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Impact of reduced idea density on pharmacy students' attainment in pharmaceutical calculations: A study protocol for a single-blind multicentre randomised controlled trial

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ABSTRACT

Introduction: To register as a pharmacist in the United Kingdom, an exam set by the General Pharmaceutical Council must be undertaken. It involves pharmaceutical calculations and shows variable pass rates. Linguistic factors, such as idea density, affect and predict comprehension time. This trial will evaluate the effect of lowering question idea density on attainment in a pharmaceutical calculations exam aligned to that of the General Pharmaceutical Council

Methods: This is a single-blind, parallel 2-arm multicentre randomised controlled trial conducted in 14 Universities across the United Kingdom. A 1:1 randomisation and a sample size of 198 pharmacy students will be sufficient to detect a 1-point difference in the mean scores between the intervention and control group during a pharmacy calculation test with two-tails, 80% power and 5% significance level. Each school will recruit a minimum of 14/15 students. Participants will sit two 12-question pharmaceutical calculation tests. All students will take the same baseline test; then, will be randomised and undertake a second test 2-week after, with standard idea density for the control group and lower idea density for the intervention. Primary outcome: the scores obtained by the students undertaking the second calculation test 2-week after the baseline. Secondary outcomes: percentage of students achieving a pass during the second test; effect of demographic characteristics (first or not-first English language speakers, age, ethnicity, year of study, specific learning disability) on students' attainment when lowering idea density

Conclusion: Results could inform the development of new standards in pharmaceutical calculations exams.

Trial registration number: NCT05526365 (registered 31/08/2022)

1. Introduction

1.1. Background and rationale

Pharmacists in the UK are registered healthcare professionals. They are responsible for the quality, correct supply and clinical

Abbreviations: CPIDR, Computerized Propositional Idea Density Rater; GPhC, The General Pharmaceutical Council; ID, Idea Density.

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suitability of medicines supplied to patients. They work in various settings, most often in community, hospital or primary care where they directly help patients with a variety of needs, and form part of the wider multidisciplinary teams responsible for specialist healthcare. (Council, 2022b) To train and register as a pharmacist in the UK, it is necessary to complete a four-year degree (MPharm), followed by a foundation training year in practice. (Council, 2021) The culmination of these five years of training is the General Pharmaceutica Council's (GPhC) registration exam, which consists of two papers.(Council, 2022a) Paper 1 requires candidates to correctly answer 40 pharmaceutical calculations in 120 minutes (three minutes per question), with a typical pass mark of 70%. The questions test the following 12 areas:

- Concentration
- Dilution
- Displacement
- Dosage & Unit Conversion
- Dose/Dose Regimen
- Estimated Kidney Function
- Health Economics
- Infusion Rate
- Molecular Weight
- Pharmacokinetics
- Quantity to Supply
- Using a Formula

An example of the type of question asked can be seen in Fig. 1, taken from the GPhC's website. (Council, 2022a)

Previous studies have shown that students from minority backgrounds, particularly Black and Minority Ethnicities (BAME), and those who speak English as a second language perform significantly worse in medical exams, including the pharmacy registration assessment, with black students showing the lowest pass rates in the 2021 sitting. (Wickware, 2021; Woolf, 2020) This attainment gap has come under increasing scrutiny recently. This is crucial not only for minority groups, but all students taking an assessment to ensure that the questions are fairly scrutinising their knowledge of a subject and not another ability such as reading proficiency (above a pre-determined minimum) or protected characteristic. (Chan et al., 2013; Richardson, 2015; Shah & Ahluwalia, 2019)

How questions are written must ensure comprehension from all candidates whilst ensuring authenticity to the real-world scenarios they will encounter as pharmacists. Control of the linguistic structure of the question could potentially achieve this by providing guidance on factors such as reading level, question length, and text presentation (e.g. font) to ensure comprehension from all candidates.

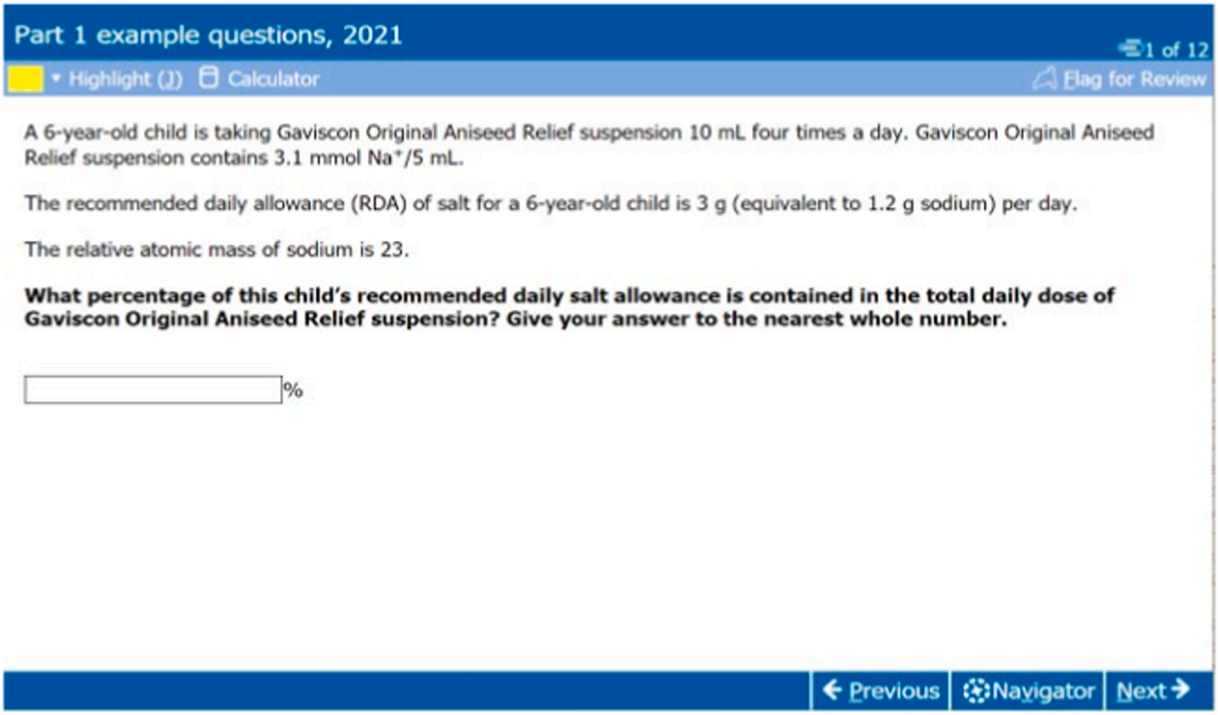

Fig. 1. A typical calculation in Paper 1 of the GPhC registration exam.(Council, 2022a).

