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A systems approach using the functional resonance analysis method to support fluoride varnish application for children attending general dental practice

Al Ross[a,*], Andrea Sherriff[a], Jamie Kidd[a], Wendy Gnich[a], Janet Anderson[b], Leigh Deas[c], Lorna Macpherson[a]

[a] Glasgow Dental School, School of Medicine, College of Medical, Veterinary and Life Sciences, University of Glasgow, 378 Sauchiehall Street, Glasgow, G2 3JZ, UK
[b] Florence Nightingale Faculty of Nursing and Midwifery, King's College London, James Clerk Maxwell Building, 57 Waterloo Road, London SE1 8WA, UK
[c] Public Dental Services, NHS Lanarkshire, Hospital Street, Coatbridge, ML5 4DN, UK

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ABSTRACT

Background: All children attending General Dental Practice in Scotland are recommended to receive twice-yearly applications of sodium fluoride varnish to prevent childhood caries, yet application is variable. Development of complex interventions requires theorizing and modelling to understand context. This study applies the Functional Resonance Analysis Method (FRAM) to produce a sociotechnical systems model and identify opportunities for intervention to support application.

Methods: The FRAM was used to synthesise data which were: routine monitoring of fluoride varnish application in 2015/16; a longitudinal survey with practitioners (n = 1090); in-depth practitioner and key informant interviews (n = 43); and a 'world café' workshop (n = 56).

Results: We describe a detailed model of functions linked to application, and use this to make recommendations for system-wide intervention.

Conclusions: Rigorous research is required to produce accessible models of complex systems in healthcare. This novel paper shows how careful articulation of the functions associated with fluoride varnish application can support future improvement efforts.

1. Introduction

1.1. Childhood caries

Dental caries is a significant public health concern with a global cost burden (Kassebaum et al., 2015; Petersen, 2008). In Scotland, caries is the predominant reason for hospital admissions for elective surgery in children (Scottish Government, 2016c) and reducing this preventable harm is a key outcome for the Scottish Government's health and well-being strategy (Scottish Government, 2014). Upon entering school, 45% of children from the most deprived areas have experienced caries, and 18% from the most affluent (Scottish Government, 2016a), reflecting a known inequality in health outcomes (Scottish Government, 2000; Levin et al., 2009).

1.2. Prevention in practice in Scotland

Childsmile (Macpherson et al., 2010; Turner et al., 2010) is a population level oral health improvement programme for Scottish children with components in schools, nurseries, family homes and dental practices. This practice-based programme delivers parental advice on diet, fluoride and tooth brushing, and clinical prevention via the application of sodium fluoride varnish (FV) to children.

1.2.1. Sodium fluoride varnish application

There is high quality evidence for the caries-preventive efficacy of FV as a safe, topical treatment (Marinho et al., 2013; Weintraub et al., 2006). All children are deemed to be at risk of caries, and thus could benefit from application (SDCEP, 2010). Dental practices delivering NHS (National Health Service) care to children are thus expected to deliver FV at six-monthly intervals from the age of two, subject to satisfactory medical history. FV application (FVA) for 2–5yr old children

* Corresponding author. K9B Level 8 Glasgow Dental Hospital and School, 378 Sauchiehall Street, Glasgow, G2 3JZ, UK.
E-mail addresses: alastair.ross@gla.ac.uk (A. Ross), andrea.sherriff@gla.ac.uk (A. Sherriff), jamie.kidd@gla.ac.uk (J. Kidd), wendy.gnich@gla.ac.uk (W. Gnich), janet.anderson@kcl.ac.uk (J. Anderson), l.deas@nhs.net (L. Deas), lorna.macpherson@gla.ac.uk (L. Macpherson).

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is carried out either by a dentist, or under the prescription of a dentist by a dental therapist, hygienist or Extended Duty Dental Nurse; EDDN and is remunerated through the Statement of Dental Remuneration (SDR) via a varnish application fee (previously, application came under a general capitation fee for most dentists). Despite evidence for improved oral health through the wider *Childsmile* programme (Macpherson et al., 2013), delivery of this key preventive intervention is still variable. National monitoring data show that in 2015/16, just 18% of 2–5 year old children registered with an NHS dentist received the recommended two applications within a year (Childsmile Central Evaluation and Research Team, 2016).

1.3. Complex interventions

In this study we synthesised evidence from mixed data sources to model the likely effects of intervening in the FV system. There is now a wealth of literature (Campbell et al., 2007; Hoddinott et al., 2010) on the difficulty of intervening successfully in healthcare systems, which are complex (Pfadenhauer et al., 2017) and involve dynamic interacting components (May et al., 2016). Developing and evaluating interventions requires a) theorizing to inform design and b) modelling of mechanisms and contextual factors likely to come into play (Craig et al., 2008).

This study approached healthcare as a sociotechnical system whereby outcomes emerge from interactions between people, organisation, technology, internal and external environment, and tasks and processes (Holden et al., 2013). One notable challenge is to be able to define and describe this system context to provide evidence for intervention design and implementation (Datta and Petticrew, 2013). Interventions in health care can take various forms, such as behavioural, educational, financial, environmental, or technical (Michie et al., 2011). However, the key is that they are based on a model of how the system in question operates. The Functional Resonance Analysis Method (FRAM; see methodology) was employed in this paper because it can represent very many interacting elements in a way that is not too simplistic to be meaningful (Carayon et al., 2014).

