Spaced Digital Image Identification Enhances Performance on Medical Neuroanatomy Practical Examinations

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INTRODUCTION

Practical examinations challenge medical students to identify anatomical structures accurately while applying spatial reasoning under strict time constraints. These assessments are particularly demanding in neuroanatomy, where structural complexity and subtle variation increase cognitive load. While cadaver-based study remains foundational, virtual identification platforms offer a low-resource, scalable alternative that may supplement or partially substitute in-lab experiences.

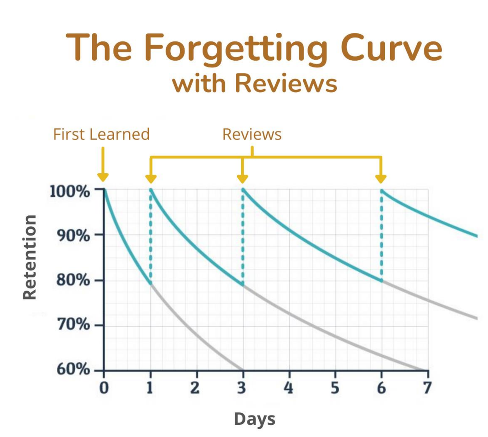


Figure 1: Representation of Ebbinghaus' forgetting curve and implications of spaced repetition (research gate).

Spaced repetition, a learning technique that strengthens long-term memory through distributed review, has shown promise in medical education but remains underexplored in the context of image-based anatomical assessment.

This study aimed to evaluate whether a spaced-repetition digital flashcard tool could improve student performance on practical examinations in a first-year medical neuroanatomy course

MATERIALS AND METHODS

Creating The Resource

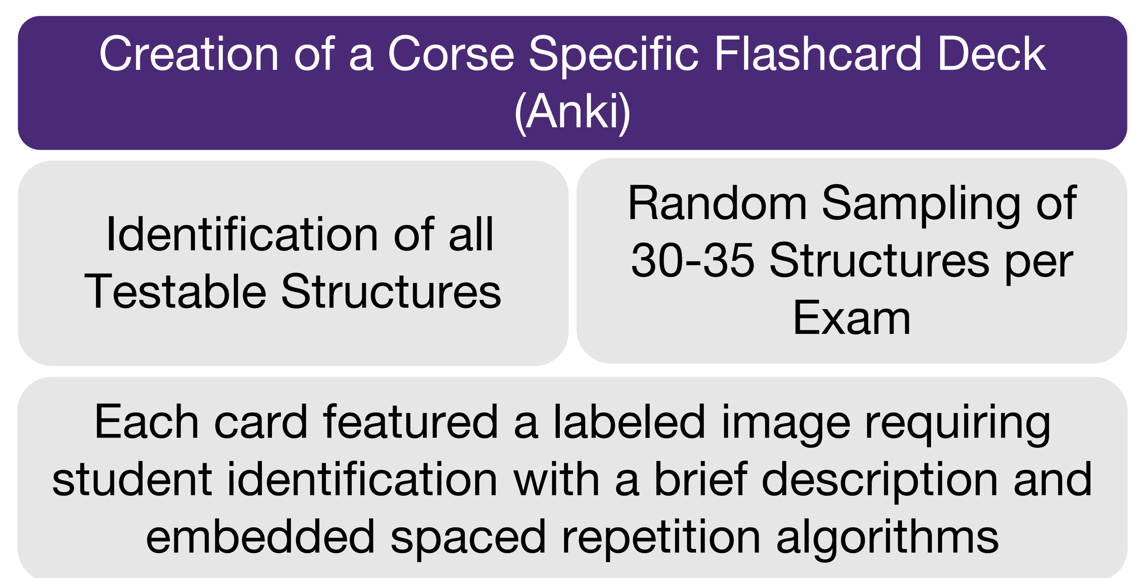
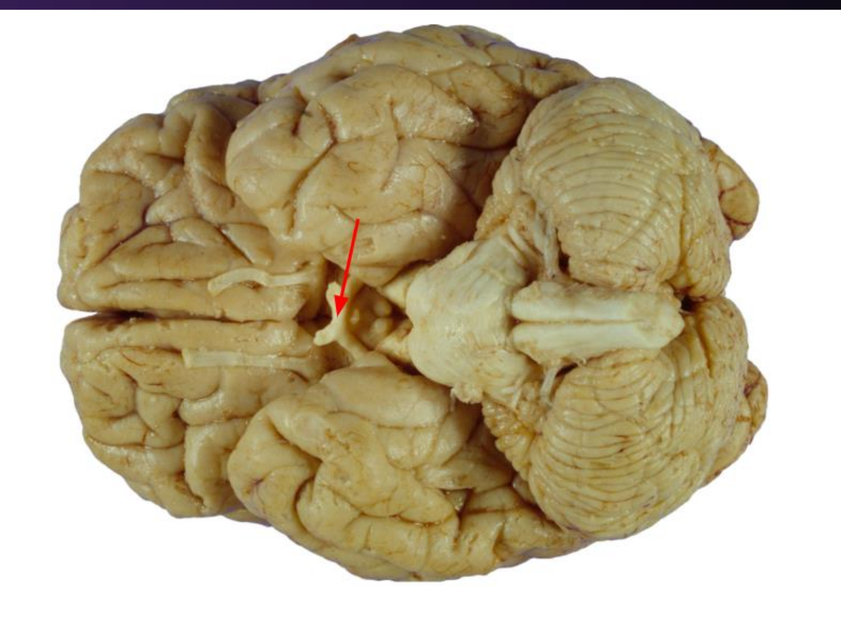


