

Extending the Self-Explanation Effect to Second Language Grammar Learning

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Abstract: Self-explanation is an instructional strategy that has shown to be beneficial for math and science learning. However, it remains an open question whether these benefits will extend to other domains like second language grammar learning. Within the domain of the English article system (teaching students when to use *a*, *an*, *the*, or no article at all), we compare two computer-based tutoring conditions in an in vivo classroom study. In the article choice condition, students select the correct article to complete the sentence. In the explanation choice condition, students are given a sentence with the correct article highlighted and choose the rule or feature that best explains the article use. Students (N=101) in both conditions show significant learning on both procedural (article choice) and declarative (explanation choice) tasks. Not surprisingly, we found that declarative instruction (explanation choice) led to significant learning of explanations, while procedural practice (article choice) led to significant learning of the procedures. More interestingly, we also found evidence of cross-type transfer such that declarative practice led to procedural gains and procedural practice led to better understanding of the declarative rules. In general the effects of prompted self-explanation appeared somewhat stronger than those of procedural practice.

Introduction

Self-explanation is an instructional strategy that has lead to increased learning by encouraging students to focus on key features of the material (Roy & Chi, 2005). However, the majority of this work has been done in math and science domains like physics (Chi, et al., 1989; Conati & VanLehn, 2000), geometry (Alevén & Koedinger, 2002), and biology (Chi, et al., 1994), with little existing work in domains like second language grammar learning. The first self-explanation studies were correlational studies that demonstrated that students who self-explain more learn more (Chi, 1989). Follow-up studies have shown that prompting students to self-explain increases learning (Chi, et al., 1994), and that having students select explanations from a list of options (rather than constructing free-formed responses like in previous studies) is also a successful technique (Alevén & Koedinger, 2002; Renkl, 1999). However, despite being called a domain general strategy (Roy & Chi, 2005), the self-explanation effect has not been extensively tested in domains other than math and science with the exception of McNamara's (2004) work on reading comprehension. Our work differs from previous work in its focus on second language grammar acquisition, a problem-solving domain where there is a strong intuition that immersive practice, without reflection on rules, is more natural and perhaps best.

In this paper we compare math and science learning and second language grammar acquisition and discuss why self-explanation may or may not be beneficial for learning English grammar constructs. We then describe two systems that we built to evaluate the self-explanation effect in an empirical classroom-based study within the context of learning the English article system (teaching students when to say “a pencil” versus “the pencil”). As expected, students in both conditions demonstrate significant learning gains on their tutored skill: students in the tutored-practice (article choice) condition learn how to select the correct article, and students in the self-explanation condition learn how to select correct explanations for article use. More surprisingly, students in both conditions also show cross-type transfer with students in the article choice condition learning how to select explanations and students in the self-explanation condition learning how to select the correct article. These results are promising and suggest that self-explanation is beneficial for second language grammar acquisition and leads to the refinement of both procedural and declarative knowledge.

Article Domain

We chose to focus on the domain of non-native English speakers learning the English article system because of the importance of acquiring article use skills, the rule-based structure of the article system, and second language acquisition theory that suggests articles are particularly well suited for a rule-based instructional approach. Grammar errors can cause writing to become “intelligible”, “irritating”, or both (Ellis, 1994), and articles are one of the last grammar points for English language learners to acquire (Master, 1997). We also chose article use as a domain because its rule-based nature makes it a good candidate for studying the effects of self-explanation in language learning. In contrast to domains like vocabulary learning where students must

memorize arbitrary mappings, article usage is generally determined through a set of heuristics based on features of the sentence (although many exceptions exist). For example, in the sentence, “Yesterday, I bought a car. Today, *the* car broke,” the article *the* is used because the noun *car* has already been mentioned. Furthermore, according to second language acquisition theory, some grammar constructs are better suited for rule-focused instruction than others. For example, articles are a type of grammar construct that is often not required for successful communication (i.e. readers likely understand the sentence, “Yesterday, I went to (no article) store” even though “Yesterday, I went to *the* store” is correct), and thus articles and their function within a sentence are unlikely to be noticed by learners without formal, rule-focused instruction (Williams & Evans 1998).