Another emerging measure by which the linguistics of a question could be monitored is idea density (ID), a metric that divides the number of ideas in a sentence by the total words used. (Kintsch & Keenan, 1973) This produces a number between 0-1, with lower numbers indicating a lower ID and vice versa. For example, the following two sentences have the same meaning but differing ID.

"The brown dog barks" Idea density = 3 ideas ÷ 4 words = 0.75

"There is a dog, which is large, and it is barking" Idea density = 3 ideas ÷ 11 words = 0.27

The concept of ID was first defined in 1973 by Kintsch and Keenan, who went on to show that the ID of a paragraph of text was a strong predictor of time needed to understand it, with a higher idea density linked to a longer comprehension time. (Kintsch & Keenan, 1973; Kintsch, Kozminsky, Streby, McKoon, & Keenan, 1975; Kintsch & Van Dijk, 1978) An increased ID has since been shown to disproportionately second language readers, with a review by Bloomfield et al. summarising the key factors affecting the learning of second language speakers, findings that as ID is increased, so too did comprehension time.(Bloomfield, Wayland, Blodgett, & Linck, 2011; Bloomfield et al., 2010) A recent research conducted by the authors of this protocol suggested that verbal ID in short lectures measured by post-lecture multiple choice question influenced the overall comprehension of students. (Lunn et al., 2022) The study showed that a reduced lecture ID facilitated a full cohort increase in test performance, which was greater in second language speakers, reducing their attainment gap to first language speakers to insignificant levels. It is reasonable to assume, however, that any reduction in ID would only benefit to a point where the sentence still scans logically, as reducing it too much increases sentence redundancy and the use of unnecessary words. The overall impact of redundancy is not fully understood, with conflicting views on its effect, particularly on second language speakers. (Feng, 2022; Sagarra & Han, 2008)

Broadly, ID can be divided into semantic and propositional idea density. Semantic ID is the number of separate concepts and assertions in a text divided by the total words used; propositional ID is a similar measure that substitutes concepts and assertions for propositional words dividing them by the total words used. (Sirts, Piguet, & Johnson, 2017) The two measures have previously been shown to be comparable to each other, with the benefit of propositional ID being that it is measurable by automated part of speech tagging, using the freely available software Computerized Propositional Idea Density Rater (CPIDR), developed at the University of Georgia. (Brown, Snodgrass, Kemper, Herman, & Covington, 2008)

As idea density predicts the time needed to comprehend text, it may influence exam performance, where quickly understanding a question is key. However, the effect of idea density on exam performance has not yet been investigated. If found to have a significant effect, it may further affect different demographics differentially (such as first and second language speakers), therefore controlling it might reduce the attainment gap between students Improving Equality Diversity and Inclusion (EDI).

Currently, there are no official checks on such easily measurable features as reading level, and little evidence for the impact and therefore benefit of such checks for ID. This study therefore sets out to determine if a reduced ID would impact the performance in exams within the context of the GPhC's pharmaceutical calculations registration exam.

To help ensure that this study works towards a real implementable change, a theory of change was developed using a logic model presented in Fig. 2.

1.2. Theory

This work is primarily based on the theory of psycholinguistics, applied to language perception in assessment. In this approach, text or language, and a person's cognition and thoughts are considered as related but separate phenomena. (Purba, 2018) As such, each individual interpretation of a question may be processed differently in time and outcome. As outlined in the Assessment for learning theory, a clear understanding of the criteria and what is being tested is needed. (Taras, 2007) If a question then, is written such that the individual interpretation of the task is ambiguous (within the limits of what could be considered authentic), then it is not completely serving its purpose. This is of particular concern where there is an imperative to have authentic assessment, as in this case, where the exam is to mimic professional activities. (Archbald, 1991) As such, if variation in question ID causes some students to misunderstand what is being tested, it will impact the fairness and authenticity of an assessment and should be addressed.

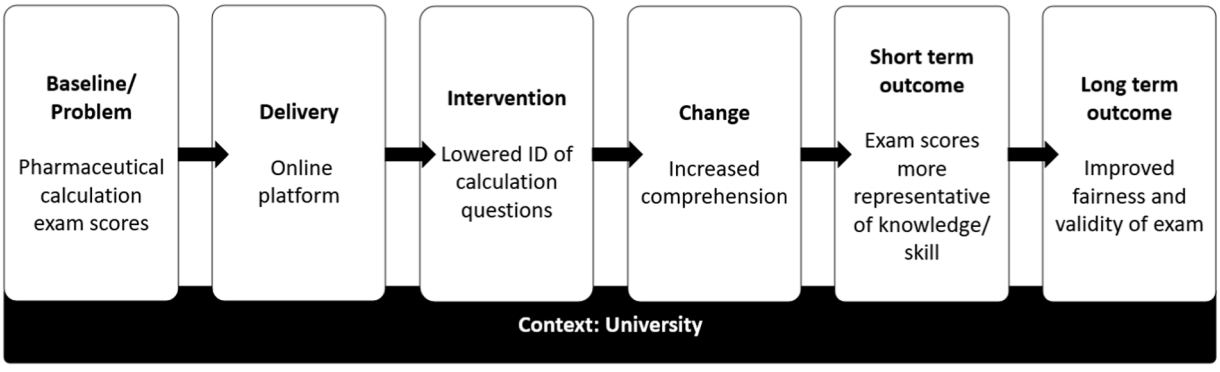

Fig. 2. Logic model for the theory of change on the adaptation of idea density in calculation exams.

2. Objectives

2.1. Key research questions

The primary research question of this study is:
What is the effect of lowering the idea density of a calculation exam on attainment amongst UK pharmacy students?
The secondary research questions are:
Does lowering the idea density of a calculation exam influence the pass rate amongst UK pharmacy students?
What is the effect of each characteristic on students' attainment in pharmacy calculation when lowering idea density?

