) *cognitive competence:* student perceptions of their aptitude with statistics (six items), (c) *value:* student valuing of or perceived worth of statistical knowledge in their personal and professional life (nine items), (d) *difficulty:* student perceptions of statistics' difficulty (seven items), (e) *interest:* the amount of interest the student places on learning statistics (four items), and (f) *effort:* the amount of work the student is willing to put into learning statistics (four items). Each item is measured on a 7-point Likert-type scale (1 = *disagree strongly*; 7 = *agree strongly*), with participants responding about how they feel toward statistics (e.g., "I will feel insecure when I have to do statistics problems"). Nolan et al. (2012) have found the SATS to have good validity and reliability across the subscales. Internal consistency was acceptable for most dimensions in the present study both at baseline (affect: Cronbach's $\alpha = 0.85$, $\omega = 0.85$; cognitive competence: Cronbach's $\alpha = 0.86$, $\omega = 0.87$; value: Cronbach's $\alpha = 0.88$, $\omega = 0.88$; interest: Cronbach's $\alpha = 0.91$, $\omega = 0.91$; effort: Cronbach's $\alpha = 0.74$, $\omega = 0.78$) and posttutorial (affect: Cronbach's $\alpha = 0.86$, $\omega = 0.86$; cognitive competence: Cronbach's $\alpha = 0.86$, $\omega = 0.87$; value: Cronbach's $\alpha = 0.90$, $\omega = 0.90$; interest: Cronbach's $\alpha = 0.93$, $\omega = 0.94$; effort: Cronbach's $\alpha = 0.75$, $\omega = 0.79$). However, the difficulty subscale had poor internal consistency (Cronbach's $\alpha = 0.67$, $\omega = 0.67$) at baseline and was only slightly better posttutorial (Cronbach's $\alpha = 0.73$, $\omega = 0.73$), so we excluded it from analyses. We calculated pre- and posttutorial scores for the remaining attitude domains by averaging across items at each timepoint, with higher scores representing a more positive attitude in a particular domain (e.g., higher score on effort reflects students' attitude that statistics do not require that much effort).

Attitudes Toward Statistical Software

Attitudes Toward R. We used the Attitudes Toward R Scale (ATR; Counsell & Cribbie, 2020) to measure students' attitudes toward the statistical software, R. One item, "How would you rate your attitudes about using statistical software like R?" was included in both the pre- and posttutorial surveys to assess changes in students' attitudes toward statistical software and R; responses were recorded using a 7-point Likert-type scale (response ranging from 1 = *very negative* to 7 = *very positive*). The remaining five items of the ATR assess students' comfort level and confidence with using R, their evaluation of R as a tool, and their motivation to learn more about R (e.g., "I am much more comfortable using R now compared to when I first started using it") on a 7-point Likert-type scale (responses ranging from 1 = *disagree* *strongly* to 7 = *agree strongly*). We included these remaining items only in the posttutorial survey to attain a descriptive understanding of students' attitudes toward R after completing the tutorials. Counsell and Cribbie (2020) have previously found evidence of convergent validity across all items. Scores from 1 to 7 were considered separately for each item in the present study rather than aggregated to give us more detailed information about each of the different attitudes toward R and to preserve additional detail in our descriptive analysis.

Perceived Ability to Use Statistical Software. The Stereotype Content Appraisal Scale, originally adapted from Fiske et al.'s (2002) stereotype content model and Carlsson and Björklund's (2010) competence Implicit Association Test, was further modified to measure participants' perceptions of their abilities to use statistical software; this measure was included in both the pre- and posttutorial surveys. The adapted scale for the present study contains two anchors on a 7-point response scale and asks participants to rate their abilities with statistical software along five different traits: competency (incompetent to competent), intelligence (unintelligent to intelligent), capability (incapable to capable), knowledge (unknowledgeable to knowledgeable), and skill (unskillful to skillful). Aligned with prior research using these original scales, an overall perceived ability to use statistical software score was calculated by averaging scores across these five traits. Evidence of excellent internal consistency supported this approach for both pretutorial (Cronbach's α = 0.93) and posttutorial (Cronbach's α = 0.94) scores.