Domain Differences

While self-explanation has been very successful at increasing learning in math and science domains, there are inherent differences between math and science and second language learning which may affect the success of self-explanation in this new domain. One key difference lies in the pedagogical goals of the domains. In math and science, often students are expected to be able to solve problems *and* explain the underlying principles. A typical example of this expectation is in geometry where students are asked to determine the angles of a triangle and provide the reason or rule(s) for their answer. However, the marker of a successful language learner is fluency, and knowing when and how to use a particular construct is much more important than knowing why. In fact, most native speakers of a language have no explicit knowledge of the rules driving their article decisions yet rarely make mistakes. Another difference lies in the presence and absence of exceptions to rules. In math and science, there are no exceptions. Provided that the proper conditions are met, a given rule will always apply. However, there are frequent exceptions to grammar rules. For example, one rule listed in an English as a Second Language grammar book states that no article should be used before the name of a disease (Cole, 2000); for example, *He has (no article) diabetes*. However, many exceptions exist (e.g. *He has **the** flu, She has **a** cold.*) Perhaps encouraging students to focus on rules and features of the sentence, which may sometimes prove to be unreliable, is not an effective learning strategy.

Tutor Designs

In our study, we compared a condition where students were tutored on which article to use in a sentence (*article choice*) to a condition where students were tutored on the features of the sentence relevant to article use (*explanation choice*). Both tutors were developed using the Cognitive Tutoring Authoring Tools (Koedinger, et al., 2004) and deployed online using Java WebStart. All student actions (answer selections, hint requests) were logged and time-stamped. Both tutors had 56 example sentences and addressed eight rules for making article decisions (e.g. “If the noun has already been mentioned, use *the*” or “If the noun is general and plural, use *no article*.”). In order to finish working with the tutor, students must have answered all questions correctly.

The article choice condition (Figure 1) mimics cloze or fill-in-the-blank activities found in many second language learning textbooks. Using dropdown menus, students select the article (“a”, “an”, “the”, or “no article”) that best completes the sentence. They receive immediate feedback on their selection and have access to a series of on-demand hints. This form of instruction is designed to give students practice using articles but does not require them to give a reason or explanation for their choice.

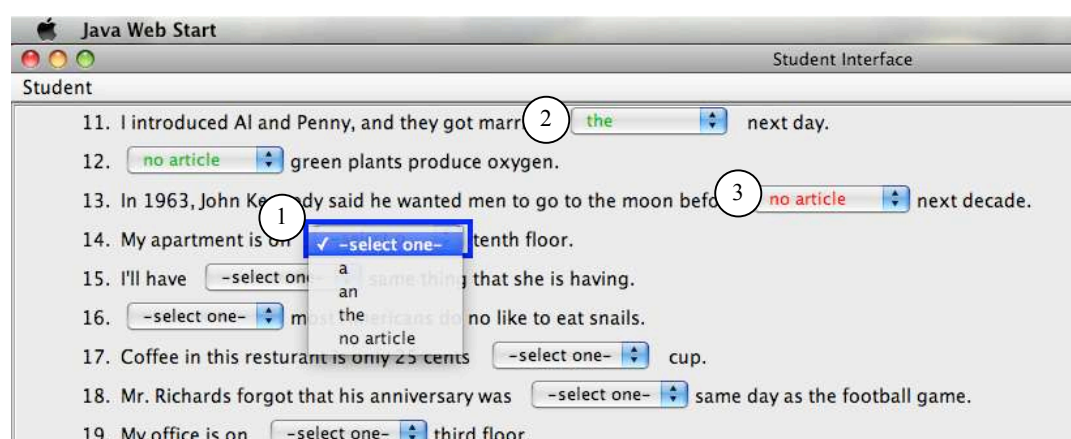


Figure 1. In the article choice condition, students choose the article (a, an, the, no article) that best completes the sentence (1), and receive immediate feedback on their selection. If the answer is right, it turns green (2), and red if it is wrong (3).

