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ORIGINAL ARTICLE

Mixed-methods pilot study exploring the influence of the novel Paediatric Anaesthetic Drug Solution tool on clinician cognitive load during simulated paediatric rapid sequence intubation in the emergency department

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Aim: Rapid sequence intubation (RSI) in children is a low-incidence, high-risk event associated with cognitive overload and potential errors producing unfavourable outcomes. Cognitive aids, such as charts, algorithms and flow diagrams, are prompts that externalise and structure mental processes to reduce cognitive load, thereby reducing errors. The Paediatric Anaesthetic Emergency Drug Solution (PAEDS) approach combines a colour-coded chart and medication box with a simplified mathematical system of volume-based dosing; the effect of which on cognitive load during a simulated RSI has not previously been described.

Methods: A randomised, cross-over trial was conducted with 26 multi-disciplinary emergency medicine clinicians (doctors and nurses) allocated to four groups, performing four high-fidelity RSI simulations, two mandating the use of the PAEDS approach. This mixed methods study followed the pragmatic ontology using grounded theory methodology. Qualitative data were collected from nine individual interviews by a process of thematic analysis via an inductive approach, to allow for appropriate open and axial coding to occur. Quantitative data collected included cognitive loading using the raw NASA-Task Load Index as well as time to intubation and drug dosage details to assess for safety.

Results: Qualitative results showed that the PAEDS approach reduced cognitive loading through the use of both the labelled medication box and colour-coded medication charts. The PAEDS approach also showed improved perceived time pressure without feeling rushed, and with no recorded drug errors. Differences in the quantitative data for total cognitive load, error and time were not statistically significant, likely due to sample size.

Conclusion: The PAEDS approach is a multifaceted system which is not inferior to current practice, with some components described as an improvement. Further research on a larger sample size needs to be conducted to assess the aspects of the PAEDS approach both collectively and independently.

Key words: education; emergency medicine; general paediatrics.

What is already known on this topic

1 Paediatric rapid sequence intubation is a cognitively intense process with individual practitioners having low exposure rates. There is no single universal standardised approach for medication preparation and delivery in paediatric rapid sequence intubation with medications being prone to error and a large source of stress. The Paediatric Anaesthetic Emergency Drug Solution approach was introduced to reduce medication error but its effect on cognitive load and acceptability had not previously been described.

What this paper adds

1 The Paediatric Anaesthetic Emergency Drug Solution approach is a tri-faceted approach which has high levels of acceptability and qualitatively shown reduction in cognitive load.

Airway compromise is the leading cause of death and morbidity in critically unwell children. Rapid sequence intubation (RSI) is a procedure in which a definitive airway is secured via endotracheal intubation whilst minimising disruption to physiology.[1] RSI is a critical skill for all Emergency Medicine staff to be proficient in. Paediatric RSI in the emergency department (ED) is a low-incidence event, accounting for only 4.6% of all ED

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intubations.[2] It is commonplace for ED-based paediatric intubations to be performed by anaesthetists in some jurisdictions,[3] however in Australasia, the majority (63.2%) of ED paediatric intubations are performed by emergency physicians,[2] with an associated mortality rate of 3.8%.[2] American data has shown a low first pass success rate of only 52%.[4]

Paediatric RSI requires multiple tasks to be completed simultaneously (including medication dosing and delivery), increasing the cognitive load.[5] Cognitive load is the processing of information done within the human working memory. Cognitive load theory involves analysing the concepts of working memory, schemata development and automaticity.[6] There are three main components of working memory[7]:

1 *Intrinsic load* – this is the load directly associated with the task. It is influenced by the complexity of the task and the individual performing it. The more experienced the learner is (more developed schema and automaticity) the less processing is required; therefore the load is less.[8]
2 *Extraneous load* – this is the 'background noise' that is not pertinent to task completion and must be filtered out.[9] Intrinsic and extraneous loads are cumulative; therefore, the task must be within the individual's working load limitations to be completed effectively.[10]
3 *Germane load* – this is the load devoted to learning, which is separate to completing the task but does occupy the same working load memory space.