- *First language speaker or not*
- *Age*
- *Ethnicity*
- *Year of study*
- *Specific learning disability*

2.2. Trial Design

The study is a single-blind, parallel multicentre randomised controlled trial to test the intervention of lower question idea density to typical GPhC calculation question idea density, with the control study questions mimicking GPhC questions as closely as possible. Participants will be randomly allocated to the intervention or control group.

3. Methods

3.1. Study setting

The study will be conducted in UK pharmacy schools that deliver a Master of Pharmacy (MPharm) programme. There are 30 such pharmacy schools, 14 of which are included within the study, with an estimated population of 6,000 eligible students.

3.2. Eligibility criteria

Participants will be selected according to the following criteria:
Participants must be

- Over 18 years of age
- Registered as a student on an MPharm course in the UK
- Be in years 1-4 of the course (levels 1-7)

Participants will be excluded if they are

- Under 18
- Not registered on an MPharm course in the UK
- Are currently undertaking a foundation year (level 3)

3.3. Intervention

3.3.1. Description of the intervention

Idea density (ID) is a linguistic measure that divides the number of propositions used in a text by the total number of words. (Sirts et al., 2017) It has previously been shown to influence comprehension time and differentially affect demographics such as age and first language. (Bloomfield et al., 2011; Kintsch et al., 1975) Given that exams are time-controlled, written scenarios where comprehension of the question is paramount to performing well in the assessment, it is reasonable to assume that question ID may influence student performance. The effect of this has, however not been investigated. This study seeks to begin to investigate this by reducing question ID in a linguistically controlled GPhC style calculation exam, by around 10-15% in all questions. ID is being reduced by 10-15% as previously a reduction in ID of this range was shown to have an impact on comprehension in short lectures. (Lunn et al., 2022) The GPhC calculation exam is typically 40 questions undertaken in 120 minutes (three minutes per question), testing 12 areas of calculation. The exams in this study will test the same 12 areas with one question in each, ensuring all major subject areas are represented and reducing the burden on the volunteer participants.

Participants will undertake two tests with 12 questions each. First, a pre-randomisation calculation test will generate the baseline data. Then participants will be randomised into the control and intervention group and will take a second test 2-week after baseline.

The first, baseline test, will be the same for all participants and has been as closely matched to GPhC questions as possible in length (number of words), font, ID and complexity as assessed by three experienced practitioners in the field. The summary of linguistic

measures can be seen in Table 1. Two weeks after the release of the first calculation test, participants will be randomly assigned to intervention and control groups and undertake another test. The second test contains new questions, following the same template as the first test (baseline). The questions for the intervention group, however, have been linguistically modified to have a statistically significant 10-15% lower ID (p=0.0036) Table 1. In contrast, the version for the control group will have a similar ID to the baseline test. Three experienced practitioners have also reviewed the questions to ensure that they are qualitatively comparable to typical GPhC calculations and that the control and intervention papers ask the same core problem. The full list of questions will be made public after the study has run to ensure that the study questions remain new and unseen by any candidate.

Following completion of both exams, students will be sent a questionnaire for them to evaluate the second (intervention or control) exam. The questions for this survey have been adapted with permission from a previously validated tool for students to evaluate written exams developed by Froncek et al, the questions can be seen in Appendix C.(Froncek, Hirschfeld, & Thielsch, 2014)

Calculations have been chosen as an area with significant failure rates amongst candidates and one that relies on the application of the information in the question, rather than past knowledge. This helps to control for prior knowledge of the participant minimising its influence on the results.

3.3.2. Control group

Participants in the control group will receive a second test that is linguistically the same as the national GPhC exam.

3.4. Criteria for discontinuing or modifying allocated interventions

1 The participant withdraws consent (before full anonymisation)
2 The study is stopped
3 The participant does not complete both tests within the time window

3.5. Strategies for monitoring and improving protocol adherence

Participants will receive email reminders to complete the tests on time.

3.6. Relevant concomitant care and interventions that are permitted or prohibited during the trial

There are no intervention restrictions that apply to this study.

3.7. Outcomes

3.7.1. Primary outcome

The primary outcome is student performance in the second calculation test 2-week after the baseline.

3.7.2. Secondary outcomes

The percentage of students achieving a pass (equivalent to 70% or above) during the second test.
The effect of each demographic characteristic on students' attainment in pharmacy calculation when lowering idea density?

- First language speaker (English as the first language) or not
- Age
- Ethnicity
- Year of study
- Specific learning disability

3.7.3. Justification of the method

This study aims to determine the effect of lowering ID in exam questions alone whilst controlling for other factors. One major factor outside the investigators control that would heavily influence performance on a knowledge-based exam is previous knowledge. It is not

Table 1
Linguistic measures of typical GPhC and study questions.

Test questions	Mean Ideas	Min./max. ideas	Mean words	Min./max. words	Mean ID	SD ID	ID comparison to GPhC sample*
GPhC Sample	33	22/40	67	50/93	0.493	0.047	N/A
Baseline (Test 1)	34	23/45	70	51/91	0.483	0.031	0.54
Control (Test 2)	37	21/54	74	54/99	0.490	0.049	0.88
Intervention (Test 2a)	39	25/56	88	64/117	0.437	0.041	0.01

* P-values from a 2-tailed t-test comparing the idea density of each set of 12 study questions to 12 GPhC sample questions.

possible for the investigators to fully know or control this, so a scenario-based calculation exam, asking the participants to determine an answer with only the information provided will be used. To ensure relevance to the pharmacy student population, and applicability to the GPhC registration exam, the style and content for the test papers was taken from the GPhC's registration exam framework, testing on each of the following areas:

- Concentration
- Dilution
- Displacement
- Dosage & Unit Conversion
- Dose/Dose Regimen
- Estimated Kidney Function
- Health Economics
- Infusion Rate
- Molecular Weight
- Pharmacokinetics
- Quantity to Supply
- Using a Formula

Questions were matched to sample GPhC questions in length (number of words), format and idea density. Complexity and level will be matched by using the GPhC syllabus to template the questions and having these reviewed by three academics experienced in pharmaceutical calculations.