In this study, we chose to operationalize self-explanation in the form of a menu-based explanation choice tutor. In this condition (Figure 2), students are presented with a sentence with the target article highlighted and asked to choose the rule that best explains the article use. Again, students receive immediate feedback on their selection and have access to hints. In this condition, students see examples of correct article use but do not make any article decisions of their own.

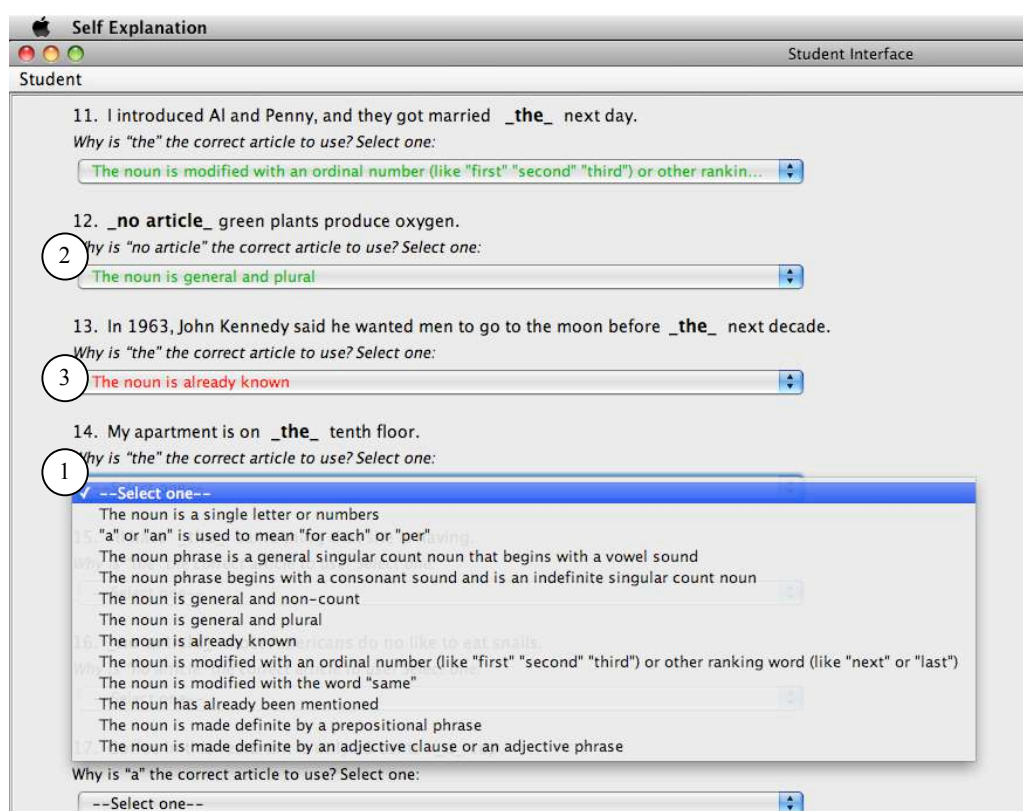


Figure 2. In the explanation choice condition, students choose the feature of the sentence that best explains the article use (1). Identical to the article choice condition, students receive immediate feedback on their selection. If the answer is right, it turns green (2), and red if it is wrong (3).

Both tutors employed a similar series of hints that were presented upon student request. The hints first identified the key feature(s) of the sentence, then provided the rule, and finally, in the article choice condition, told students which article to select (Table 1).

Table 1: Example hint sequence for the article choice and explanation choice tutors.