We now describe how a FRAM model was synthesised from various data sources during the developmental stage of an intervention in General Dental Practice to prevent childhood dental caries.

2. Aims

This study aimed to identify and describe the system context for applying FV, by modelling related activities in practice. A specific objective was to identify opportunities for intervention to support dental teams in applying higher rates of varnish to their child patients.

3. Methods

3.1. The functional resonance analysis method

The Functional Resonance Analysis Method (FRAM) is a method for modelling complex organisational systems (Hollnagel, 2012) derived from Resilient Health Care theory (Braithwaite et al., 2015; Cook, 2006), which is concerned with how success is achieved through adaptation in complex environments (Anderson et al., 2016; Hollnagel et al., 2013). Recent papers have shown promise in using the FRAM to understand implementation of guidelines (Clay-Williams et al., 2015) and to guide safety management efforts (Pickup et al., 2017; Raben et al., 2017b). FRAM involves identifying functions (technological, human or organisational activities) in everyday work. The basic unit of analysis is a function hexagon (see Figs. 1 and 2).

Functions are specified according to six aspects:

- Inputs (I): Drivers; starting aspects which are transformed by the function
- Preconditions (P): Necessary conditions for the function to take place
- Resources (R): Consumables necessary for the execution of the activity
- Time (T): Temporal constraints
- Control (C): How the function is monitored e.g. through supervision
- Outputs (O): Resulting states or objects

The key to applying FRAM is to model: a) which functions are variable; and b) how they link to others. Some variability, from psychological or social factors such as individual differences, training/competency, or teamwork/communication, is inherent in the carrying out of functions. However, there is also variability from the complex ways in which activities relate to one another. Preconditions, time, control, or resources for a function may not be forthcoming from previous one (e.g. the function < obtain consent > may not give rise to the output 'consent' that is a precondition for a subsequent function < give treatment >). The idea of 'resonance' in FRAM is that the ways in which functions link is important, because compound variability may have amplified effect (positive or negative), thus giving information for improving system performance.

FRAM has no 'objective' system boundary, rather the analysts decide on the scope of the model according to utility and relevance to the research aims. To avoid infinite regress, FRAM allows for *background functions* (output only) and *stopping functions* (input only) which delineate system boundaries. The central purpose of FRAM is "to represent the dynamics of the system rather than to calculate failure probabilities" (Hollnagel, 2012)In this study we synthesised triangulated data from various sources to build the FRAM model. We now describe the work briefly by detailing data sources, and procedures for building and validating the synthesised model.

3.2. Data used for modelling

3.2.1. Routine monitoring data

The Scottish Dental Informatics Programme processes NHS primary care dental claim forms which, in addition to assisting payment for practitioners, provides data for the monitoring of FV activity. We accessed the last available full-year dataset (from April 2015 to March 2016). Claims data were managed in IBM SPSS v22.0 and SAS/STAT software.

3.2.2. Surveys

Data were gathered from a longitudinal survey (Gnich et al., 2015) of salaried and non-salaried General Dental Practitioners (GDPs) in Scotland, conducted before (time 1; n = 1090; response rate 54%; Aug–Oct 2011) and after (time 2; n = 709; new response rate 65%; Feb–May 2013) the introduction of the varnish application fee. Questionnaires were theory-based (Michie et al., 2005) and designed by a panel including clinicians, psychologists, and dental public health specialists. Dentists were asked to self-report application rates, then to rate barriers and facilitators to application.

3.2.3. Staff interviews

In- depth, semi-structured interviews were carried out with a criterion-based sample of practice staff (n = 36; Sep–Nov 2014) to identify functions associated with FV application.

We recruited using a sampling frame of practices where FV application rates were high (90th percentile) or low (10th percentile) as a proportion of children attending a *Childsmile* appointment. Table 1 shows participating practices and staff and further stratification. Interview questions were designed to elicit: a detailed description of FV activity in the practice setting; factors facilitating or inhibiting application; and recommendations for improving application rates.

3.2.4. Key informant interviews

Targeted interviews (n = 7; May–Nov 2015) were then carried out to elicit expert opinions on important functions identified in practitioner