3.8. Participant timeline

Participants will be contacted by the relevant member of staff at their institutions to enrol and allocated to either control or intervention groups at T_0 as outlined in Table 2 (designed according to SPIRIT 2013) and Fig. 3 (Consort flow diagram), which summarises the enrolment, baseline, intervention and assessment schedule.(Chan et al., 2013)

3.9. Sample size

The sample and power calculation were conducted using a standard deviation (σ) of 2.25, a normal distribution with an expected mean of 8 (μ_1) in the intervention group and 7 (μ_2) in the control group. The result was that a sample size of 79 participants per group (total =158) would give us a power of 80% to detect a difference of 1 point score, giving an effect size, Cohen d= 0.44 (d= (μ_1- μ_2)/σ)), with an alpha of 0.05 and a two-tail test. To allow for a drop-out rate of 20%, the required sample size will increase to 198. The calculations were informed by a previous study conducted by the authors. (Lunn et al., 2022)

The equation used for the sample and power calculation was

$$n = \left[\left(Z_{\alpha/2} + Z_{\beta} \right)^2 \times 2 \cdot \sigma^2 \right] \Big/ (\mu_1 - \mu_2)^2$$

$$n\,\text{final} = 2n/(1 - 0.2)$$

n= sample required in each group; $Z_{\alpha/2} = 1.96$; $Z_{\beta} = 0.84$; $\sigma = 2.25$; $\mu_1 = 8$; $\mu_2 = 7$

Table 2
Schedule of enrolment, intervention and assessments.

	Study period				
	Enrolment	**Allocation**	**Post-allocation**		**Closeout**
Timepoint	**-T_0**	**T_0**	**T_1**	**T_2**	**T_3**
Enrolment					
Recruitment of Pharmacy schools	X				
Informing MPharm students	X				
Student self-enrolment	X				
Student pre-randomisation test (baseline)	X				
Student randomisation to control/intervention		X			
Interventions					
Control- test standard ID				X	
Intervention- test lower ID				X	
Assessment					
Baseline test score			X		
Control test standard ID score				X	
Intervention test lower ID score				X	
Student feedback questionnaire				X	
Statistical analysis					X

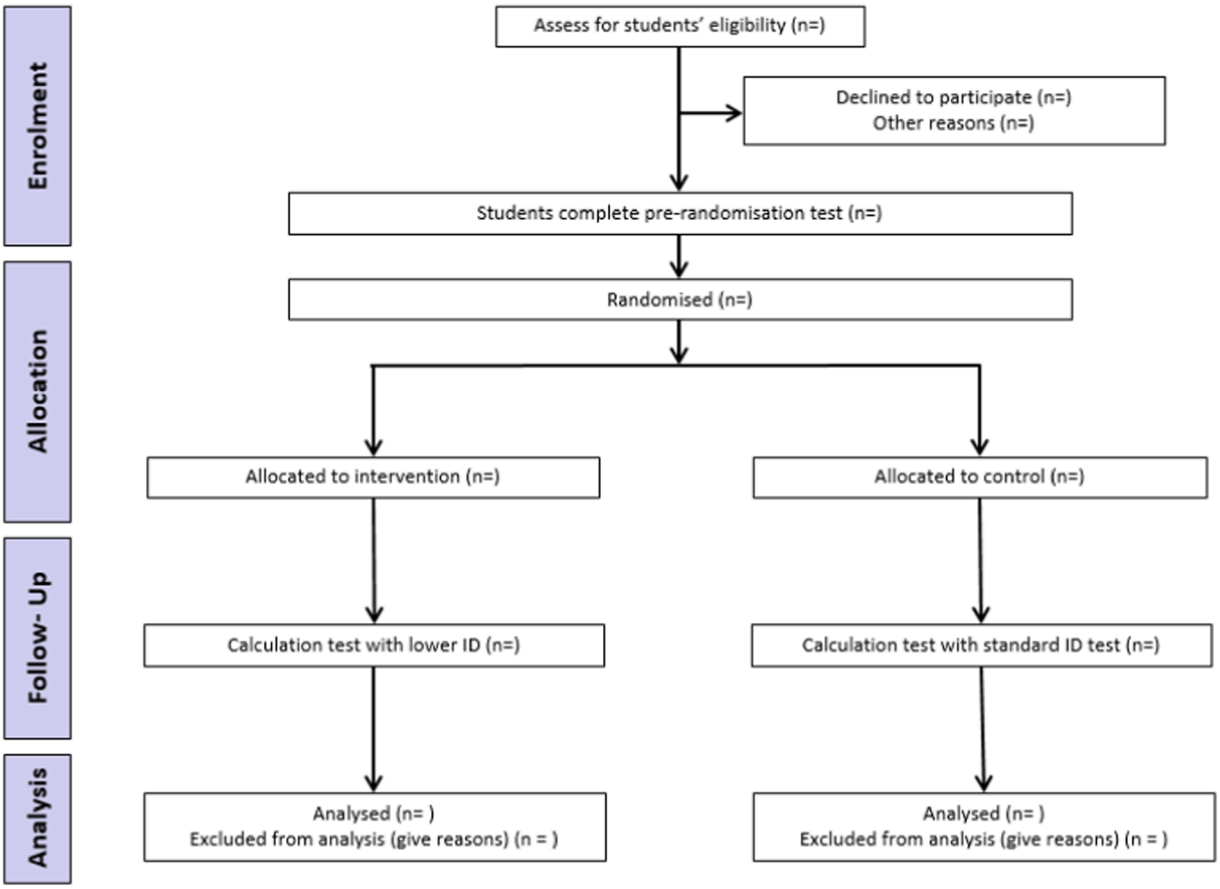

Fig. 3. CONSORT flow diagram of study.

3.9.1. Recruitment

Fourteen pharmacy schools across the UK were approached, and 14 agreed to participate, the locations of which are shown in Fig. 4. This gives an eligible population of around 6,000 students. Students in each institution are to be approached by the participating member of staff at their organisations to inform them of the study and disseminate *via* email and/or other appropriate internal channels the invitation to participate in the study, which contains all participation information and electronic consent form.

3.10. Randomisation, sequence generation, allocation and blinding

3.10.1. Randomisation

An academic expert in statistics from UCLan will oversee the randomisation process. After giving consent to participate in the study, all students will automatically be given the baseline test. Following a one-week window to take this test, students will be randomly divided into equal-sized (1:1) control and intervention groups and sent a second test for the control and one for the intervention groups.

Students will be blinded to allocation; performed using sequentially generated random numbers. The control and intervention exams will be identical in all but the idea density of the questions.