Target Sentence: My office is on the third floor.

| Article Choice Hints | Explanation Choice Hints |
|--|--|
| 1. "Third" is an ordinal number. | 1. "Third" is an ordinal number. |
| 2. Use "the" with ordinal numbers and other ranking words like "next" or "last". | 2. Please select "The noun is an ordinal number (like "first", "second", "third") or other ranking word (like "next" or "last"). |
| 3. Please select "the" from the highlighted menu. | |

Hypothesis

Our study addresses the question of whether self-explanation is a helpful instructional strategy for second language grammar learning. We hypothesize that students in the explanation choice condition will show greater learning gains on article choice and explanation choice tasks than those in the article choice tutor. One hypothesis for how prompts for self-explanation enhance learning is that they encourage students to notice relevant features of the problem and enable students to become aware of gaps in their own knowledge (Roy & Chi, 2005). This feature focusing technique may be beneficial to second language learning students by helping them attend to parts of the sentence that are important for making article decisions and ignore irrelevant parts.

Within the field of second language learning, there have been several studies that have investigated the differences between explicit and implicit grammar instruction. The findings from this study also contribute to

this debate, since although both conditions are examples of focus on form instruction (Doughty, 2001), the explanation choice condition which supports explicit practice of rules is an example of explicit instruction, while the article choice condition affords a more implicit approach to learning. While both approaches have their own merits, according to a meta-analysis by Norris and Ortega (2000) instructional strategies that include explicit focus on rules, like the explanation choice condition, are more effective than strategies that are more implicit in nature, like the article choice condition.

Self-explanation may also help students by strengthening multiple processes by which to make article decisions. For example, students could solve the problem through an implicit strategy in which they choose the article that sounds the most correct, or, if they become proficient at the rules, they could use an explicit strategy and make their article decision based on the features of the sentence and the rule that applies. Thus, even though the ultimate goal is to create expert *users* of the rule and not expert *explainers* of the rule, self-explanation may still be a beneficial instructional technique.

Method

The study took place during one 50-minute class period. Students (N=118) were adult English language learners (mean age = 27.9, SD=7.2) enrolled in the University of Pittsburgh's English Language Institute who came from a variety of first language backgrounds. In total, there were 13 first languages represented; however the majority of students spoke Arabic (37%), Korean (18%), or Chinese (15%) as their native language. Students participated in the study as part of their normal grammar class. There were three class levels: intermediate (n=30), intermediate-advanced (n=61) and advanced (n=27). The session started with an introduction to the tutoring and testing interfaces as well as a brief overview of the rules covered by the tutor. As adult language learners, all of the students had received some prior instruction on article use, and the goal of the demonstration was simply to introduce the vocabulary that was used in the tutors and to explain the tasks that the students would be completing. Students then completed the article choice and explanation choice pretests. Next, students were randomly assigned within each class to either the article choice or explanation choice condition and completed the tutored problems. Finally, students did the article choice and explanation choice posttests (Figure 3). Pre- and posttest forms were counterbalanced.

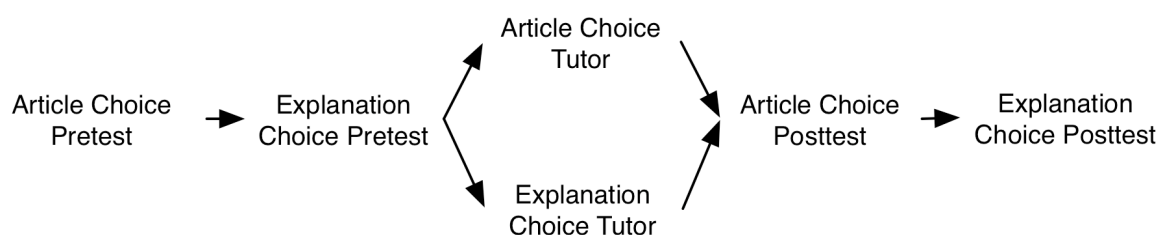


Figure 3. The sequence of tasks students completed as part of the study.