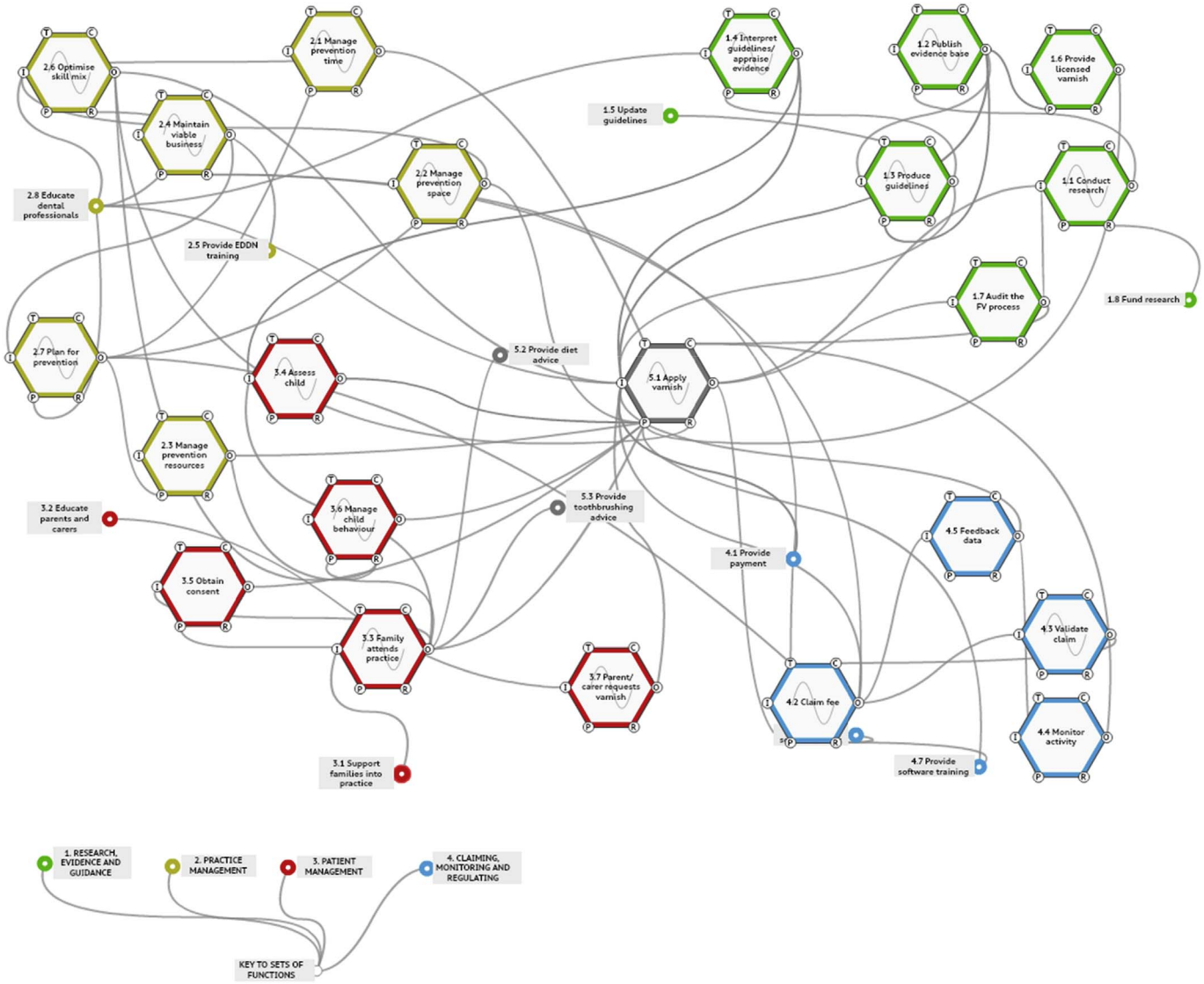

Fig. 1. FRAM model of functions linked to fluoride varnish application.

interviews and survey responses. This stage involved a purposive, non-probabilistic sample to ensure participants could inform the study. Specific roles are necessarily withheld so as not to identify individuals, but those sampled had significant senior level experience in *Childsmile* programme management and training; General Dental Practice management; Dental Public Health; and the Scottish Government. All 43 interviews from practitioners and key informants were fully transcribed verbatim and transferred to QSR NVivo 10.0 software for analysis.

3.2.5. World café

At an early stage of the analysis, the emergent model was reviewed and discussed at a workshop which employed an adapted 'World Café' method (Broom et al., 2013). Attendees (n = 56) took part in facilitated round table discussions and included NHS clinical directors, specialists in dental public health, *Childsmile* programme managers and co-ordinators, dentists, NHS operational managers and Oral Health Educators. All world café notes were typed verbatim after the event and transferred to electronic files.

3.3. Building and validating the FRAM model

We followed FRAM procedure, which is to first identify a broad set of initial functions, then to link further specific functions where they have aspects in common (see Fig. 1). The dedicated FRAM Software (FRAM Model Visualizer v0.4.1) prompts for new functions where needed, and automatically links functions where aspects match. For example, if 'guidelines' are identified as input to the function 'apply varnish', the software prompts for a function that gives rise to this aspect (e.g. 'produce guidelines') and so on.

For ease of interpretation and reporting, functions were grouped into sets, which are sub-processes in the overall system that connect together in a coherent manner (Raben et al., 2017b).

A representative sample of source data (e.g. text excerpts, questionnaire results, workshop notes) was coded independently by two researchers to FRAM functions in the initial model. A reliability of 84% was achieved, and disagreements were then resolved to produce a revised model where appropriate. The system boundary (placing of background functions) was agreed with members of the *Childsmile* Central Evaluation and Research Team. Colleagues at the 10th Workshop on the Functional Resonance Analysis Method in Lisbon, Portugal in June 2016, including the developers of FRAM and experts in its use in healthcare, also checked integrity and reliability of the formal analytic steps taken.

4. Results

Fig. 1 shows the final model.