The students are the unit of randomisation and intervention.

3.10.2. Block size

As the randomisation will be 1:1, the block size multiplier will be 2, 4, 6 and the block size 4, 8, and 12. This approach will reduce bias and balance allocating participants to the treatment arm. Furthermore, the process will adopt block permutation, meaning that treatment assignments within blocks are determined to be random in order but that the desired allocation proportions are achieved exactly within each block.

3.10.3. Sequence generation

A computerised random number generator will generate the sequence.

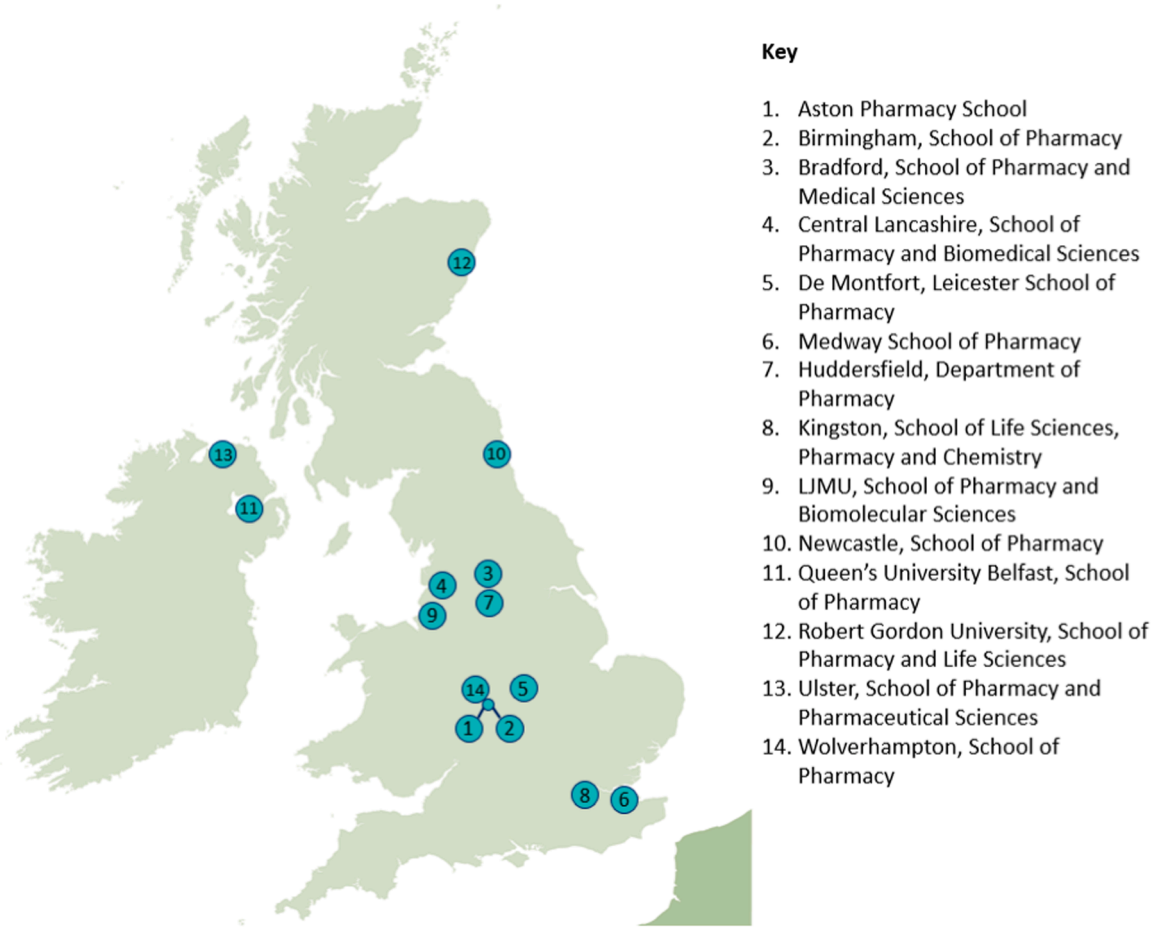

Fig. 4. Map of the UK showing the location of the 14 schools of pharmacy taking part in the trial.

3.10.4. Allocation concealment

It won't be possible to use a centralised randomisation service. Therefore, a research team member using an online system will generate an allocation schedule.

3.10.6. Blinding

This is a single-blinded study. Participants will be blinded as to whether they are control or intervention; this will not, however, be possible for the investigators to ensure that each participant receives the correct exam.

3.11. Data Collection

Data will be automatically collected when participants fill out the questions using the online platform Qualtrics™. All responses will be given in English and numbers only. All responses will only be accessible using a password-secured account to comply with the General Data Protection Regulation (GDPR). Each test will take a maximum of 36 minutes to complete, and students will have their responses automatically recorded and completed after that time.

3.12. Data Management

Input data will be saved and stored automatically on the JISC system. This will be downloaded to a secure, password-protected university laptop and only anonymised data will be shared any further than this or over email. It is not envisaged that any paper data will be created that is not anonymised, but in the case that it will be kept in a locked cabinet in a university office that is also locked when unoccupied.

3.13. Statistical Methods

The statistical analysis will be performed following the intention to treat (ITT) approach.

Primary outcome

The effect of lowering the idea density of a calculation exam on attainment amongst UK pharmacy students will be assessed by comparing the mean or median scores achieved by the students in the second test, and the average student performance of in each question between cohort arms. The student t-test will be used for comparing the arms of the trial if normally distributed variables, while the Mann-Witney test will be for non-normally distributed variables. The baseline and the second test in each arm will be compared using the paired t-test or the non-parametric equivalent (Wilcoxon sign rank test). If the baseline line data is unbalanced, further analysis will be performed using linear models (e.g. hierarchical linear models (HLM)) embedding baseline data and universities. Still, if the assumption of HLM won't be met, then Generalized Linear Mixed Methods (GLMM) or Generalized Estimating Equations (GEE) will be used.

Secondary outcomes

The pass rate is a dichotomous variable (pass or fail), and the passing grade is 70%. Pearsons' Chi-Square or Fisher Exact test will be used to assess whether lowering the idea density of a calculation exam increases UK pharmacy students' pass rate. Results will be presented using percentages (proportion), and the likelihood of improvement will be determined as an odds ratio.