Measures

All students were assessed on both procedural knowledge (article choice) and declarative knowledge (explanation choice) items. Article choice items were isomorphic to those in the article choice tutoring condition, and students chose the article that best completed the sentence. The explanation choice items were also identical in form to those in the explanation choice tutoring condition, where students were given a sentence with the correct article highlighted and asked to explain why that article was used. Two test forms were created, each with twelve article choice and twelve explanation choice items. For each problem type, there were eight questions that used rules taught in the tutor (tutored items) and four questions that used rules that were not taught in the tutor (control items). These items were included in order to measure effects other than those from the tutoring system (e.g. students becoming familiar with the interface or students becoming fatigued).

Data Sample

Since students participated in the study as part of their normal class activity, there was limited time within which to collect data. Overall, 86% (101 out of 118) of the students completed all tasks; however, attrition between conditions was not the same with 95% (55 out of 58) of students in the article choice condition and 77% (46 out of 60) of students in the explanation choice condition completing all tasks ($\chi^2(1, N=118) = 7.9, p = 0.005$). Pretests scores for the remaining students were not significantly different ($t(1, 99) = 1.31, p = 0.192$) (Table 2), but the trend is the direction of concern (i.e., consistent with the hypothesis that low prior knowledge students were dropped from the explanation choice sample) with the explanation choice group having an average pretest score of 62.9% and the article choice group at 58.9%. Based on observation and anecdotal comments from the classroom teachers, students who ran out of time before completing the posttests fell into one of two categories: students with low prior knowledge and students with high prior knowledge who were

very meticulous and conscientious in their choices. One student did not take the pretest due to technical error and was dropped from analysis.

Table 2: After attrition, the pretest scores were slightly higher than before attrition but there was no significant difference between conditions.

| Tutoring Condition | Total Sample | | Sample After Attrition | |
|--------------------|--------------|-------------------|------------------------|-------------------|
| | N | Pretest Mean (SD) | N | Pretest Mean (SD) |
| Article Choice | 58 | 0.583 (0.162) | 55 | 0.589 (0.159) |
| Explanation Choice | 59 | 0.604 (0.145) | 46 | 0.629 (0.137) |

Even though the pretest scores were not significantly different and we have reason to believe that attrition may also occur because of the diligence of good students, we thought it best to use a statistical analysis designed to address such a situation. Propensity score matching (PSM) is a technique that is often used in quasi-experimental designs to correct for bias. PSM is similar to other types of matching but it combines several variables into one score on which to cluster participants. Prior work has shown that using propensity scores to divide students into five groups and then using this subclassification as an additional variable often removes over 90% of the bias caused by each of the covariates (Rosenbaum & Rubin, 1984). In our study, we wanted to account for bias due to attrition and thus first calculated a propensity score (1 = highly likely to complete the study, 0 = very unlikely to complete the study) for each student by running a logistic regression with the binary variable of whether or not students completed the posttests as the dependent variable. Covariates used in the regression include: the log of the time spent on the article choice pretest, the log of the time spent on the explanation choice pretest, the log of the time spent using the tutor, article choice pretest score, explanation choice pretest score, and course level (intermediate, intermediate-advanced, advanced). The participants were then divided into groups based on propensity score and this value was used as a between-subjects variable in all the analyses.

The main reason for grouping students using propensity score and not a single measure was that individually none of the other variables were highly correlated with completion rate. However the propensity score, which combines several measures, is highly correlated with whether or not a student would complete the posttests ($r(115)=0.84$, $p < 0.001$) and thus a better metric on which to group.

Results

The following analyses were done with and without the PSM variable and resulted in the same conclusions. Because we believe they are less biased and thus a more accurate description of the findings, here we report the results that include the PSM variable.

Learning Gains

Repeated measures ANOVA analyses show that students in both conditions demonstrate significant pre to posttest improvement on both the article choice measure ($F(1, 95) = 29.44$, $p < 0.001$) and the explanation choice measure ($F(1, 91) = 15.09$, $p < 0.001$). In order to determine if tutoring condition had an effect on posttest scores, a MANCOVA was calculated using article choice and explanation choice posttest scores as the dependent variables, propensity group and tutoring condition as the independent variables, and article choice and explanation choice pretest scores as covariates. This reveals a significant effect for condition ($F(2, 88) = 5.38$, $p = 0.006$). Finally, in order to understand the specific affects of the conditions, we ran univariate between-subjects tests for each test type. These showed that condition significantly affected explanation choice posttest scores ($p=0.023$) but not article choice posttest scores ($p=0.153$).

