Cognitive Biases and their Effect on Mobile Learning: The Example of the Continued Influence Bias and Negative Suggestion Effect

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ABSTRACT

Cognitive biases can consciously and subconsciously affect the way we store and recall previously learned information. In the use case of mobile learning, biases such as the *Negative Suggestion Effect* (NSE) can make us think a statement is correct because we wrongfully selected it in a previous multiple-choice test. In some cases, the suggestion effect is so persistent that even corrections can not stop us from drawing assumptions based on the misinformation we once learned. This effect is called the *Continued Influence Bias* (CIB). To avoid the creation of such incorrect and sometimes persistent memories, learning applications need to be designed carefully. In this position paper, we discuss the influence of the presented number of answer options, feedback, and lesson design on the strength of the NSE and CIB and provide recommendations for countermeasures.

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CCS CONCEPTS

• **Human-centered computing** → *Ubiquitous and mobile computing design and evaluation methods*; • **Social and professional topics** → *Student assessment*; • **Applied computing** → *E-learning*.

KEYWORDS

Cognitive Bias, Negative Suggestion Effect, Continued Influence Bias, Mobile Learning

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INTRODUCTION

The growing pervasiveness of technology, woven into our daily lives, comes with increased responsibility for technology creators and designers. It is vital that we become aware of the influence that technology has on users' lives because it is used to disseminate information and thus, forms opinions, beliefs, and actions. One example is a 1998 study reported in the media suggesting a link between childhood vaccines and autism [9]. Nowadays, social media is often blamed as one of the instruments spreading misinformation even faster (cf. [7, 12]), such as the negative consequences of vaccines, or the media's incorrect picturing of infectious disease outbreaks as caused by the Ebola or Coronavirus.

Although social media companies like Facebook try to limit misinformation and their spread by hiring fact-checkers and removing false content [11], rectifying misinformation once it has spread, remains a difficult task. The study showing links between vaccines and autism was later retracted, and the claims substantiated [9], however, a large percentage of the public years later still believes that this information is true or at least that research is so far inconclusive.

One reason for this persistence in beliefs is the *Continuous Influence Bias* (CIB), a cognitive bias leading people to continue to rely on misinformation, although those have been retracted [12]. Cognitive biases can be defined as "systematic and predictable errors in judgment that result from reliance on heuristics" (in Blumenthal-Barby and Krieger [2], page 1). Heuristics are strategies for decision making based on prior experience [1], of which a person can be aware or unaware.

A memory effect closely related to the CIB is the *Negative Suggestion Effect* (NSE). The NSE describes the phenomenon occurring in testing or exam situations, where a learner later remembers the incorrect answers they chose in the test as the correct ones, as discussed later in detail. In this position paper, we will outline the effects of the NSE and CIB in the scenario of mobile learning and present implications

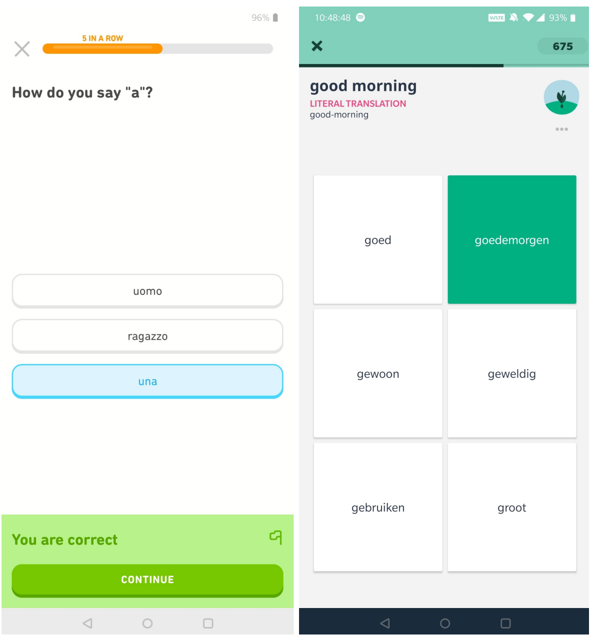

Figure 1: Screenshots of two language learning apps: The Duolingo app presenting three translation options (left), while Memrise displays six options (right).

for the design of learning applications using the example of multiple-choice questions and feedback design.