The effect of each of the following characteristics on students' attainment in pharmacy calculation when lowering idea density will be assessed using binary logistic regression.

- First language speaker or not
- Age
- Ethnicity
- Year of study
- Specific learning disability

PASS 2021 software will be used for creating permutated block randomisation and sequence generation.

Validity and Reliability of the tests

Content validity was assessed a-priori by a panel of experts involved with the GPhC examinations; they reviewed all questions and answers. The reliability will be assessed a posteriori using Cronbach's alpha. The statistical significance is set at $p \leq 0.05$.

The statistical analysis will be performed using SPSS version 28/29 and Excel for Microsoft 365.

3.14. Data Monitoring

This study will be short, lasting around three weeks, with only a single intervention. Therefore, no interim analysis will be possible that would require data monitoring.

3.15. Risk and Safety Issues

We envisage no safety issues or risks, the study will be undertaken by the participants on any internet capable device of their choosing, personal or university owned and is formatted correctly to be viewed easily on a PC, laptop, tablet or mobile phone device.

3.16. Harm

There will be no harm to the participants, all responses will be anonymised after completion and the full question and answer set will be sent to all participants who fully complete the study once finished, for them to use as a learning aid.

3.17. Auditing

No auditing has been planned at this time.

4. Research and dissemination

4.1. Research ethics approval

Ethics approval was obtained from the lead university, Liverpool John Moores Univ*ersity, UK. (REF* 22/PBS/004 obtained 12/08/2022)

4.2. Protocol amendments

We are not expecting to make any changes to the eligibility criteria, outcomes, and analyses during our study.

4.3. Consent, invitation and confidentiality

All relevant documentation for participant consent has been included (Appendices A & B), and the procedures are summarised below.

4.3.1. Informed consent

All participants will confirm they have read the participant information and give their informed consent electronically before being able to participate in the study.

4.3.2. Who will contact the pharmacy students?

The pharmacy students will be contacted by the participating staff member at their institution verbally and then with full details via email and/or any other suitable internal platform.

4.3.3. How will pharmacy students consent?

All participants will confirm they have read the participant information and give their informed consent electronically before being able to participate in the study.

4.3.4. Confidentiality

Informed consent will be obtained from all participants included in the study. All data will be handled following the requirements of the Data Protection Act (2018) and/or the GDPR 2016. The data will be completely anonymised with any identifiable reference to the participants removed prior to publication.

4.3.6. Declaration of interest

This study is being funded by the Association for the Study of Medical Education (ASME).

4.3.7. Dissemination policy

Dissemination of the study will begin in a co-ordinated fashion between all participating institutions. Students will be informed verbally in person of the study and sent full information via email and/or any other suitable internal platform such as Canvas, Blackboard, Moodle etc. Once the first test is complete, contact with the participants will be via email, and only students who have given their consent will be contacted further.

4.3.8. Ancillary and post-study care

There should be no need for post-study care. However, all completing participants will be sent a copy of the questions with correct answers at the end of the study. If any student becomes worried at their performance in the tests, they will be able to access support with the participating member of staff or appropriate numeracy tutor at their own institution.

4.3.9. Plans, if any, for granting public access to the full protocol, participant-level data set, and statistical code.

The research team plan to publish the research protocol and register it on a trial registry. Therefore, the protocol will be in the public domain. Once completed, we envisage the study being written up and submitted to a peer-reviewed journal for publication. Once submitted, the data set will be available in the Liverpool John Moores repository. All data will be anonymised in line with GDPR requirements.

5. Patient and public involvement

The outcomes of this study primarily affect students, so we sought to obtain the opinions of pharmacy students. A small group of current and recently graduated LJMU pharmacy students was assembled including third- and fourth-year students and a graduate who had recently sat the GPhC registration exam. Due to time constraints in when the students were available it was necessary to have developed a draft study protocol before seeking their views, but before ethics approval to allow for any changes. Because of this, the panel was initially presented with a very brief conceptual overview with an opportunity for discussion before presenting a detailed plan of the study so not to influence their opinions.

After the initial conceptual overview explaining that we were seeking to determine the effect of the wording of pharmaceutical calculations on student performance, the students were positive about the proposed approached. Various anecdotes about specific questions, where the wording had confused them were shared, including one from the 2022 registration exam. One student expressed that “red-herring”, or distractor information sometimes left them feeling unsure about how they had performed in a question, feeling anxious about having not used all the information. This information is included to make scenarios more authentic to the real world and is beyond the scope of this study, but would be an interesting point of investigation in the future.

Having agreed that it was a worthwhile study the students also spoke about how they would go about investigating it. They decided that two tests (control and intervention) would be needed and that in an ideal world they would have students take both in a paired analysis. The students were unsure however as to how you would avoid the issue of training from one test to the next and were not aware of the analytical issues around cohort cross-over studies.

The students were then presented with the full study plan. Discussion following this was positive towards the study. After seeing an

example of how the questions would be changed linguistically, they commented that it was interesting as:

"That's how I re-write the questions when I'm working them out anyway".

Students wanted to be kept up to date with the study results and one student was keen to become more involved in the study, which we hope to facilitate. The most striking comment that came from this discussion was

"It's an awful to think that some people fail just because it's a poorly worded question- in real life you would just ask someone to re-word what they were saying"

This comment really showed that the students saw the importance of improving the linguistics of a written exam and that the study was worthwhile.

6. Discussion

At the heart of this study is the aim of improving exam performance, such that they more accurately test a candidate's knowledge and ability in a specific topic rather than their comprehension of a written passage. As such, it is essential that questions are written in a way that is suitable to the area and as widely understood by students in the time allowed as possible.

Idea density has been shown to be a predictive metric in determining the time taken to comprehend a text. However, the effect of idea density has not been studied in the applied, time-pressured scenario of a written exam where comprehension is critical in effectively answering questions and performing suitably to demonstrate your knowledge and understanding. Guidelines typically exist regarding time to allow per question in many exam settings, such as writing positively framed questions, streamlining potential responses, ensuring grammatical correctness and avoiding leading statements. (Dell & Wantuch, 2017) Such guidelines, whilst valuable, do not account for the linguistic measures of a question rather than the total number of questions presented. This leaves a lot of room for differences and discrepancies between questions. Such differences could then lead to students not being tested fairly, disproportionately affecting specific demographics over others (second language speakers, mature students and those with specific learning differences). Various metrics may be considered to determine the linguistic suitability of a question, such as overall length, readability score, minimum IELTS score of students on the course and, as is being investigated here, idea density. All of these factors should be considered. However, as ID has been shown to affect comprehension time, it may be an excellent linguistic measure, currently underexplored, which could go some way to ensuring that knowledge and ability are being tested rather than the ability to read.