Figure 4 uses normalized gain (Hake, 1998) scores to illustrate these results: both groups are learning the skill on which they were tutored (article choice students show improvement on the article choice task, and explanation choice students show improvement on the explanation choice task). More surprisingly, both groups are also learning the transfer skill (article choice students show improvement on the explanation items, and explanation choice students show improvement on the article choice items). Furthermore, the effects of the self-explanation condition appear stronger than those of procedural practice. Despite having no tutored practice on article choice items, students in the explanation choice condition are showing equal gains on the article choice measure compared to students in the article choice condition and significantly higher gains on the explanation choice measure.

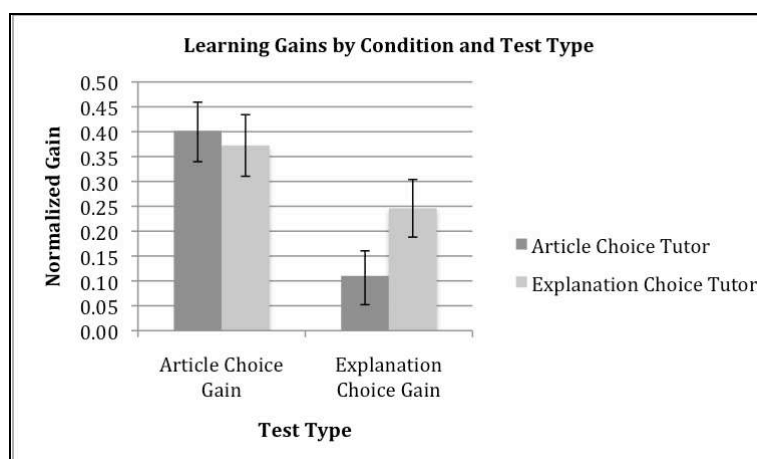
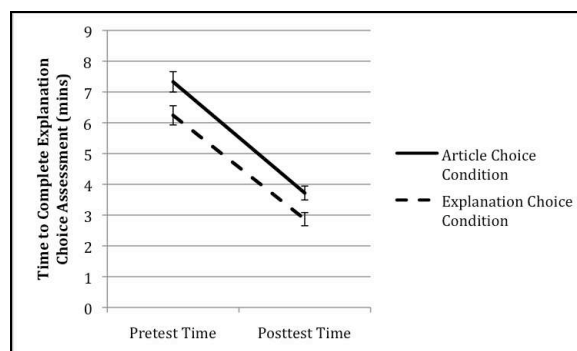
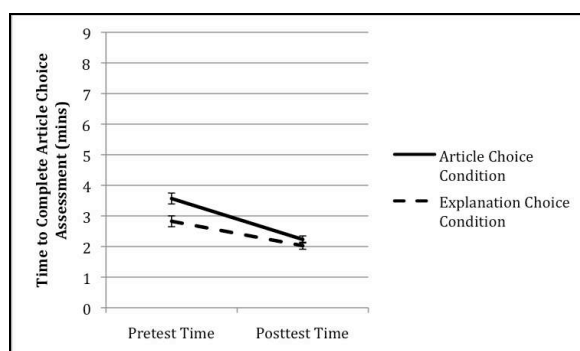


Figure 4: Normalized gains scores for article choice and explanation choice measures.