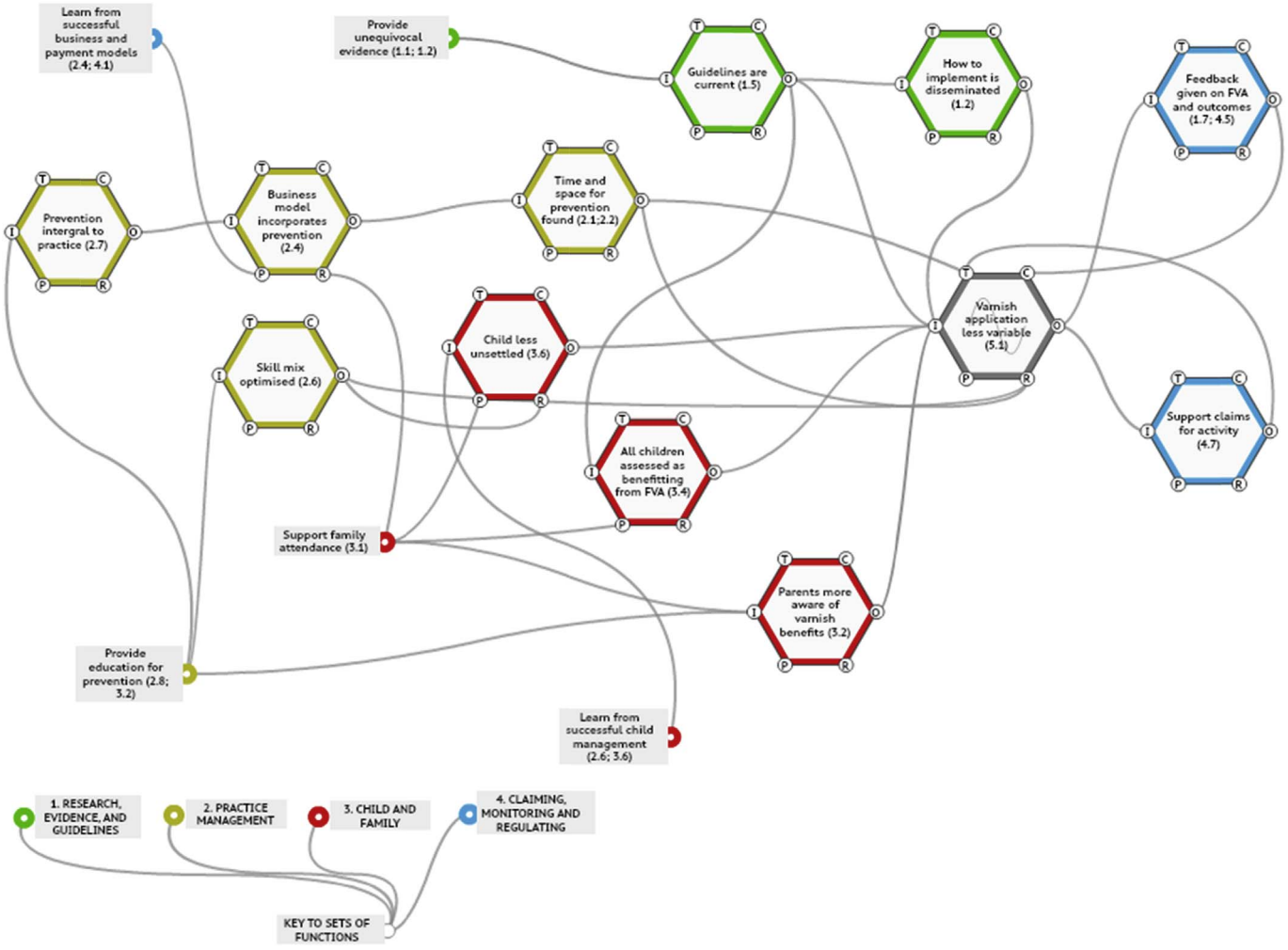

Fig. 2. Projected FRAM instantiation showing the aims of a system intervention to improve functioning and increase varnish application.

Table 1
General Dental Practices and staff participating in interviews.

Practice ID	Fluoride varnish application rates	Practice size	Interviewees (n = 36)	Geographical Health Board in Scotland
1	High	Large	GDP; Dental Nurse	Tayside
2	High	Large	GDP x3; Dental Nurse; VT Trainee	Highland
3	High	Large	GDP; Dental Nurse	Grampian
4	High	Small	Practice manager; GDP	Dumfries & Galloway
5	High	Small	GDP	Highland
6	High	Small	GDP; EDDN	Highland
7	High	Small	GDP; Dental Nurse x2; VT Trainee	Tayside
8	Low	Large	Practice manager; EDDNs x3; GDPs x2	Tayside
9	Low	Large	GDP; EDDN	Greater Glasgow & Clyde
10	Low	Large	GDP	Highland
11	Low	Large	GDP; Dental Nurse; Trainee Nurse	Grampian
12	Low	Large	GDP; Dental Nurse	Fife
13	Low	Small	GDP	Grampian
14	Low	Small	GDP; VT Trainee	Fife
15	Low	Small	GDP	Greater Glasgow & Clyde
Total 15 Practices	*4 Highland; 2 Greater Glasgow & Clyde; 2 Fife; 3 Grampian; 3 Tayside; 1 Dumfries & Galloway*	*8 Large;7 small*	*18 GDPs; 5 EDDNs; 7 Dental Nurses; 1 trainee nurse; 3 VT trainees; 2 practice managers*	

Fig. 1 shows there were 33 linked functions (see Appendix) closely associated with FV application. As well as those relating to research, evidence and guidelines, and patient management tasks and processes, there are also linked organisational functions around practice management, and external claiming, monitoring and regulatory functions, which illustrates some of the system complexity. Activities and aspects will vary in different practices and locations, but Fig. 1 shows a general model of the system. The application of varnish emerges (or otherwise) directly and indirectly from the interaction of many activities such as interpreting guidelines and appraising evidence, assessing children for risk, managing child behaviour, managing time and space, maintaining business models, and educating professionals. For ease of interpretation, results are now for each of the smaller sets (Raben et al., 2017b) of closely linked functions indicated in Fig. 1.