Figure 2: The supplemental flashcard deck was created using the ANKI platform. The deck covered a random subset of testable neuroanatomical structures from the course. Each card featured a labeled image requiring student identification and included embedded spaced repetition algorithms within ANKI.



Optic Chiasm: X-shaped structure demarcating the crossing over of each optic nerve. Crossing fibers arise from the medial retinal fields (lateral visual fields)

Figure X- Example flashcard design. Red arrow indicated structure to be identified.

Evaluation Design

Students in the 2022 Medical Neuroscience course at Brody School of Medicine participated voluntarily. Participation was anonymous, and students self-selected into one of three groups based on flashcard usage: **Group R** (used with spaced repetition), **Group NR** (used without spaced repetition), or **Group N** (did not use the deck). Following each of the four course units, students completed a digital practical and reported their usage of the flashcard deck for that unit. Exam questions were independently classified as either anki deck-associated or non-associated. Performance comparisons between and within groups were conducted using two-sample and paired t-tests, respectively.

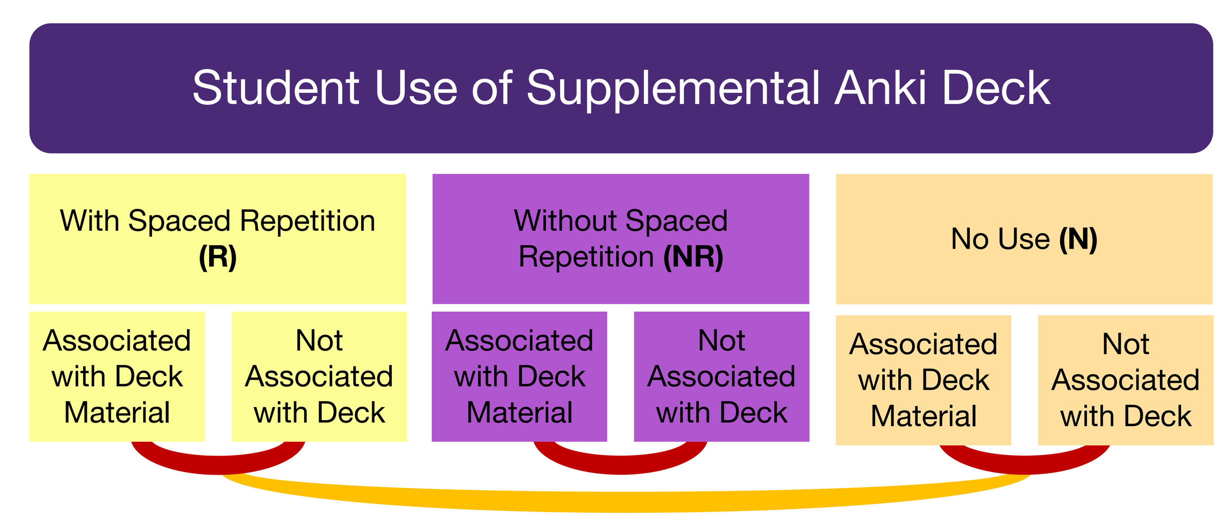


Figure 3: Students were divided into 3 groups based on supplemental deck usage (R, NR, N). Exam questions were classified as deck-associated or non-associated. Comparisons were made within groups (red, paired t-test) and between groups (gold, Two-sample t-test).