Students' Learning Experiences

Participants completed a nine-item questionnaire regarding their experiences with the tutorials. We created seven quantitative items for the purposes of this study to understand how students perceived the tutorials as a learning tool. We developed these items to tap into the four levels of evaluating training programs, namely *reaction* (e.g., "The online tutorials were a good use of my time"), *learning* (e.g., "Completing the online tutorial resulted in an increase in my skills/knowledge"), *behavior* (e.g., "The online tutorials made me interested in learning more about other kinds of programming"), *results* (e.g., "The online tutorials helped me gain an understanding of how statistical methods can be applied in research"; Kirkpatrick & Kirkpatrick, 2006, 2007). Participants indicated their agreement (1 = *strongly disagree*; 7 = *strongly agree*) with each of these nine items. One open-ended question was also included, so that students could further elaborate on "what was most useful about the online tutorials?"

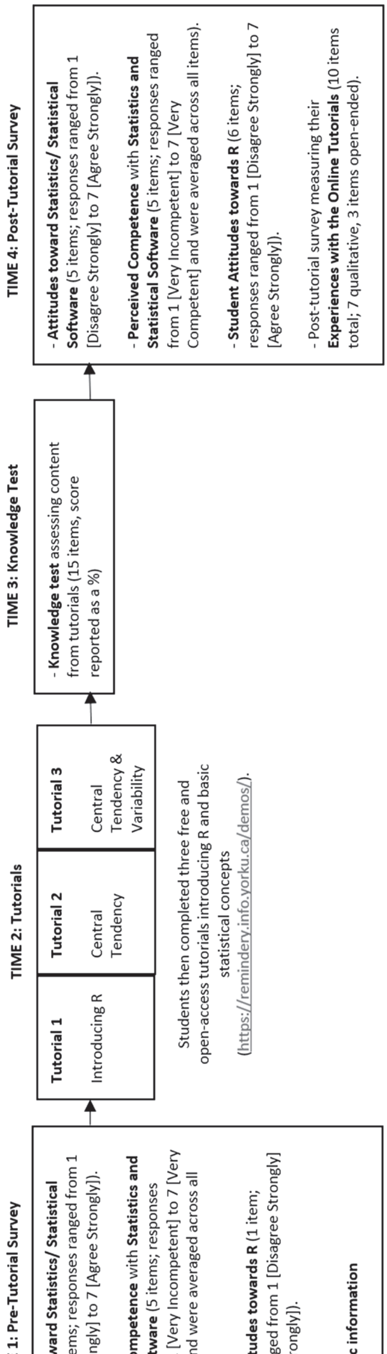
Students' Knowledge of R

Participants completed a 15-item multiple-choice knowledge test after completing the online tutorials. Students completed the test online and each question assessed knowledge of a topic covered in one of the three tutorials, for example, "What is the difference between OBJECTS and FUNCTIONS?"; "What does the following line of code do? CATS <- c(2, 5, 6, 7, 9)?". Tests were scored as the percentage of correct responses.

Procedure

Eligible participants were enrolled in courses during the Fall of 2020; all courses were delivered remotely due to the COVID-19 pandemic. Three different instructors spanned these seven sections, two of whom included the teaching of non-R statistical software (jamovi) in their courses, while the third focussed on hand calculations. Study procedures were incorporated into the course design, such that participants were required to complete four tasks throughout the 12-week semester in exchange for a total possible 4% participation points (for 4 of 7 sections) or for 4% bonus points (for the remaining 3 sections). Students were able to complete all study components at a time of their choosing in order to respect the university's call for flexible learning approaches for students during the pandemic and their first semester of entirely online education. Only those who provided consent to participate in the research study above and beyond completing the tasks for course credit were included in the study. Consenting participants were entered in a draw to win one of five $50 gift cards. Participation and consent status were anonymous to all course instructors. Only data from students who consented to share their information for the purposes of research are included in the current analyses. All procedures were approved by the institution's ethical review board.

Figure 1
A Visual Representation of Study Components



Note. This figure demonstrates what students who consented to participate completed throughout the 12-week duration of their introductory statistics course.

Students completed four tasks to be a part of the study (see Figure 1): pretutorial survey, three R tutorials, knowledge test, and posttutorial survey. These four tasks could be completed at the student's time of choosing, as long as it was within the 12-week period of the semester. First, students completed a pretutorial survey measuring baseline attitudes toward statistics and statistical software, and basic demographic information. Next, students completed three online tutorials introducing the basics of R. After completing the tutorials, participants completed a multiple-choice knowledge test assessing their abilities to use R based on the material covered in the tutorials. Last, students completed a posttutorial survey regarding their experiences using the tutorials and their attitudes toward statistics and statistical software. Students completed the surveys and knowledge test through Qualtrics, while the tutorials were completed through the students' web browser.