4.1. Set 1 research, evidence, and guidelines functions

Guidelines, which recommend universal application, are a moderate driver (input) for application overall. However, interpretation of guidelines and appraisal of evidence is highly variable. Some practitioners view evidence for the effectiveness of FV as being somewhat equivocal, with some being worried about safety/toxicity. This interacts with a variable assessment of whether children are suitable (see patient management functions). Here, many dentists exercise clinical judgement and may decide a child is at low risk of caries even though guidelines deem that all children can benefit from application.

Examples of evidence for modelling functions in this area included:

- Interviews: *My understanding of it is that it has a limited positive effect on the low risk patients. With the high risk ones, if they're using fluoride toothpaste, which is what we promote anyway, again it's of limited evidence as to the additional benefits. I think the evidence that is promoted, as far as I understand, was* [from] *areas where non fluoride toothpaste was being used. That's the message that's drifting back to the profession* [ID1]; *In the end, it also comes down to clinical judgement […] Personally, I don't tend to slavishly follow the […] guidelines* [ID9]
- Longitudinal survey: The higher GDPs rated their knowledge that FV is advocated in current guidelines, the higher their self-reported rates of FV application (at time 1)
- World café: uncertainty about evidence for varnish; myths surrounding fluoride risks persist; evidence itself may not change 'entrenched positions'

4.2. Set 2 practice management functions

Application takes place within a resource-pressured system. This preventive activity depends to a large extent upon a further set of functions for managing surgical time and space, which may be at a premium in smaller practices. Prioritising prevention is traded-off against potential negative effects on the business viability of the practice. Payment via the application fee drives application to an extent as might be expected. Whilst reportedly insufficient to remunerate for the time involved, the presence of the fee/code may also help in establishing prevention as part of the professional role of dental staff. Using the resource of the wider dental team is a potential route to overcoming barriers. Examples of evidence for modelling functions in this area included:

- Interviews: *We have a Childsmile nurse but we don't have a room or a space for them […] the surgeries are full […] so we can't really have the resource for somebody to do the Childsmile intervention* [ID 22]; *Time. Short staffed, we don't have enough staff. Also, the surgeries, we don't have enough physical space. […]* [ID 3]; *[…]having to set up a decontamination unit […] a lot of the spare space has been taken up […] it doesn't matter how much [remuneration] you throw at it, you just don't have the space* [ID 43]; *My current nurse is very good at getting the [varnish] out and she'll remind me.* [ID20]; *I think we have to [move to] a much broader team approach […]you know, so that you've got almost the practice nurse doing all the prevention.* [ID 38]
- Longitudinal survey: The more GDPs asserted that FV application was an important part of their professional role, the greater their self-reported rates of FVA at both time points. Financial compensation for FVA did not appear to independently drive self-reported rates of FVA at either time point. After the introduction of the varnish payment fee, GDPs scoring more positively for the items "applying FV is important" and "applying FV is a priority for me" were more likely to have higher self-reported rates of FVA. Self-reported rates of FVA increased over time, most markedly for GDPs who did not originally work in *Childsmile* practices, and for younger children, and those at perceived increased risk of caries
- Monitoring data: A Kruskall Wallis test showed a small effect for practice size during 2015/16 whereby smaller practices (one or two dentists) apply less varnish per registered child ($p = .038$) suggesting a resource issue; there is no significant difference in applications per actual appointment (participating children), suggesting that it is preventive activity overall that is somewhat suppressed in smaller practices, rather than FVA *per se* (see discussion)
- World café: GDP is a business; FV can be applied by dental team; don't need surgical rooms; some resistance to expansion of the nursing role

4.3. Set 3 patient management functions

As reported above, assessing children for increased risk (e.g. based on family circumstance) emerged as a key function in patient management. Managing younger children who might be unsettled was linked to non-application, and nurse involvement improved management of child behaviour. Parental requests for varnish (or the rarer refusal to consent) are important inputs to FVA (consent is of course a precondition). Examples of evidence for modelling functions in this area included:

- Interviews: *In terms of caries risk what we were taught was their social history, their family history and their diet history. It does depend […]* [ID2]; *If there is a higher risk we'll speak with the dentist who might strongly advise it. […]; They're still babies at two. Getting them in the chair and getting them to keep their mouths open for the amount of time is hard […]* [ID10]; *Yes, you're influenced by the parent. Sometimes a parent will ask for it because they know other children who get it.* [ID9]
- Longitudinal survey: GDPs self-reported higher rates of FVA for their child patients (of all ages, but particularly for 2–5 year olds) whom they considered to be at increased risk of caries compared to standard risk. GDPs who perceived that parents of their child patients wanted varnish applied were more likely to self-report higher FVA rates (at time 1)
- Monitoring data: Trend analysis for 88,211 fluoride varnish claims for 2–5yr olds in 2015/16 shows 2 year olds are least likely to receive varnish ($p < .0001$)
- World Café Table 2: problems applying varnish to young children; uniform and mask can be off-putting; need flexible protocol as in using play spaces and other environments; using nurses; need to increase parental demand/expectation

4.4. Set 4 claiming, monitoring and regulating functions

Finally, interviews often cited time and resource difficulties in the seemingly straightforward function of claiming the application fee, despite training in the claim process being provided. Documentation was difficult to understand and varnish was reportedly sometimes applied but not claimed for, having an effect on the ability to monitor claims, a control function.