NEGATIVE SUGGESTION EFFECT IN MOBILE LEARNING

Thanks to the ubiquity of mobile devices, mobile learning applications (MLAs) can be used in a variety of situations. MLAs are designed along with the "micro-learning" approach [10] – featuring micro-content units and micro-interactions, thus, focusing on short learning sessions and high overall repetition count [4]. As a result of this specific usage pattern, the learning apps are limited to use simple tasks such as sorting and ordering by drag & drop, fill in the blanks, or multiple-choice.

Although multiple-choice is frequently used, not only in digital learning, it comes with one major downside: it requires the presentation of incorrect alternatives, so-called "lures". If a student comes across a multiple-choice task for which they do not know the answer, it is possible that the student picks an incorrect lure answer. When the student is asked the same question again at a later point in time, they will lean toward choosing the incorrect answer all over again. This effect is called the *Negative Suggestion Effect* or *Negative Testing Effect*. In other words, reading incorrect multiple-choice answers can lead to the creation of false knowledge [16]. Not only does the number of lures in the multiple-choice test increase the possibility of choosing the lure in the final test, but it also decreases the positive effect of testing or *Testing Effect* [16]. This effect is based on the fact that retrieving information from the long-term memory promotes later retention (cf. [15]). In a study by Roediger and Marsh [16], the authors showed that the number of incorrect answers increased linearly with the number of previously read alternatives (i.e., 51% correct responses in a cued-recall test when showing two alternatives, 45% for four alternatives, 43% for six).

Unfortunately, showing the learner the correct answer is not always a successful countermeasure. When Brown, Schilling, and Hockensmith exposed students to wrong information after an initial test, they discovered that this misinformation influenced a final multiple-choice test even if the misinformation was identified as such [3]. As stated earlier, the persistence of misinformation is called *Continued Influence Bias*.

In the following, we summarized related literature on three different facets of mobile learning applications that influence the extent of the Negative Suggestion Effect: (1) the number of presented alternatives, (2) the provision of feedback and corrections, and (3) the lesson structure and skipping options. For this purpose, we draw on various literature from the field of psychology and cognitive science on counteracting the NSE as well as CIB. We underline these findings by discussing examples from existing mobile learning applications.

Number of Presented Alternatives

As outlined above, when performing two consecutive tests, the number of incorrect answers in the

[1]see https://www.duolingo.com/, last accessed February 11th, 2020

[2]see https://www.memrise.com/, last accessed February 11th, 2020

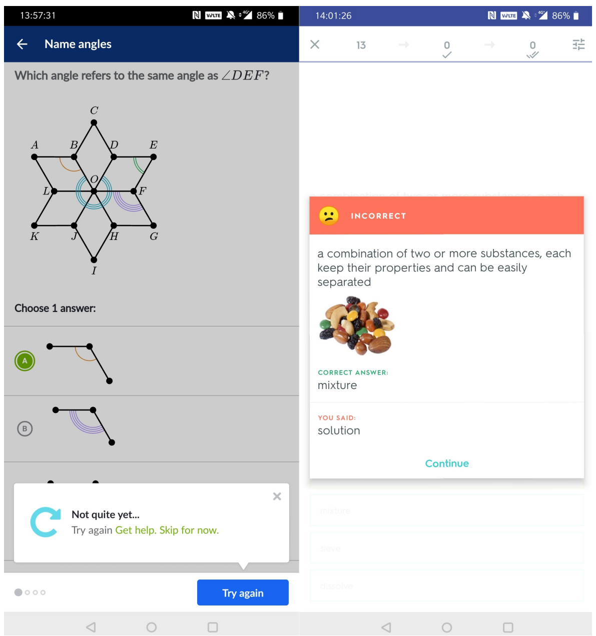

Figure 2: Left: Khan Academy showing corrective feedback; Right: Quizlet with Comparative feedback of correct and incorrect answer.

[3]see https://www.khanacademy.org/, last accessed February 11th, 2020

[4]see https://quizlet.com/, last accessed February 11th, 2020

final test increased linearly with the number of alternatives presented during the first test. The number of correct answers decreased by 8% when the multiple-choice task included six instead of two alternatives. Exemplary MLAs available in the Google Play Store differ in the number of answer options they provide. Comparing the designs of two language learning apps, Duolingo[1] often presents three to four different alternatives for the multiple-choice tasks, while Memrise[2] displays up to six options (see Figure 1).