The ED is a high-risk environment for medication errors with rates of up to 39% in the paediatric population.[11] Paediatric dosing of medications is largely weight dependent, therefore, medications must be individually calculated, drawn up and then administered to the patient.[5] The number of calculations required can be overwhelming, leading to cognitive overload and subsequent lack of confidence.[12] The ED is also a dynamic, rapid paced setting where time pressures and frequent distractions can impact on an individual's mental capacity (cognitive load).[13] Paediatric RSI has both large intrinsic and extraneous loads, with a higher proportion of non-automatic actions (reduced automaticity due to the higher intrinsic load),[14] and a large emotional burden associated with caring for a sick child.[15] Additional cognitive load also comes from being rare events.[12]

There is a consensus in the literature that medications in paediatric RSI are a large source of stress and error, and there is no universal approach for medication preparation and delivery in resuscitation. The Paediatric Anaesthetic Emergency Drug Solution (PAEDS)[16,17] is a volume-based drug calculator where each medication is diluted and prepared as a 0.1 mL/kg dosage (e.g. a 21-kg child requires 2.1 mL of a given medication). These medications are limited to the ones in the chart and have all been standardised for concentration and dilution (see Data S1). They are colour coded as per the Australian Standard.[18] PAEDS includes all medications required for a paediatric RSI in an ED and these are stored in a labelled box.

This pilot study is designed to assess the influence of the PAEDS approach on the cognitive load of Emergency Medicine clinicians during simulated paediatric RSI.

Methods

Participants

Study participants were recruited via emailed invitation from a single mixed, tertiary emergency department in Sydney, Australia. A total of 26 participants made up the final convenience sample, consisting of 4 consultant emergency physicians (Fellow of the Australasian College of Emergency Medicine (FACEM)), 8 resuscitation-trained emergency nurses and 14 emergency medicine registrars.

Study design

This was a mixed methods study of convergent design, following a pragmatic ontology with grounded theory as the employed research method. The research was carried out in a cross-over trial format where participants were allocated to one of four study groups (A-D) using stratified randomisation. Each group undertook four unique paediatric RSI simulations (see Data S1) where two scenarios mandated the use of the PAEDS approach and two allowed for the team leader to pragmatically manage the situation as they would in their practice, defined as 'standard approach'. Assignment to each scenario and the required approach was randomised with teams informed immediately prior to commencing the simulation. All groups had access to the Newborn and Paediatric Emergency Transport Service (NETS) calculator (an online paediatric clinical calculator showing the concentrations, dilutions and doses required for a given weight). In this study, the four EM Consultants were the team leaders, in the two mandated scenarios they all chose to use the NETS calculator as their 'standard approach'.

Data collection

Individual participant interviews were held which followed a flexible script. All participants were invited to participate; there were no exclusion criteria. These interviews were audio recorded, transcribed and analysed using thematic analysis.

Two quantitative measures were used to assess the clinical safety and suitability of the PAEDS approach. Firstly, medication dose error (defined as a dose given exceeding ±10% of the prescribed dose, the syringes were checked after each simulation for their dilution and amount given vs. the prescribed dose) and secondly, time to medication delivery (defined as the interval between verbalisation of a drug order by the team leader and the time to delivery). These were recorded in real time by an observing member of the research team.

Cognitive load was assessed immediately after the completion of each scenario using the raw NASA-TLX questionnaire, a validated tool assessing six cognitive domains (mental, physical, temporal demand, effort, performance and frustration)[19,20] (see Data S1). The raw NASA-TLX is a scale from 0 to 100 that was completed electronically by all participants immediately post scenario. On all scales (except for performance where it is 0 for perfect performance and 100 for failure) 0 would represent very low demand and 100 would represent very high demand.

Analysis

Qualitative data were obtained from interview transcripts which were reviewed and analysed using thematic analysis by a single researcher. The process started with transcription and allocation of pseudonyms, giving a unique code (PT01-09) to each participant, and then coding commenced. Coding was done manually, the initial step of coding using grounded theory is open coding, where the researcher identifies pieces of data that had a common idea and was labelled with a code. Multiple codes were developed and were subsequently organised using axial coding. Axial coding draws connections between codes to ultimately develop themes. Finally, selective coding was used to further organise the data into global themes which were represented via thematic networks.[21]

The quantitative data were first analysed for normality using the Shapiro–Wilk test. Normally distributed data are presented as mean and standard deviations whilst non-normally distributed data are presented as median and interquartile ranges. The Wilcoxon rank sum test was used to assess the degree of significance in the observed differences.

Ethical considerations

This study was approved by the hospital's human research ethics committee (LNR/20/LPOOL/ETH02295) and the University of Dundee ethics committee. Written consent was obtained from all participants prior to their involvement. All data were stored in de-identified form using participant identifier numbers and uploaded into Research Electronic Data Capture (REDCap) (Nashville, TN, USA).

This study conforms with the Standards for QUality Improvement Reporting Excellence guidelines.[22]

Results

Qualitative results

Out of the 26 participants, only 9 completed the interviews due to limited self-selection to participate. Interviews were analysed and theme webs were developed based on three clear categories drawn from the dataset: paediatric resuscitation is a stressful event; cognitive aids improve safety and implementation strategies need to be robust and well planned.