Surprisingly, we see cross-task transfer for both conditions: students using the article choice tutor show a small but significant gain on the explanation choice items, and students using the explanation choice tutor, who had no tutored practice with the article choice task, are showing equally high gain scores as those who used the article choice tutor. In addition to the tutored rules, students were also assessed on four control rules that were not included in the tutored material. These items were included in order to measure effects other than those from the tutoring system (e.g. students becoming more familiar with the interface, fatigue, etc.). For these untutored items, results of a repeated measures ANOVA investigating pre-to-post change across both conditions showed no improvement for the article choice items ($F(1, 95) = 0.01, p = 0.931$) and a significant decrease on the explanation choice items ($F(1, 91) = 7.59, p = 0.007$). These results support the conclusion that the observed learning gains on the tutored rules were the result of students' experiences with the tutors and not an unobserved, external factor. The decrease in explanation performance on untutored items may reflect students' tendency to use explanations consistent with the tutored items, which, of course, are incorrect for the untutored items.

Processing Time

We also recorded the amount of time it took students to complete each assessment. Since measures of fluency include both accuracy and speed, reducing the amount of processing time that a student requires is an important goal. One concern with using self-explanation for teaching grammar is that it might take students longer to generate a response if they use an explicit, rule-based strategy than if they use an implicit one. A repeated measures ANOVA with log-transformed pre and posttest completion times as the dependent variables and condition and propensity group as the independent variables, show that students in both conditions are significantly faster at completing the posttest than the pretest for both measures (article choice: $F(1, 95) = 76.28, p < 0.001$, explanation choice: $F(1, 91) = 275.32, p < 0.001$) (Figures 5 & 6). A MANCOVA analysis with log-transformed completion times for article choice and explanation choice posttests as dependent variables, condition and propensity group as independent variables, and the log-transformed completion times for the pretests as covariates shows no main effect for condition ($F(2, 88) = 0.37, p = 0.689$). While students in both tutoring conditions are completing the posttests significantly faster than they complete the pretests, students in the self-explanation condition are completing the posttests just as fast as those in the article choice condition.



Figures 5 & 6: Students in both conditions and for both measures completed the posttest significantly faster than the pretest. More importantly, self-explanation instruction does not appear to be hinder students' speed in completing the measures.

Hint Usage

As mentioned above, the hint structure of the two tutors was very similar, and thus if students in both groups heavily relied on the hints, their experiences with the tutors might be similar despite the task (article choice vs explanation choice) differences. However, the log data show that students rarely request a hint (Figure 7). Approximately 80% of students using the article choice tutor and 75% of students using the explanation choice tutor requested hints on fewer than five problems (out of a total of 56 problems) and approximately 50% from each group never requested a hint. This suggests that any similarities seen in learning between the two conditions is not a result of students seeing similar hints.

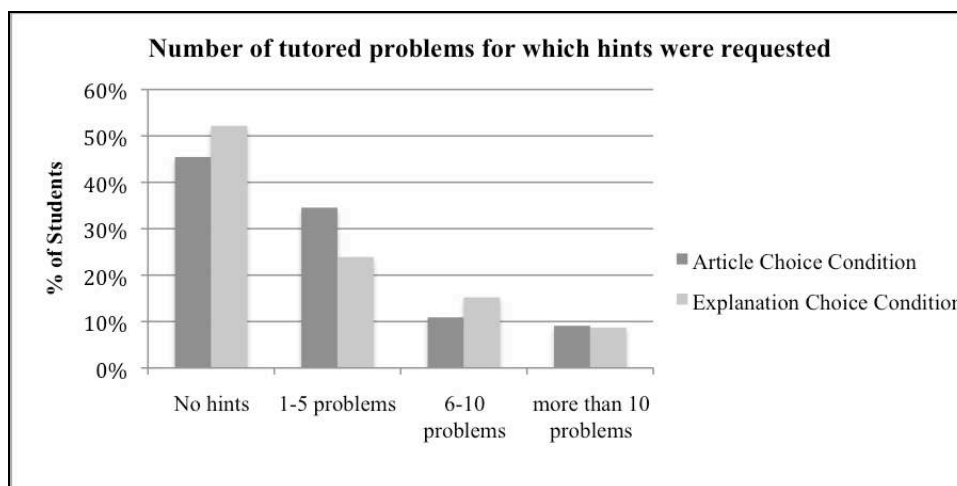


Figure 7: Overall, students using either tutoring system rarely asked for a hint to complete the problems.