Monitoring FVA activity via collated data currently has a limited effect in encouraging FV application, however various feedback loops were suggested as potentially effective, including clinical audit, and

comparing application rates with peer norms. Examples of evidence in this area included:

- Interviews: *The SDR document […] is double Dutch. It's not written in plain clear English at all.* [ID30]; *Quite often we don't even put the forms in for the Childsmile because I just don't understand it to be honest.* [ID22]; […] *It's not so much about getting paid because the fee for preventive items tends to be fairly low, but it's just the fact that it's there. It ticks a box; it reminds you to do these things […]* [ID9]; *maybe develop […] for GDP practices[…] fluoride varnish applications as a very simple audit* [ID39]; *we've been potentially looking here at a peer review process using* [monitoring] *data […]Re-emphasising the evidence. Supporting them, showing them how to make the claims.* [ID 38]
- World café: simplification of payment bands; feedback on prevention activity levels

4.5. Designing the intervention using the FRAM model

The next step towards intervention was to examine the FRAM system model in Fig. 1 to identify variable functions affecting application to be targeted for improvement.

In FRAM modelling, the term 'instantiation' refers to the specifying of particular functional relationships from the general model. Instantiations can describe past events, or projected future states (Hollnagel, 2012) that might be expected to follow an intervention.

Once the general model is produced, giving an empirically-derived framework, the basic aim of intervention is then to amplify certain signals and dampen others to affect the aimed-for change. Fig. 2 shows the projected instantiation in this case for intervention to increase the likelihood of varnish application.

The functional improvements shown in Fig. 2 are now being targeted via an intervention toolkit, co-designed with GDPs. Practitioners showing highest application rates have been recruited and have described how they successfully negotiate the various functions and configurations in Fig. 2 to produce the outputs we have identified as important.

This toolkit of successful strategies will be delivered alongside feedback on personal FV application rates, and trialled (after piloting) to see if it increases national application rates.

Many different configurations are of course possible. It is not feasible to 'intervene' to support one dentist or practice at a time, thus the toolkit approach allows practitioners to engage with which ever strategies might be of interest, supporting the range of system functions so that varnish application is less variable overall.

A final advantage of basing intervention design on the FRAM model means that post-intervention instantiations can be used during process evaluation of the final trial, to allow specific effects (or otherwise) to be traced across the system.

5. Discussion

This paper draws from multiple data sources and uses the Functional Resonance Analysis Method to inform an intervention to increase rates of fluoride varnish application in dental practice. The use of FRAM informed the design process via a system model which identified which linked functions should be targeted to induce a combined effect ("resonance") on application rates. The system model will also allow for clearer articulation in future of the effect of intervention on the various functions.

5.1. System modelling and intervention

Organisational factors are frequently cited as important in clinical practice (Krein et al., 2010) yet organisational theories themselves are under-utilized in supporting routine delivery of care (Nilsen, 2015; Yano, 2008). Here, the innovative use of FRAM has shown that interventions to improve FV application rates should have multiple components, and take into account emergent effects from interacting functions. The model shows how any single intervention (for example training or education, financial incentive, or new guidelines on effectiveness) may have limited effect if other system dynamics are not attended to.

It is important that the intervention is being co-designed by practitioners who make decisions about varnish application in the context of everyday work (Flach et al., 2017). FRAM is concerned with work-in-context, e.g. managing everyday trade-offs between thoroughness and efficiency, clinical and behavioural needs etc. (Hollnagel, 2009). Thus the intervention will provide a repertoire of strategies for dealing with variable conditions that practitioners can draw from (Cook, 2006; Hollnagel et al., 2013; Wears et al., 2015).

5.2. Barriers to preventive dentistry

Previous research has identified broadly similar factors (e.g. patient expectations, and perceptions around the professional role of dentists) affecting the delivery of caries prevention in general (Templeton et al., 2016). Business pressure means the cost-effectiveness of different remuneration models for FV application is likely to be of continued interest (Birch, 2015) because this affects aspects of the model such as time, space and staff resources (Brocklehurst et al., 2013b; Conquest et al., 2015). We have reported that, in terms of evidence-based practice, practitioner beliefs about effectiveness (Elouafkaoui et al., 2015), clinical judgement relating to need, and patient preferences, seem to be somewhat stronger drivers than the available research evidence on its own (Vander Schaaf et al.) How to best extend duties across the dental team is known to be a somewhat intractable problem (Brocklehurst et al., 2013a), but interesting research is seeking to understand how best to utilise the team to increase efficiency and lower costs (Brocklehurst et al., 2016).