R Tutorials

Students completed three open-access online tutorials introducing them to R (https://remindery.info.yorku.ca/demos/). These tutorials were designed specifically for early undergraduate students who typically do not have a strong background in computer programming. The goal of these online tutorials is to scaffold students' introduction to using R in a risk-free and easy-to-use experience. The tutorials are designed to be interactive and engaging; they include a *try-it-yourself* component and text-based hint options, so students can perform coding while having real-time automated assistance with their code if they have problems. All three tutorials can be accessed through a web browser; they do not require the download or installation of R. The first tutorial covers the basics of R, including R as a programming language and how to store data into objects. The second and third tutorials cover the calculation of descriptive statistics (measures of central tendency, variability) using R, with slightly increasing sophistication. Each tutorial takes about 15–20 min to complete. All three tutorials include a brief introduction or explanation of the particular topic and skill to be learned, a demonstration of the coding skills or knowledge, and interactive practice questions with embedded R coding for students to apply their knowledge.

Results

Students' Experiences Learning R Through Online Tutorials

Quantitative Analyses

We used descriptive statistics to examine quantitative items. Given the ordinal nature of these variables, we calculated medians and modes, as well as the percent of respondents who agreed with each item (i.e., percent of sample responding with 5, 6, or 7). Students' experiences with the tutorials were positive overall, with medians and modes above the midpoint of the scale for all individual items (see Table 1, for descriptive statistics). Most notably, more than two thirds of students agreed that the tutorials were an effective way to learn the basics of R, that the tutorials increased their skills/knowledge, and that they helped them gain an understanding of how statistics can be applied in research.

We conducted post hoc follow-up analyses to determine if these results varied for students enrolled in a course that included point-and-click statistical software (e.g., jamovi) in the curriculum or those with varying general academic ability (i.e., cumulative GPA). Inclusion of other software in course curriculum was not related to students' experiences learning through the tutorials (r_{pb}s between −0.010 and 0.120, ps between 0.06 and 0.88), suggesting that students' experiences with the tutorials were similar regardless of whether students were in a course that included instruction in any software. However, cumulative GPA was significantly correlated with one of the nine experience items, such that those with a lower GPA at the start of class found the tutorials to be a more effective way to learn R, though this association was relatively weak ($r = -0.16$, $p = 0.01$).

Qualitative Analyses

Participants responded to the open-ended question: "Indicate what element(s) of the tutorial was most useful." We thematically analyzed responses to further understand student experiences. Of the 273 participants, 267 responded to the open-ended question. The qualitative analysis was a multistep process. The first author started by reading all responses individually to get a sense of what key themes were emerging. The first author then created first-order codes capturing lower order themes (e.g., "Being able to run R within the tutorial" and "Ability to use the tutorials and quizzes multiple times"). We later organized first-order codes into broader second-order codes when appropriate, which represented broader themes observed in the data. For example, the first-order themes in the example above would fall under the second-order code "Tutorial format." We then determined the frequencies for each higher level theme to identify the most common themes. Themes were only included in the summary of this analysis if there were 10 or more instances of a particular theme. Most students reported more than one element that they found beneficial from the tutorials, so identified themes are not mutually exclusive. Once these initial first- and second-order themes were

Table 1
Students' Experiences Learning R Through Online Tutorials

Experience items	*Mdn*	Mode	% agreement
The online tutorials were a good use of my time.	5	6	73.2
The online tutorials were an effective way to learn the basics of R.	6	6	82.0
Completing the online tutorial resulted in an increase in my skills/knowledge.	6	6	78.8
The online tutorials helped me to understand course content.	5	6	65.9
The online tutorials made me interested in learning more about other kinds of programming.	5	5	51.3
The online tutorials helped reduce my anxiety about learning R.	6	5	58.2
The online tutorials helped me gain an understanding of how statistical methods can be applied in research.	5	6	72.5

Note. Item scores range from 1 (*strongly disagree*) to 7 (*strongly agree*). $n = 273$. Percent agreement (% agreement) was calculated by summing the frequency of "agree" responses (scores of 5 = *somewhat agree*, 6 = *agree*, 7 = *strongly agree*) and dividing by total number of responses.

established, the second author independently and iteratively coded the responses for key themes until there was 80% agreement between coders. The two coders met to resolve coding disagreements.