Paediatric resuscitation is a stressful event

This is largely related to the cognitive load of the scenario with two cognitive burdens (emotional and knowledge based) being explored. An unwell child made participants feel emotionally invested in their care and overcautious behaviour was reported when involved in paediatric resuscitation. A lot of staff reported unfamiliarity with sick children and lack of exposure to this population causing an additional cognitive load.

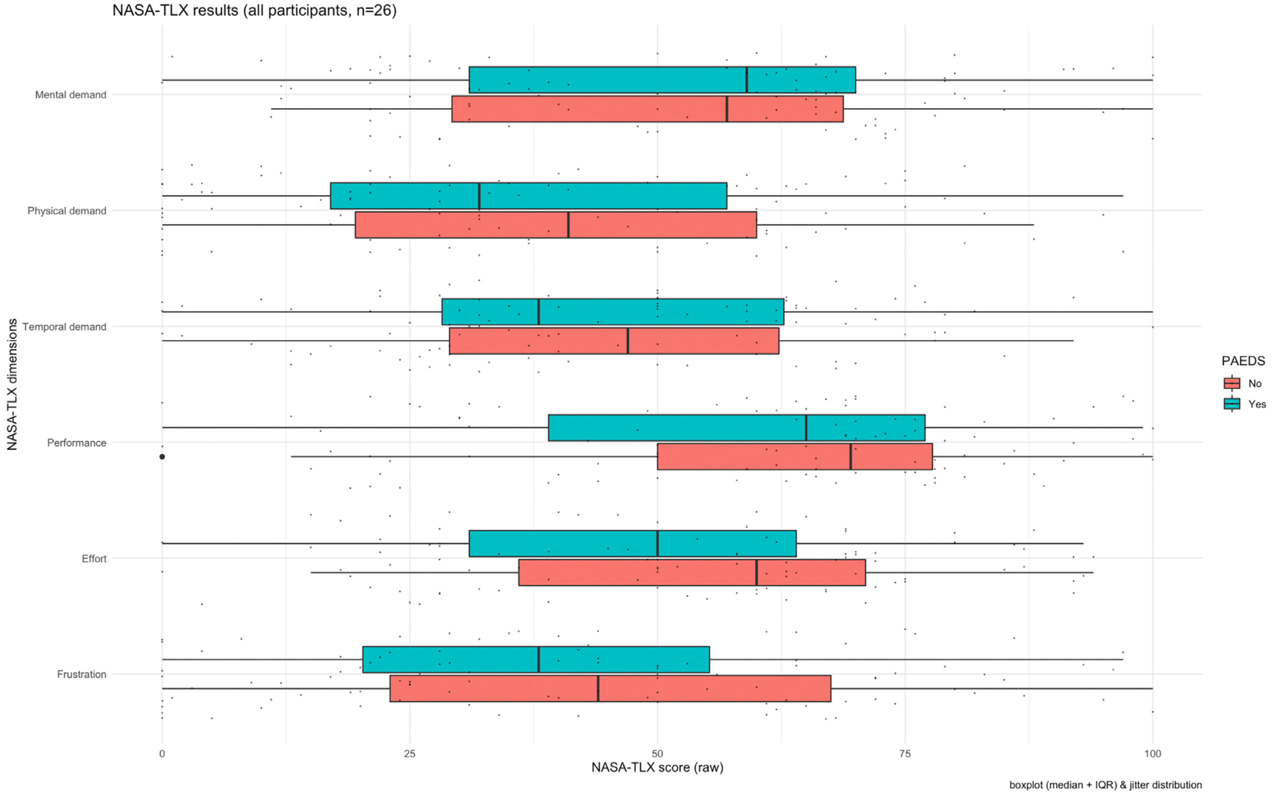

Fig. 1 NASA-TLX scores (all participants).