The impact of ID has further been exacerbated in those with English as a second language. It may also affect mature students and potentially those with specific learning differences such as dyslexia. For this reason, and if the study numbers are such that this is possible, secondary subgroup analysis may be employed to investigate specific effects on these populations further.

This study is specifically investigating idea density within the context of pharmaceutical calculations. This area was chosen as it is a topic that is delivered across all UK pharmacy schools to a set of 12 criteria set out by the GPhC and tested post-graduation in a national standardised test. This ensures that all students will have been taught to a similar level following the same topics. In addition, it is scenario-based with all required information being supplied to the candidate, which reduces the confounding effect of previous knowledge among students. The test focuses on the application of provided knowledge rather than factual recall. Furthermore, the test is not multiple-choice, requiring the candidate to input a number, which removes the confounding issue of the linguistics of multiple-choice options.

7. Conclusions

To the best of our knowledge, this is the first study in the area to assess the impact of idea density on pharmacy calculation exam performance. The potential impact of this study could be to guide the linguistics of how to write more inclusive questions and improve academic practice when examining candidates. In addition, this work aims to explore how exams can be improved to ensure that core knowledge and skills are being tested, rather than understanding written English above a minimum level. This improvement may be of particular importance to minority students who speak English as a second language addressing one potential reason for the achievement gap, so future research will focus on investigating this sub-group specifically.

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Protocol version

This is version one of the study protocol, any amendments will be periodically updated on the trial registry.

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Declaration of Cometing Interest

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Appendix A

Participant information, supplied to potential participants electronically.

LIVERPOOL JOHN MOORES UNIVERSITY

PARTICIPANT INFORMATION SHEET PHARMACY STUDENTS

Research Ethics Committee Reference Number: 22/PBS/004

Title of Study: Influence of reduced idea density on student performance in pharmaceutical calculations, a randomized controlled trial.

You are being invited to take part in a research study. You do not have to take part if you do not want to. Please read this information, which will help you decide.

1. What is the purpose of the study?

In this study you will take two 12 question practice GPhC style calculation exams.

This study aims to determine the impact of how questions are worded on student performance in GPhC style pharmaceutical calculation exams. We will specifically be looking at something called Idea density, which is a measure of the number of idea/propositions used in a text divided by the total number of words used.

This study hopes to answer the following questions:

- Does idea density influence performance on pharmaceutical calculations exams?
- If it does, does it affect some populations more than others?

2. Why have I been invited to participate?

You have been invited because you are an undergraduate pharmacy student registered at a UK school of pharmacy.

You can take part if you are:

- Over 18 years of age
- Registered as a student on an MPharm course in the UK
- Be in years 1-4 of the course (levels 1-7)

You must not take part if you are:

- Under 18
- Not registered on an MPharm course in the UK
- Are currently undertaking a foundation year (level 3)

3. Do I have to take part?

No. You can ask questions about the research before deciding whether to take part. If you do not want to take part that is OK. We will ask you to give your consent using an online form.

You can stop being part of the study at any time, without giving a reason, you may withdraw from the study by contacting either Dr Andrew Lunn (A.M.Lunn@LJMU.ac.uk) or Prof. Andrea Manfrin (AManfrin@uclan.ac.uk).

If, however you decide to withdraw once all data has been collected (questions have been submitted anonymously), we will be unable to remove data from you, however it will not be traced back to you.

4. What will happen to me if I take part?

If you are interested, follow the link provided, which will direct you to an online platform (JISC) where you will take the first part of the study.

The study will require you to complete some basic demographic details about yourself and provide your email address. Your email

address will be used to contact you with the tests and to link your data together, after this has been done your email address will be deleted so that the data is anonymized and cannot be linked back to you.

You will then take two 12 question calculation tests that you will do a week apart from each other. Each test will take around 30 minutes to complete (maximum time allowed is 36 minutes). The tests are based on the GPhC registration calculation test.

Once you complete both parts of the study you will be sent a copy of all of the questions with the answers for you to use in your learning after.

We will collate the study findings and compare them to those from the other UK universities who are running the same study. You may request a copy of the findings by contacting the study team principal investigator Dr Andrew Lunn (LJMU) A.M.Lunn@ljmu.ac.uk

5. Are there any potential risks in taking part?

Participating in the research is not anticipated to cause you any disadvantages or discomfort. The potential physical and/or psychological harm or distress will be the same as any experienced in everyday life

6. Are there any benefits in taking part?

The immediate benefit to you taking part will be the extra learning opportunities and calculation practice. We hope that by completing the tests you will gain valuable numeracy/calculation experience at the level required to pass the GPhC registration exam, this will also aid you in your university exams. If you complete the study, you will be sent all the questions, with the correct answers for you to use in your studies in the future.

You will also be entered into a prize draw to win one of 150, £20 Amazon vouchers.

You will also be contributing to improving how we write questions and test you, making the test more inclusive, helping to ensure that they test your core skills alone.

7. Payments, reimbursements of expenses or any other benefit or incentive for taking part

There will be no payment for taking part in this study. Unfortunately, we cannot reimburse any expenses you may incurred.

8. What will happen to information/data provided?

The information you provide as part of the study is the **study data**. Any study data from which you can be identified (e.g. from identifiers such as your name, date of birth, audio recording etc.), is known as **personal data.** Your participation in this study will involve the collection/use of personal data, which is your email address.

We will keep personal data safe and secure. People who do not need to know who you are will not be able to see your email address. The personal data collected will include:

- Your email address
- Study data. We will use a code/pseudonym so that you cannot be directly identified from the data.

Study data will be kept for *three years* after the study has finished.

Your personal data may be accessible to individuals who are in a position of authority or influence over you. If you think that you could be disadvantaged in some way you should not participate if this risk is not acceptable to you.

We will write our reports in a way that no-one can work out that you took part in the study.