Responses suggest that students had positive experiences with many aspects of the tutorials. The first-order themes were grouped into eight second-order umbrella themes representing what students found most useful about the tutorials: (a) hints; (b) the "try-it-yourself" portion; (c) explanation and instructions; (d) tutorial content; (e) tutorial format; (f) use of real examples; (g) simplicity in design; and (h) gradual progression between tutorials and topics. Additional details including first-order themes and sample responses for each theme appear in Table 2. The largest number of students ($n = 121$) reported that the hints were the most useful element of the tutorials. One student noted specifically, "the hint function was extremely helpful when I found myself stuck." Students also commonly mentioned benefiting from the chance to engage in active coding within the tutorials through the "try-it-yourself" portion, which allowed students to apply different coding strategies to real-life problems ($n = 57$). For example, one student said "the most useful part of the tutorials were the activities that had you apply the knowledge gained. This helped me develop a better understanding."

Participants also appreciated the detailed examples and instructions used in the tutorials ($n = 30$). One student noted "I appreciated that [the tutorials] used local examples of data recorded in Toronto. The instructions were highly clear with each step of the tutorials." Another student noted "the examples allowed me to learn by looking at how the syntax and the functions were supposed to be used correctly." Additionally, students reported enjoying the tutorial content ($n = 26$) and format ($n = 21$). For example, one student noted that they appreciated "being able to view the R software in the web browser and being able to create a code and run it live."

Students' Knowledge of R

We calculated descriptive statistics for percentage grades on the Posttutorial Knowledge Test to determine whether students demonstrated some knowledge of R after completing the tutorials. Students demonstrated working knowledge of R after completing the tutorials, as evidenced by an average score of 69% (reflecting a C+ in Canadian university grading standards), although there was a relatively large amount of variability in student scores ($SD = 18.64$). Further examination of the grade distribution showed that almost two thirds (65.6%) of the sample achieved at least a C+ grade (65% or higher based on Canadian university grading standards) and more than half (55.3%) achieved at least a B− grade (70% or higher based on Canadian university grading standards).

Students' Attitudes About Statistics

Student attitudes toward statistics were neutral to positive both before and after completing the online R tutorials, as evidenced by average scores on the attitudes toward statistics scales (which were at or slightly above midpoint; see Table 3). We used five dependent-sample *t* tests to test the hypothesis that students' attitudes about statistics would improve after completing the online R tutorials. As shown in Table 3, analyses provide minimal support for this hypothesis. A statistically significant mean difference was found for effort, indicating that effort scores were lower posttutorial than pretutorial, though the size of this difference was small. Lower scores on this measure reflect a less positive perspective within each attitudinal domain. For example, lower posttutorial scores on effort suggests that students have a more negative attitude about the amount of effort it takes to learn statistics after completing the R tutorials compared to before. In other words, after completing the R tutorials, students in our sample reported a belief that learning statistics requires more effort than they believed prior to completing the tutorials. We found no statistically significant changes from baseline to posttutorial for students' statistics anxiety, perceived competence in statistics in general, or their valuing and interest in statistics.

Students' Attitudes About Statistical Software

Attitudes Toward R

We analyzed student attitudes toward R after completing the online tutorials using two approaches. First, using descriptive statistics and Wilcoxon signed-ranks tests, we compared students' pre- and posttutorial responses to the question, "How would you rate your attitudes

Table 2
Thematic Coding Analysis—"Indicate What Element(s) of the Tutorials Was the Most Useful"

Second-order categories	First-order code	Representative quote
Hints (n = 121)	Hints were the most useful element	"The most useful element was the "HINT" option. I am not good at math and it is very difficult for me to comprehend and process anything mathematical. I found that following the hints step by step is what guided me through the tutorials and without them I would have felt discouraged, confused, and possibly would have even given up."
"Try-it-yourself" (n = 57)	Embedded coding within the tutorials	"Playing around with coding by ourselves was the most helpful part because it allows me to experiment on my own time and have a deeper understanding of the code rather than just reading and taking notes."
	Quizzes	"I found the mini-quizzes based on the coding to be useful, I felt like I was putting the coding I learned to use and it made me more comfortable using R."
Explanation and instructions (n = 30)	Instructions	"The instructions were highly clear with each step of the tutorials."
	Explanations	"The carefully worded explanations and step by step walk through—I felt it was a very well-designed tutorial."
Tutorial content (n = 26)	Descriptive statistics	"Learning mean, mode, and median."
Tutorial format (n = 21)	Being able to run R within the tutorial	"Being able to view the R software in the web browser and being able to create a code and run it live."
	Ability to use the tutorials and quizzes multiple times	"The fact that we can do the assignment and tutorials multiple times."
Use of real examples (n = 19)	Real-life examples and data	"I appreciated that it used a local example of data recorded in Toronto."
	Themed examples	"The tutorials' consistent use of the same examples helped me visualize the progressive use of R for multiple statistical purposes. It helped me make connections between topics we learned in class and tutorial concepts."
Simplicity in design (n = 15)	Easy to follow along	"They were easy to follow through with language that was almost as if i was having a conversation with someone which made me feel more comfortable."
Gradual progression between tutorials and topics (n = 11)	Eased slowly into new topics	"I appreciated the slow-moving intro of tutorial one that allowed me to get my feet wet with no prior coding experience of any kind."