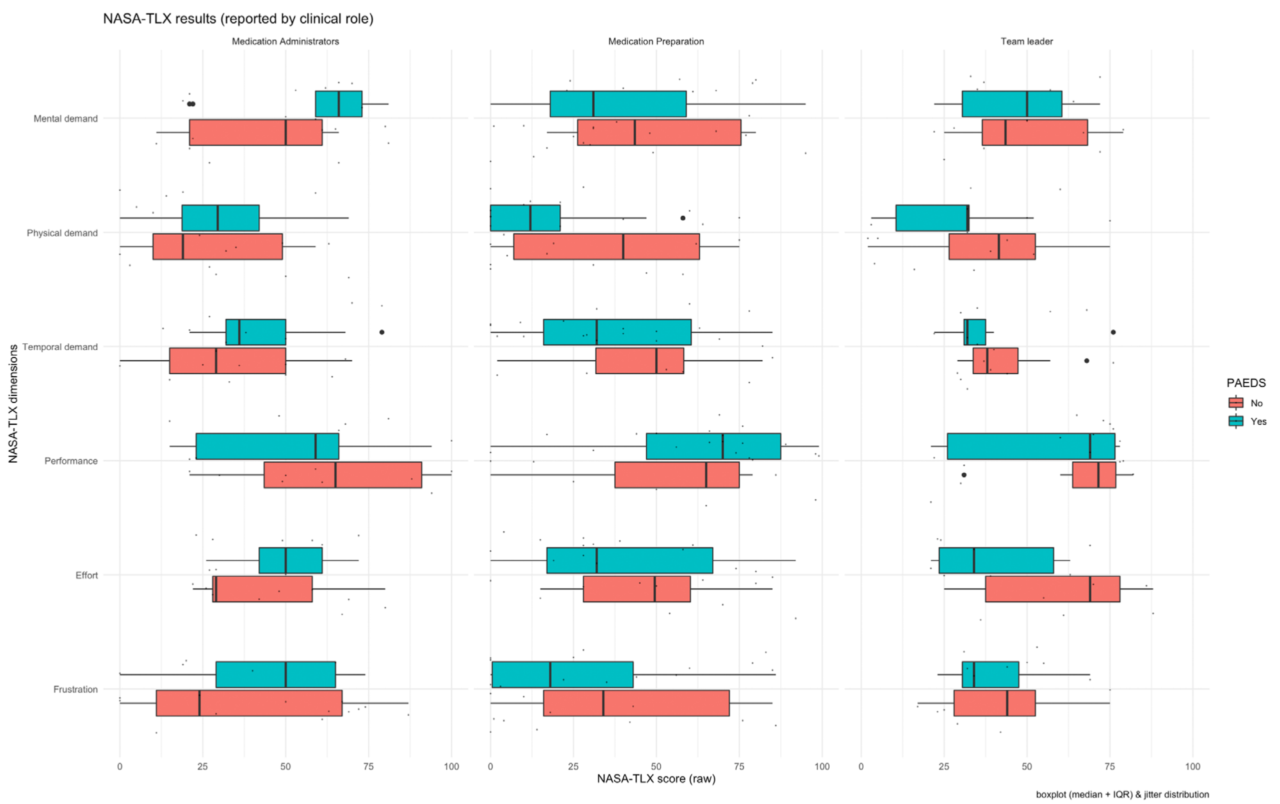

Fig. 2 NASA-TLX scores (by clinical role).

Cognitive aids improve safety

Significant anxiety surrounding weight-based dosing was a theme, especially the calculations involved to get the correct dose. The PAEDS approach was reported in these interviews to feel faster, and the limited medication choice reduced stress around medication choice. The medication box was helpful in these interviews keeping the medications safe, and it could be labelled and taken with the patient on transfers.

One team leader mentioned that it cognitively loaded them because it deviated from their well-established practice. The PAEDS approach also had some negative feedback from staff who did not like the fact they could not quickly work out the milligram dose given.

The colour coding of the medication chart was felt to be helpful as it was quick and easy to use.

Implementation strategies need to be robust and well planned

Interviewees largely were receptive to the PAEDS approach; however, if it were to be implemented, they would want further teaching and opportunities for practice prior to its commencement. This would have to be senior led and be the accepted practice for the department.

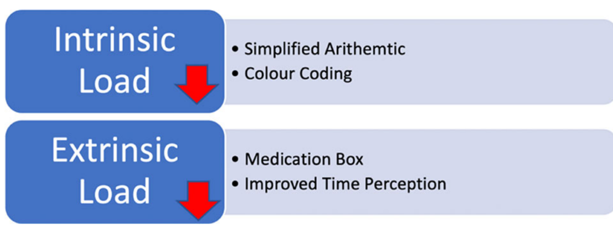

Fig. 3 How does the Paediatric Anaesthetic Emergency Drug Solution approach alter cognitive load?

Quantitative results

Cognitive load data from the raw NASA-TLX questionnaire were analysed in four discrete groups; the entire clinician cohort (Fig. 1), and three, predefined subgroups: drug administrators, drug preparation clinicians and team leaders (Fig. 2). There was typically one drug administrator and two participants responsible for medication preparation in each scenario, except for two scenarios which had two drug administrators and one scenario that had three staff preparing medications.