RESULTS

Total data points: n=341

- No deck use (N) = 126
- Use without repetition (NR) = 98
- Use with repetition (R)=126

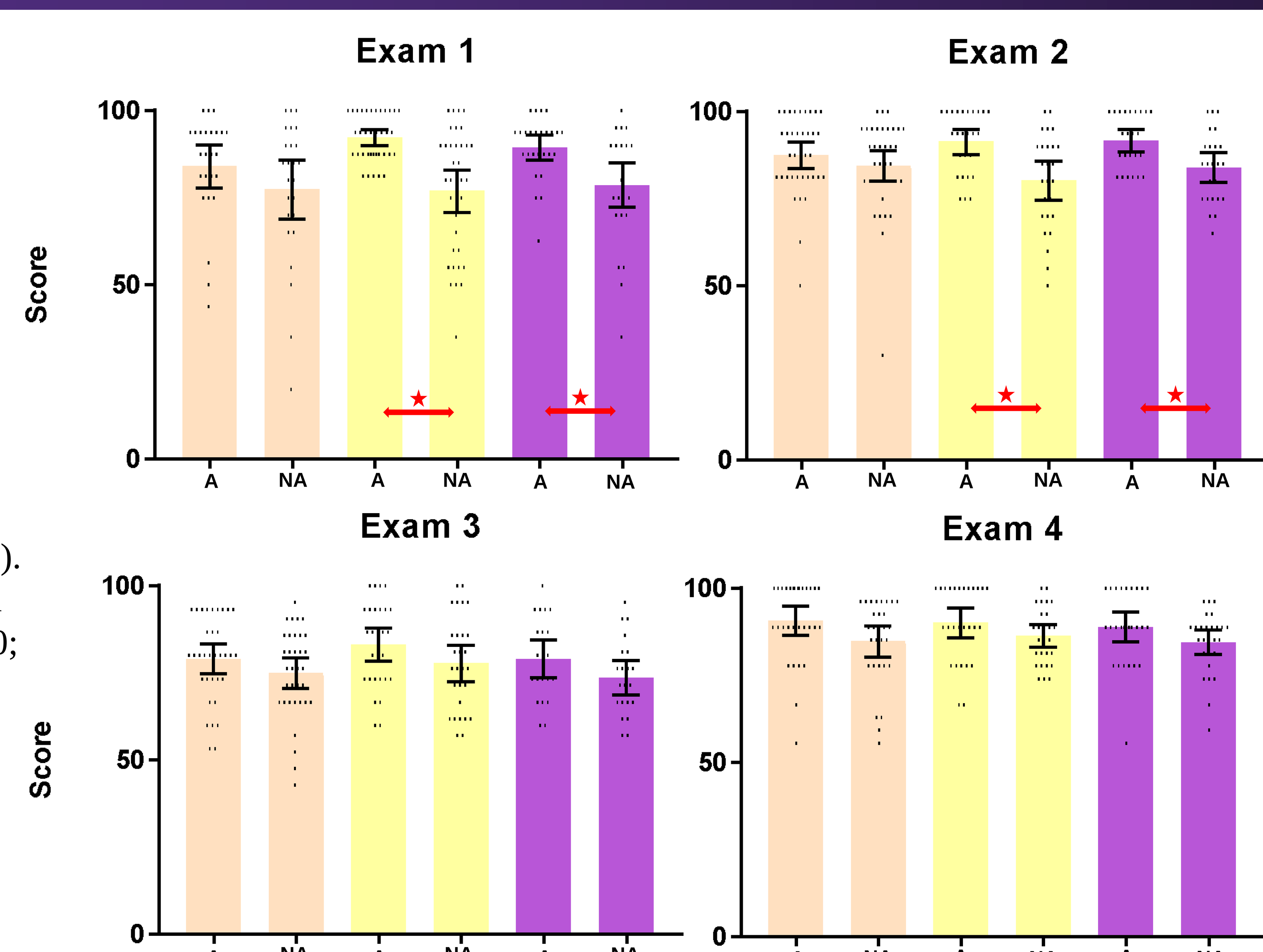
Overall exam scores: No significant differences between groups on total scores ($p > 0.20$).

Between-group comparison (deck-associated questions):

- R group outperformed N group (mean 89.35 vs. 85.29; $p = 0.0076$).
- Strongest effect observed in Exam 1 (R mean 92.18 vs. N mean 84.00; $p = 0.0051$).

Within-group trends (flashcard-associated vs non-associated):

- Largest improvement in R group (+9.34 points; $p < 0.001$)
- NR group: +7.10 points; $p < 0.001$
- N group: +4.72 points; $p = 0.008$