Note. n = 267.

Table 3
Pre- and Posttutorial Differences in Students' Attitudes Toward Statistics

Attitude toward statistics	Pretutorial *M* (*SD*)	Posttutorial *M* (*SD*)	*t*	*p*	*d*	95% CI
Affect	4.21 (1.22)	4.20 (1.22)	0.53	0.96	0.00	[−0.12, 0.12]
Cognitive competence	4.85 (1.09)	4.97 (1.04)	−1.30	0.20	−0.08	[−0.20, 0.04]
Value	5.07 (1.00)	5.07 (1.01)	−0.04	0.97	−0.00	[−0.12, 0.12]
Interest	5.02 (1.27)	4.89 (1.38)	1.12	0.26	0.07	[−0.51, 0.19]
Effort	6.51 (0.58)	6.06 (0.85)	7.00	<.001	0.42	[0.30, 0.55]

Note. CI = confidence interval.
Higher scores reflect a more positive perspective within each attitudinal domain, for example, higher score on effort suggests a belief that learning statistics does not require a lot of effort. $n = 273$.

about using statistical software like R?" Student attitudes toward R were neutral before ($M = 4.13$, $SD = 1.58$, $Mdn = 4.00$) and after completing the three tutorials ($M = 4.28$, $SD = 1.77$, $Mdn = 5.00$) with no change after the tutorials were completed, Wilcoxon $W = 10, 971$, $p = 0.17$, $r_{pb} = -0.11$.

Next, we examined the mode, median, and percent agreement (i.e., proportion of responses that were 5 or higher on the 7-point scale) for items assessing students' attitudes toward R after completing the tutorials (e.g., "I am much more comfortable using R now compared to when I first started"; Table 4). Students generally held slightly positive attitudes toward R after completing the tutorials.

Students' Perceived Ability to Use Statistical Software

An examination of descriptive statistics suggests that students held neutral to slightly positive attitudes about their abilities to use statistical software both before ($M = 4.36$, $SD = 1.28$) and after ($M = 4.70$, $SD = 1.23$) completing the tutorials. We used a dependent-samples *t* test to test the hypothesis that these perceptions of ability would increase after completing the tutorials. Results supported this hypothesis such that ratings of their ability to use statistical software were higher after completing the tutorials than prior, $t(270) = -3.33$, $p < .001$, though this difference was small (Cohen's $d = .20$).

Follow-Up Analyses

We conducted additional post hoc follow-up analyses to examine if results for students' knowledge of R or their attitudes toward statistics and statistical software varied for students in a course that included point-and-click statistical software (e.g., jamovi) or based on academic ability (i.e., cumulative GPA). These analyses confirmed that students' performance on the knowledge test, changes in attitudes toward statistics, statistical software, and R were independent of these factors (see Supplemental Materials, for more detail).

Discussion

Our research examined the effectiveness of a set of open-source online tutorials introducing R to undergraduate psychology students (https://remindery.info.yorku.ca/demos/). Results suggest that these tutorials are a moderately effective

Table 4
Students' Attitudes Toward R

Experience items	*Mdn*	Mode	% agreement
I am much more comfortable using R now compared to when I first started.	5	6	73.6
Having learned R will help me analyze more of my own data in the future.	5	5	64.1
The skills I've learned in R will be useful for getting a job.	5	4	51
While not an expert in R, I am confident that I can find information about R functions and packages to help me analyze data.	5	6	69.3
I am interested in learning more about data analysis in R.	5	5	53.1

Note. Item scores range from 1 (*strongly disagree*) to 7 (*strongly agree*). Percent agreement (% agreement) was calculated by summing the frequency of "agree" responses (scores of 5, 6, 7) and dividing by total number of responses. $n = 273$.

tool for providing students with basic R skills, and students had positive experiences learning with the tutorials. Moreover, students' attitudes toward statistics and statistical software were generally neutral to positive before and after completing the tutorials and remained relatively stable. That said, students did perceive statistics as requiring greater effort after learning about R through the tutorials, the only attitude toward statistics that changed from pre- to posttutorial, but they also reported increased ability to use statistical software after the tutorials.