5.3. Study strengths and limitations

Rigorous research to produce systems models of healthcare processes, situating behaviour in the context of task, organisation and environment, is necessary as a basis for designing effective quality improvement interventions (Waterson, 2009). This research enhances previous thematic work identifying barriers and facilitators in this area (Suga et al., 2014; Witton and Moles, 2013) by showing specific links between inputs and outputs to guide intervention.

We used GDP list numbers and child registrations as proxies for size of practice, but there are other variables such as the presence of full and part-time staff, and the roles of dental nurses, which may give further insight into the set of practice management functions associated with preventive activity. It is necessary in FRAM modelling to set a system boundary. Some of the background functions in our results point to further sets of functions in important areas such as education and facilitating family attendance in practice that were beyond the scope of the current analysis situated in practice. In addition, the level of analysis here is broadly organisational, but if desirable, FRAM can be applied at a more granular level. We have a further video-recording study underway to model varnish application in detail which will give insight into more proximal ergonomic aspects such as use of equipment, application of clinical skills and capabilities, and physical and communicative activities in practitioner-child interactions.

Finally, we did not weight functions in this study, rather inducing a general model of functions, synthesised as appropriate from various qualitative and quantitative data, to target intervention at those that produce variable output. This is akin to the approach of Raben et al. who suggest FRAM as a method for identifying leading indicators for health care processes (Raben et al., 2017a). Future work might consider weighting function output probabilistically. It is possible for example to have professionals rate the reliability of functions (akin to building a Bayesian belief network) and derive probabilistic estimates of likely effects (Rosa et al., 2015; Smith et al., 2017).

6. Conclusions

Regular fluoride varnish application is important for prevention of childhood caries. We used the Functional Resonance Analysis Method to show how application is variable in practice and linked to many interacting activities with their own inputs, outputs and resource aspects. The new Scottish Government Consultation Exercise on the Future of Oral Health (Scottish Government, 2016b) notes that NHS dentistry is "embedded in a restorative culture" and has a clear focus on improving systems of preventive care in the General Dental Service, particularly this important area of child health. This transition, to less emphasis on managing and restoring caries, and more on prevention and control of the disease (Glick et al., 2012; Pitts, 2004), can benefit from the use of dynamic organisational models such as the one we have described, as we move towards a new Dental Action Plan due in 2017/18.

Declarations

Ethical approval and consent to participate

Glasgow University Medical, Veterinary and Life Sciences (MVLS) College Ethics Committee approved this project as a specific work package under the ongoing evaluation of the *Childsmile* programme (No. 200150076; end date March 2019). We sought ethical review advice from the West of Scotland Research Ethics Service who advised that under the terms of the governance arrangements for research ethics committees in the United Kingdom, NHS ethical review was not required and university approval would suffice. All interview and survey participants gave fully informed, written consent.

Competing interests

Conflicts of interest: none.

Funding

The project was funded by the Scottish Government. The funders played no role in the design of the study, collection analysis and interpretation of data, or in writing the manuscript.

Authors' contributions

LM and AR conceived the study. LD, WG and AR designed and managed the different aspects of primary and secondary data for synthesis. AR and JA led the FRAM analysis and conducted reliability tests. AS and JK led the numerical interpretations and statistical tests.

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Appendix. List of FRAM functions and main contribution to fluoride varnish system

Set	< Function->	Description	Output	Input from	Input into
1. Research, evidence, and guidelines functions	1.1 < Conduct research >	Conduct research on the effectiveness, risk and implementation of FV	Research findings	< Fund research > (1.8) < Apply varnish > (5.1);	< Publish evidence base > (1.2)
	1.2 < Publish evidence base >	Publish the results of research including trials, and synthesis in systematic reviews	Published evidence on effectiveness, risk and implementation	< Conduct research > (1.1)	< Produce guidelines > (1.3); < Provide licensed varnish > (1.6); < Apply varnish > (5.1);
	1.3 < Produce guidelines >	Making synthesised evidence available to practitioners in accessible form through guidelines	Guidelines	< Publish evidence base > (1.2) < Update guidelines > (1.5)	< Interpret guidelines/appraise evidence > (1.4); < Apply varnish > (5.1) < Provide diet advice (5.2) > ; < Provide tooth brushing advice > (5.3)
	1.4 < Interpret guidelines/ appraise evidence >	The interpretation/ appraisal of evidence and guidelines by professionals	Translated evidence on risk, effectiveness and implementation	< Produce guidelines > (1.3)	< Assess child > (3.4); < Apply varnish > (5.1);
	1.5 < Update guidelines >	The process whereby guidelines are maintained to reflect best evidence	Guidelines are current	n/a (background function)	< Produce guidelines > (1.3)
	1.6 < Provide licensed varnish >	The making available of a licensed product	Licensed varnish	< Publish evidence base > (1.2)	< Apply varnish > (5.1)
	1.7 < Audit the FV process >	Audit the varnish application process	Audit data	< Apply varnish > (5.1)	< Apply varnish > (5.1)
	1.8 < Fund research >	Fund research on effectiveness, risk and implementation	Research funding	n/a (background function)	< Conduct research > (1.1)