9. Who is organising the study?

This study is organised by Liverpool John Moores University

10. Whom do I contact if I have a concern about the study or I wish to complain?

If you have a concern about any aspect of this study, please contact *Dr Andrew Lunn A.M.Lunn@ljmu.ac.uk* and we will do our best to answer your query. You should expect a reply within 10 working days. If you remain unhappy or wish to make a formal complaint, please contact the Chair of the Research Ethics Committee at Liverpool John Moores University who will seek to resolve the matter as soon as possible:

Chair, Liverpool John Moores University Research Ethics Committee; Email: FullReviewUREC@ljmu.ac.uk; Tel: 0151 231 2121; Research Innovation Services, Liverpool John Moores University, Exchange Station, Liverpool L2 2QP

11. Data Protection

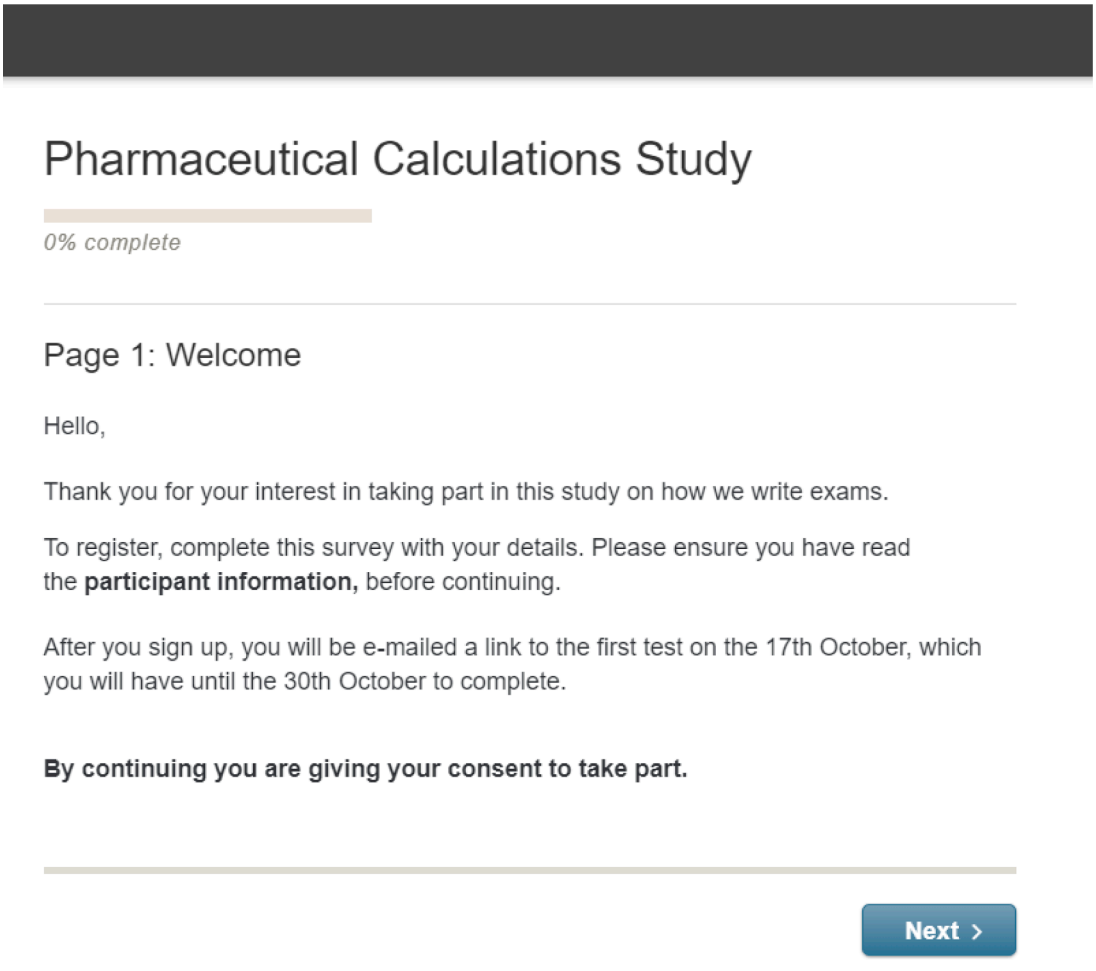
Liverpool John Moores University is the data controller with respect to your personal data. Information about your rights with respect to your personal data is available from: https://www.ljmu.ac.uk/legal/privacy-and-cookies/external-stakeholders-privacy-

policy/research-participants-privacy-notice

12. Contact details
Principal Investigator: *Dr Andrew Lunn*
Member of LJMU staff
LJMU Email address: *A.M.Lunn@ljmu.ac.uk*
LJMU School/faculty: *Pharamcy and Biomolecular Sciences*
LJMU Central telephone number: 0151 231 2121
IF APPLICABLE Supervisor Name: *INVESTIGATOR TO INSERT*
LJMU Email address: *INVESTIGATOR TO INSERT*

Appendix B

Electronic participant consent as it will appear to potential participants on the Qualtrics platform.



Appendix C

Questions used for the student feedback questionnaire, adapted from the validated assessment feedback questionnaire published by Froncek et al. (2014).

1 Predict your score out of 12
2 The content of the exam for registration level was

1-too easy, 2-easy, 3-about right, 4-hard, 5-too hard

For the five remaining questions please select how much you agree or disagree with each statement

1 The exam was too difficult for me
   a 1-strongly disagree, 2- disagree, 3-somewhat disagree, 4-neither agree or disagree, 5-somewhat agree, 6-agree, 7 strongly agree
2 I think the instructions were understandable
   a 1-strongly disagree, 2- disagree, 3-somewhat disagree, 4-neither agree or disagree, 5-somewhat agree, 6-agree, 7 strongly agree
3 The answer format caused me problems
   a 1-strongly disagree, 2- disagree, 3-somewhat disagree, 4-neither agree or disagree, 5-somewhat agree, 6-agree, 7 strongly agree
4 I am satisfied with my performance in this exam
   a 1-strongly disagree, 2- disagree, 3-somewhat disagree, 4-neither agree or disagree, 5-somewhat agree, 6-agree, 7 strongly agree
5 I was able to process the exam completely within the given time
   a 1-strongly disagree, 2- disagree, 3-somewhat disagree, 4-neither agree or disagree, 5-somewhat agree, 6-agree, 7 strongly agree

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