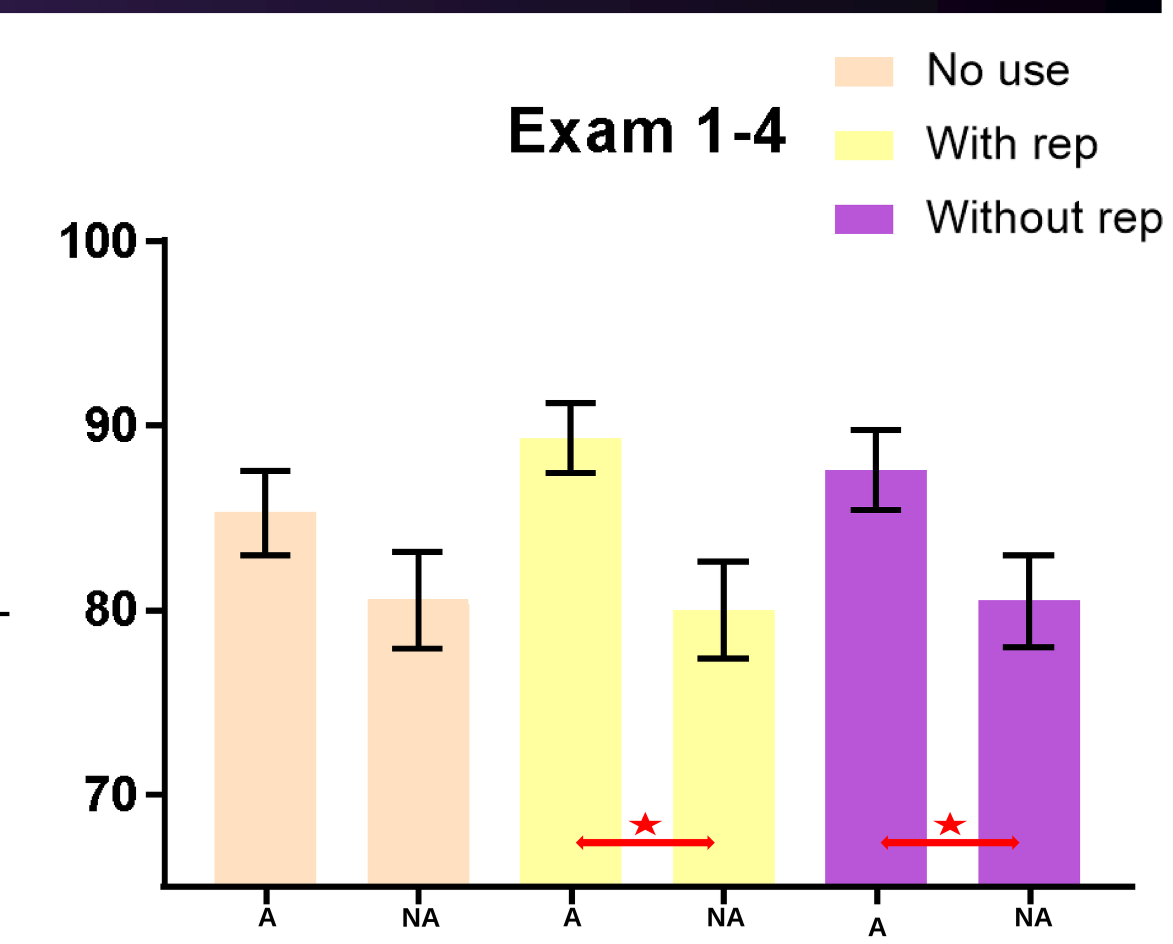


Figure 4: Mean scores (± SEM) are shown for flashcard-associated (A) and non-associated (NA) questions across four exams and cumulatively. Groups are color-coded by deck use. No use (orange), with spaced repetition (yellow), and without repetition (purple). Red stars indicate significant differences ($p < 0.05$). The strongest effects were observed in the spaced repetition group, especially in Exams 1 and 2.

DISCUSSION

Performance Trends: Spaced digital flashcards enhanced performance on associated exam questions, with the strongest effects observed early in the course. This likely reflects the tool's utility during initial phases of neuroanatomy, when students were still establishing effective study strategies.

Learning and Use Patterns: Students were evenly distributed across usage groups. Improvements were most evident in content directly reviewed with the flashcards, particularly when used with spaced repetition, supporting their value as a targeted review aid rather than a broad learning enhancer.

Resource Variability: Declining trends may reflect both changing study habits and student-driven modifications to the deck. While open access promoted learner autonomy and customization, it also introduced variability in content exposure, possibly reducing consistency over time.

Limitations: Interpretation is limited by self-selection bias, inconsistent deck engagement, and the open-ended nature of resource use. Additionally, assessment was conducted through digital practicals, limiting generalizability to in-person, cadaveric examinations.

FUTURE DIRECTIONS

Spaced digital image identification offers a scalable, low-resource strategy to enhance early neuroanatomy learning. Its flexible, student-driven format may promote learner autonomy and engagement, particularly during high-cognitive-load content. Further research is needed to determine its impact on long-term retention, performance on cumulative or cadaveric practicals, and its effectiveness across diverse learner profiles. Key unanswered questions include how best to structure deck content, optimize timing and frequency of spaced review, and support equitable use among students with varying digital fluency. Broader implementation across anatomy courses may also reveal how structured digital repetition can shape study habits, reduce performance gaps, and foster a more supported and self-regulated learning environment.

ACKNOWLEDGEMENTS

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