2. Practice management functions	2.1 < Manage prevention time >	Allocate time for preventive activities	Managed prevention time	< Family attends practice > (3.3); < Plan for prevention > (2.7);	< Maintain viable business > (2.4); < Apply varnish > (5.1)
	2.2 < Manage prevention space >	Find appropriate space for preventive activity	Managed prevention space	< Family attends practice > (3.3); < Plan for prevention > (2.7);	< Maintain viable business > (2.4); < Apply varnish > (5.1)
	2.3 < Manage prevention resources >	Maintain and utilise available resources	Managed prevention resources	< Plan for prevention > (2.7)	< Apply varnish > (5.1)
	2.4 < Maintain viable business >	Undertake preventive activity within a successful business model	Viable business model	< Provide payment > (4.1); < Claim fee > (4.2); < Plan for prevention > (2.7)	< Manage prevention time > (2.1); < Manage prevention space > (2.2); < Manage prevention resources > (2.3)
	2.5 < Provide EDDN training >	Train Extended Duty Dental Nurses (EDDNs) through training course and observed procedures	Qualified and experienced EDDNs	n/a (background function)	< Optimise skill mix > (2.6)
	2.6 < Optimise skill mix >	Utilise dental team in preventive activity	Skill mix for prevention	< Provide EDDN training > (2.5)	< Manage child behaviour > (3.6)
	2.7 < Plan for prevention >	Plan prevention to be integral to practice	Prevention integral	< Educate dental professionals > (2.8)	< Manage prevention time > (2.1); < Manage prevention space > (2.2); < Maintain viable business > (2.4)
	2.8 < Educate dental professionals >	Educate dental professionals on preventive approach	Prevention core part of professional role	n/a (background function)	< Plan for prevention > (2.7)
3. Patient management functions	3.1 < Support families into practice >	Help facilitate registration and attendance at practice for parents with young children	Registration and attendance	n/a (background function)	< Manage prevention time > (2.1); < Manage prevention space > (2.2) < Family attends practice > (3.3)
	3.2 < Educate parents and carers >	Educate parents and carers on benefits and safety of varnish	Educated parents and carers	n/a (background function)	< Family attends practice > (3.3); < Obtain consent > (3.5); < Parent/carer requests varnish > (3.7)
	3.3 < Family attends practice >	Family attends practice	Child in attendance	< Support families into practice > (3.1); < Educate parents and carers (3.2)	< Manage prevention time > (2.1) < Manage prevention time > (2.2)
	3.4 < Assess child >	Assess child for suitability	Child assessed	< Interpret guidelines/ appraise evidence > (1.4)	< Apply varnish > (5.1)
	3.5 < Obtain consent >	Obtain consent	Consent	< Educate parents and carers (3.2)	< Apply varnish > (5.1)
	3.6 < Manage child behaviour >	Manage child behaviour	Settled child	< Optimise skill mix > (2.6)	< Apply varnish > (5.1)
	3.7 < Parent/ carer requests varnish >	Parent/carer requests varnish	Request for varnish application	< Educate parents and carers (3.2)	< Apply varnish > (5.1)

4. Claiming, monitoring and regulating functions	4.1 < Provide payment >	Provide payment for varnish application	Specific fee for application	n/a (background function)	< Maintain viable business > (2.4); < Apply varnish > (5.1)
	4.2 < Claim fee >	Claim for application of FV	Claims	< Supply software/ forms > (4.6); < Supply software/ training > (4.6); < Apply varnish > (5.1)	< Maintain viable business > (2.4); < Validate claim > (4.3); < Apply varnish > (5.1)
	4.3 < Validate claim >	Validate claim	Validated claim	< Claim fee > (4.2)	< Claim fee > (4.2)
	4.4 < Monitor activity >	Routine monitoring of FV claims at national level	Data on FV application	< Apply varnish > (5.1)	< Feedback data > (4.5); < Apply varnish > (5.1)
	4.5 < Feedback data >	Feedback collated data to dentists or practices	Data fed back to GDPs/practices	< Monitor activity > (4.4);	< Apply varnish > (5.1)
	4.6 < Supply software/ forms >	Supply software/forms	Software/forms	n/a (background function)	< Claim fee > (4.2)
	4.7 < Provide software training >	Provide software training	Dentists trained in claiming for activity	n/a (background function)	< Claim fee > (4.2)
Core *Childsmile* functions	5.1 < Apply varnish >	Apply varnish	Varnished teeth	< Conduct research > (1.1); < Publish evidence base > (1.2) < Produce guidelines > (1.3); < Interpret guidelines/ appraise evidence > (1.4) < Provide licensed varnish > (1.6); < Audit the FV process > (1.7); < Manage prevention time > (2.1); < Manage prevention space > (2.2); < Manage prevention resources > (2.3); < Assess child > (3.4); < Obtain consent > (3.5); < Manage child behaviour > (3.6); < Parent/carer requests varnish > (3.7); < Claim fee > (4.2); < Monitor activity > (4.4); < Feedback data > (4.4)	< Conduct research > (1.1); < Publish evidence base > (1.2) < Produce guidelines > (1.3); < Audit the FV process > (1.7); < Claim fee > (4.2); < Monitor activity > (4.4)
	5.2 < Provide diet advice >	Provide diet advice	Advised parents/ carers	< Produce guidelines > (1.3)	n/a (stopping function)
	5.3 < Provide tooth-brushing advice >	Provide toothbrushing advice	Advised parents/ carers	< Produce guidelines > (1.3)	n/a (stopping function)

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