Results from both the quantitative and qualitative data collected indicate that students had overall positive experiences with the tutorials. Quantitative findings showed students reported positive experiences completing the tutorials regardless of whether they were enrolled in a course that included (non-R) statistical software in the curriculum. Interestingly, students with lower cumulative GPA tended to give higher ratings of the tutorials' effectiveness as a tool for learning the basics of R. Hence, online tutorials appear to be an effective way to introduce a range of undergraduate psychology students to R, and may be especially helpful for students who are not high academic achievers, though additional research is needed to confirm these results.

Participants' responses to open-ended questions further elucidated which aspects of the tutorials students found effective. Most commonly, students found the hints provided, the interactive "try-it-yourself" approach, and the clear instructions to be the most effective components. Themes from student responses can perhaps best be understood when considering the generation of students in the sample. Research suggests that members of Generation Z ("Gen Z," the predominant generation represented in undergraduate student cohorts) prefer to acquire knowledge instantly using the internet, have a shorter attention span, and prefer short bursts of information as opposed to reading long paragraphs of text, and that they favor e-learning approaches (Hampton & Keys, 2017). The aspects that the students found most effective relate to their belonging to Gen Z as they rated the hint feature as the most helpful element followed by the hands-on R coding completed within the tutorials. Although their preference for the hint function may just be their impatience for getting to the right answer, one can also presume it reflects a desire for more guidance and structure. These findings together provide important information with which we can improve these tutorials even further, as well as details to note for others endeavoring to create their own e-learning approaches to introduce undergraduates to R or other statistical software.

Students demonstrated knowledge of basic R skills after completing the tutorials, though knowledge test scores were not especially high and there was a moderate amount of variability. We suggest two possible explanations for these lower scores and high variability. First, it is perhaps not surprising that students' knowledge acquisition was minimal and inconsistent across students given that programming in R is inherently difficult, especially for beginners learning complex statistical concepts for the first time. The aim of the tutorials was to introduce R in a risk-free manner, so that students could be exposed to programming, without feeling the pressure to master it. Second, scores on the test had no direct impact on students' grades in their statistics course as poor performance did not reflect in their overall grade in the class, which may account for students' varied performance on the knowledge test.

Our goal was to present these tutorials in a risk-free manner, so that students could be gently exposed to R, without feeling the pressure to master R to earn course grades. We believe this is the key difference that sets our study apart from previous research that has required students to master software skills to perform well in the course (Jatnika, 2015). Results from follow-up analyses suggest that students' knowledge of R was similar regardless of whether students were in a course that taught (non-R) software or were of varying academic ability. Thus, the tutorials were effective for a range of students and could be used with equal effect both in courses that include instruction in other software and those that do not.

To our knowledge, our study was the first to statistically compare psychology students' attitudes about statistics and software before and after learning R. In line with Counsell and Cribbie (2020), student attitudes toward statistics were neutral to positive both before and after the tutorials. Further, we found no pre- to posttutorial changes in students' attitudes toward statistics, valuing of statistics, competence in statistics, nor interest in statistics. However, students did perceive learning statistics as requiring more effort after completing the tutorials.

A possible reason for the stability of most attitudes toward statistics may be that there was no cause for students' attitudes *about statistics in general* to change, as the tutorials were targeted toward learning R skills rather than to teaching general statistical concepts. Alternatively, students completed all study components at their time of choosing. Some students may have completed all components of the study on the same day. Hence, it is perhaps unlikely that attitudes toward statistics would be changed over such a short period of time. Additional research with more clearly defined assessment timepoints could clarify our results. Although technically a null finding, the lack of negative change in students' attitudes after learning software is still noteworthy, particularly compared to past research findings (e.g., Rosen et al., 1994). The tutorials provided students an introduction to R that did not negatively impact their attitudes toward statistics and statistical software, despite introducing a new and complicated tool. Previous research found that attitudes toward statistics can become more negative after the introduction of software (e.g., Rosen et al., 1994), but our tutorials did not have this effect.