However, the number of alternatives for a specific student to create an effective learning setting depends on their prior performance. Butler et al. [5] have shown that when the results of an initial multiple-choice test were very high, including additional lures can further increase the performance. If the initial results were not as good, the Negative Suggestion Effect applies, decreasing the performance.

Similarly, Roediger and Marsh [16] recommend reducing the number of answer options if the content is unknown to the learner. For mobile learning, this translates to the necessity of learning progress monitoring and adaptation. When new content is introduced, multiple-choice questions should only include a few lure options, i.e., one or two alternative answers. As the learners progress and consolidate their knowledge, more lures can be included in the tasks.

Provision of Feedback and Corrections

In contrast to the CIB, the NSE can be, in many cases, counteracted by corrective and explanatory feedback to the learner [6]. Feedback should clarify which answer is correct. However, prior research is inconclusive when it comes to the question if the incorrect answer should be repeated in the corrective statement. In a study by Ecker, Hogan, and Lewandowsky [8] on the retraction of misinformation (in this case, fictional reports), retractions that explicitly repeated the misinformation were shown to be more effective in reducing misinformation effects. Since the authors report that their results oppose prior findings, these statements need further validation and have to be seen with caution.

In the context of mobile learning, we encourage designers to provide at least unambiguous feedback indicating that the given answer is incorrect. In the example of the Khan Academy[3] app seen in the left screenshot in Figure 2, the feedback visualization lacks clarity. The chosen yet incorrect answer is colored in green, and the user has the option to skip the question without correcting their answer. In contrast, the Quizlet[4] app (see right screenshot of Figure 2) visualizes the feedback more clearly, showing both the incorrect and the correct answer in the pop-up dialogue. Since automated learner assessment can specifically watch out for situations where learners repeatedly input the wrong answer, adapting the feedback to the current situation can be an option. Simple corrective feedback can be sufficient for the first incorrect trial; however, after choosing the wrong answer multiple times, the feedback should become more explicit targeting the CIB. At this point, clearly visualizing both correct and incorrect answers for the user to compare (along with the Quizlet example) can be helpful.

Feedback can either be provided immediately or delayed. Prior research found no effect of the feedback timing on the influence of the NSE. However, presenting feedback delayed, e.g., after a lesson, can function as another repetition of the content and, thus, enhance retention (for a summary on feedback presentation see Marsh and Cantor [14]). Therefore, both options are appropriate; the feedback timing should fit the lesson length and task difficulty.

Lesson Structure and Skipping Option

In line with the recommendations for the feedback design, ending lessons with a wrong answer could further strengthen the incorrect memory (even if the corrective feedback is shown). To mitigate the CIB effects, we recommend continuing the lesson until the last question is actively answered correctly. This feature is currently implemented in the language learning application Duolingo as it asks the learner to repeat all incorrect questions until all of them are answered correctly.

Furthermore, preliminary results of Marsh, Agarwal, and Roediger [13] showed that providing the learner with the option to skip the question slightly reduces the negative testing effect for some groups. In their study, undergrad students benefited more greatly from skipping than high-school students. Marsh et al. conclude that the effectiveness of skipping questions is depending on the meta-cognitive skills of students in judging if they know or do not know the answer to a question. Since mobile learning applications target a broad audience of potential users, skipping will not be an effective tool to reduce the NSE for all of them. As it also reduces the positive testing effect, we recommend not including a skipping option and rather focusing on targeting the NSE through the design recommendations presented above.

CONCLUSION

In this position paper, we summarized and discussed related literature on the effects of the Negative Suggestion Effect and Continuous Influence Bias in the use case of learning. If we want to support the users of learning apps as much as possible, we need to mind these effects and inform our application design carefully to mitigate them. By considering the number of answer options, the provision of corrective feedback, and a clear lesson structure, we can help avoid the strengthening of incorrect memories. Although remembering the wrong answer in a learning application might not be as severe and important as the spreading of misinformation about vaccines, we want to use this position paper to raise the awareness of memory biases induced by technology. Memory biases are ubiquitous and can appear for every form of information presentation. Their persisting nature should not only be considered for learning situations but technology usage in general.

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