In the entire clinician cohort, effort, frustration level and physical demand all appeared to be lower in the PAEDS approach group. In the 'drug administrators' cohort, physical demand appeared to be lower in the PAEDS approach group, but frustration was lower in the standard approach group. For the clinicians responsible for medication preparation, there appeared to be lower mental, temporal and physical demand in the PAEDS group. Frustration was also lower in this group. In the 'team leaders' cohort, all domains other than performance were lower in the PAEDS approach. None of these reported differences, between all groups and across all domains, reached statistical significance. Unfortunately, it became apparent that the NASA-TLX questionnaire for performance was misinterpreted by some participants where as written, 0 is perfect performance and 100 is failure. In this study, some participants admitted they had scored conversely (0 failure, 100 is perfection) therefore this significantly impedes interpretation of the component of this dataset.

There were no significant differences between groups for either time to sedative medication delivery (PAEDS, 8.82 min vs. standard 8.76 min, $P = 0.95$) or paralytic drug delivery (PAEDS, 9.3 min vs. standard 8.4 min, $P = 0.96$) during the simulated RSI. There were three drug errors in this study, all occurring in the 'standard approach' group, which all used the NETS calculator; this was in three different groups and three different scenarios without a clear pattern. There were no errors in the PAEDS approach group.

Discussion

In this pilot study, the PAEDS approach demonstrated several perceived benefits during simulated paediatric RSI scenarios.

The colour-coded medication chart at the centre of the PAEDS approach provides two elements of assistance to clinicians. Firstly, it acts as a cognitive aid and secondly is the colour coding, both elicited positive responses. Cognitive aids are designed to provide accessible knowledge and to reduce intrinsic load by decreasing the reliance on memory, which can cause errors.[23] Colours are a key part of the PAEDS approach as they improve attention span and increase transfer of knowledge to long-term memory compared to monochromatic information[23] Colour coding information reduces cognitive load as colours are processed subconsciously, not contributing to working load memory.[23]

Volume-based dosing had a mixed reception when discussed during focussed interviews, with a clear split based on their years of clinical experience. The more junior members of staff (medical and nursing) who did not have an established resuscitation system felt it was a useful cognitive offload tool. However, a senior member of staff felt it was cognitively onloading as it was a change to their current, well-established practice. There were reported feelings of frustration (an extraneous cognitive load) by the medical staff as they only knew the volume of medication being given and not the actual dose (e.g. milligrams).

The medication box in the PAEDS approach was described as useful, and it was considered easier to keep track of controlled medications.

These data suggest that the elements of the PAEDS approach can individually, and therefore collectively, reduce both intrinsic and extraneous cognitive load. By reducing intrinsic and extraneous cognitive load the aim is to improve access to germane load, in order that learning and development can be completed after an important experience (however, this component of cognitive load theory was not specifically assessed in our study). Overall, the data suggest that the PAEDS approach can reduce cognitive load and free working load memory (see Fig. 3).

Whilst the data were not statistically significant in terms of time to intubation or medication errors due to a small sample size, the results are promising. The PAEDS approach had no errors with its use (compared to three with the standard approach) despite not being a familiar approach to staff suggesting it has ease of use and acceptability.

Limitations

As a single-centre study, the small sample size means that there may be reduced generalisability to other EDs which do not comprise the same demographic as the study centre. There was a risk of selection bias due to self-selection of participants into the qualitative follow-up groups. As paediatric RSI is a low-incidence event, it was not possible to study this approach in real clinical scenarios, therefore it was conducted in simulated environments which are inherently different to real life practice. The decision to undertake RSI had already been made thereby reducing that specific decision-making cognitive burden.

Conclusion

The PAEDS tool shows promise as a patient safety tool for demonstrating cognitive offloading with the three described elements being important (volume-based dosing, colour-coded chart, medication box). Whilst this approach was not superior to current standard care, it had high levels of staff acceptability. This is an area of high importance for future research as it has the potential to improve the clinical outcome for a very vulnerable population.

Recommendations

1 Further research is needed to understand the impact of the PAEDS approach as a collective approach, but also to study the impact of the three individual elements to see what has the largest impact and improvement in cognitive load. The gold standard would be a clinical randomised control trial where children requiring an RSI are randomised into groups of standard approach or combinations of the elements of the PAEDS approach.
2 Cognitive aids should be encouraged in the resuscitation environment; however, an understanding of what makes a good cognitive aid is crucial.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Data S1. Paediatric Anaesthetic Emergency Drug Solution (PAEDS) material. Qualitative Data Codes. NASA-TLX questionnaire.