Notably, students' perceptions of the greater effort needed to learn statistics after completing the tutorials aligns with prior research showing R has an initially steep learning curve (Dempster & McCorry, 2009; Rode & Ringel, 2019). Counsell and Cribbie (2020) also found evidence from students' qualitative responses indicating that they found learning statistics and R to be a lot of work upon reflecting on their learning experience. It is perhaps not surprising that learning even the most basic of programming skills required to use R to analyze data would alter students' perceptions of how much effort is needed to learn statistics.

In contrast to Counsell and Cribbie's (2020) findings, we found that students held neutral to slightly positive attitudes about statistical software both before and after completing the tutorials. Although students' general attitude toward R (i.e., "How would you rate your attitudes about using statistical software like R?") remained neutral after completing the tutorials, they generally indicated somewhat positive attitudes in terms of their ability to use R after the tutorials (the latter were measured only following tutorial completion). Moreover, students' perceived competence to use statistical software increased a small amount after completing the tutorials. This was true for students who were simultaneously exposed to non-R software in their course and those who were not, indicating that the tutorials were effective in improving students' belief in their capacity to use statistical software. Findings also held for different levels of GPA, supporting the notion that the tutorials were effective across a range of academic ability.

These findings differ from those of Counsell and Cribbie (2020), who reported stable, neutral attitudes toward statistical software before and after learning about R; but these differences were not compared statistically. Variation in course design may explain these differences. For our study, mastery of R was not required of students to succeed in their statistics course, whereas performing in R was built into the course design in Counsell and Cribbie's study. As such, perhaps students are slightly more positive about R when first learning about it in a scaffolded, risk-free manner such as the online tutorials, as opposed to within a course where grades are directly connected to their ability to use R. That said, given the general lack of research in this area, additional study is needed to further corroborate students' attitudes about statistical software after learning about R.

Limitations and Future Directions

Despite these important findings, some limitations are worth noting. First, given the nature of most longitudinal studies, a large number of students did not complete all four study components and were hence removed from our analyses (37% attrition rate). As a result, there is a possibility that our self-selected sample might have included higher performing or more motivated students. This self-selection may explain why students in our study had more positive attitudes about statistics than those from Counsell and Cribbie (2020). Unfortunately, this is a common limitation of pedagogical research that we could not entirely remove from our study design.

Second, most participants came from a section that incorporated non-R statistical software (jamovi) in the course design; only 22% were from sections without any software component included. Although we performed post hoc comparisons between students across these groups and did not find differences in our results, future research ought to include more equal groups across teaching software versus no software courses to verify our findings.

Finally, students were able to complete study components at a time of their choosing; some students completed everything in a single day or over a very short time period, perhaps muting potential changes in attitudes toward statistics and statistical software. Future research should replicate this study using a more structured timeline to verify our results.

Conclusion

Results of this research support the use of open-source online tutorials (https://remindery.info.yorku.ca/demos/) as a modestly effective way to scaffold undergraduate psychology students' introduction to R. Students had positive experiences with the tutorials and demonstrated adequate knowledge of R basics after completing the tutorials, suggesting minimal risk to their learning experience. Moreover, attitudes toward statistics and statistical competency were neutral to positive and stable pre- and posttutorial, suggesting that the tutorials offer a means to introduce students to a complex tool without negatively impacting their attitudes about statistics. Students also perceived themselves as more capable of using statistical software after completing the tutorials, which may further increase the likelihood that they will continue to want to learn more in the future. Notably, findings were consistent across differences in course design and academic ability, supporting the use of these tutorials across a range of teaching contexts and student abilities.

As demonstrated from our study design, tutorials such as these are effective and can easily be implemented into introductory statistics courses for psychology students to start building their skills in R, which may facilitate success in both undergraduate and graduate education, as well as subsequent employment. These tutorials could also be incorporated into statistics courses that include instruction of R as part of the course design. The tutorials could be assigned as activities that students complete early in the course (either inside or outside of class time) to become comfortable and familiar with R's programming language and basic functionality before creating one's own code or adapting existing packages. Given that the tutorials are completed in a web browser and do not require students to download and install any software, nor to find and open packages or data sets in R, they may help teach some basic skills prior to introducing those more complex elements of using R throughout the course's duration.

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