Effects of First Language

Finally, in order to determine if a student's first language (L1) had an effect on learning or if there was an interaction between tutoring condition and first language, we first classified participants' first languages into one of three categories: L1 has both a definite and indefinite article, L1 does not have a definite but does have an indefinite article, or L1 has neither a definite nor indefinite article (Dryer, 2008) and then repeated the MANCOVA analysis described above, adding first language category as an additional independent variable. Results show no main effect for first language ($F(4, 104) = 1.31, p = 0.270$) and no interaction between first language and tutoring condition ($F(12, 104) = 0.683, p = 0.765$).

Discussion

Both tutoring conditions were successful at increasing students' procedural knowledge (article choice) and declarative knowledge (explanation choice). These results suggest that students can learn from self-explaining not only in math and science domains, but also in new domains like second language grammar learning. The self-explanation prompts help students both to correctly use articles and to explicitly identify the rules driving these decisions. Further supporting this finding is the timing data that shows students in the explanation choice condition are solving the posttest problems just as quickly as their article choice counterparts. Thus, self-explanation improves both facets of fluency, speed and accuracy, just as well as practice.

While one might expect students in the article choice condition to improve on the article choice posttest and students in the explanation choice condition to improve on the explanation choice posttest, the fact that we see cross-task transfer for both tutoring conditions is somewhat surprising, although not unprecedented. In their study looking at the effects of self-explanation in geometry learning, Aleven & Koedinger (2002) saw similar results in that students in both the self-explanation condition and problem-solving condition showed significant learning in their ability to problem solve *and* in their ability to provide explanations or reasons. One key difference is that in the geometry study, students in the self-explanation condition had practice with both procedural (problem solving) *and* declarative (explaining) skills, while in our study, students in the self-explanation condition did not have any procedural (article choice) practice and were tutored on declarative skills (explanation choice) only. We hypothesize that the combination of worked examples (i.e. seeing the correct article highlighted in the problem sentence) and self-explanation prompts encourages students to focus on the features of the sentence that are important for making article decisions. They are then able to recall and apply these rules when presented with procedural items on the posttest.

We see a similar but smaller effect for students in the procedural (article choice) condition in that despite having no tutored practice on choosing explanations, they show significant improvement on the

declarative items in the posttest. We hypothesize that the procedural instruction may have led to an increase in declarative knowledge through students inductively learning the rules and perhaps a priming effect by the pretest. Since all students took the explanation choice pretest, which asked them to use declarative knowledge, students may have been looking for and inductively generating the rules from the tutored problems they completed, accounting for the small but significant increase in declarative knowledge.

One limitation of this work is the generalizability of the results. Since the entire study was conducted during one class period, we had limited time within which to collect data. Due to this limitation, less than 80% of the students in the explanation choice condition finished all five stages of the study. While we used propensity score matching to account for the attrition in the analysis, we cannot make strong claims about those students for whom we have no posttest measures. As noted by the classroom teachers, students who did not finish likely fell into one of two categories: those with low prior knowledge and those with high prior knowledge who were very diligent. Perhaps self-explanation is not appropriate for all students. The metalinguistic challenges involved in choosing explanations in a foreign language might be too difficult for the low prior knowledge students, and asking very diligent students to self-explain each step may be an inefficient use of class time. To address these issues, on-going research is investigating interventions designed to foster feature-focusing behavior while minimizing metalinguistic difficulties as well as interweaving procedural and declarative tasks in order to reduce the amount of overall time needed to complete the tutor.

In conclusion, this study is one of the first to investigate the effects of self-explanation on language learning and presents promising results that prompted self-explanation helps students with procedural skills and enables them to develop explicit knowledge of the rules. Further work is needed to investigate the robustness of this effect and the extent to which this knowledge transfers to real-world production.

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