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Designing interventions to improve tooth brushing

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This paper provides an outline of an industrial approach to behaviour change, which ranges from a process to design and develop behaviour change interventions, to the development and use of technology to shape and measure behaviour (and subsequently changes therein). The focus here is on the normal population (with varying degrees in health status) in developed as well as emerging markets, cutting across a wide range of cultures and nationalities. The key desired behaviours of interest are: tooth brushing twice a day, and if adhered to, brushing for two minutes with a full coverage of all teeth. The approach taken starts with a succinct overview of key theoretical features of behaviour change, which have been assembled into a process for intervention design. Different examples of interventions will be discussed, with the main distinction of group size and scale. In this approach technology is used to provide detailed 1-to-1 feedback, and/ or to measure behaviour in a laboratory setting, and beyond that in the wider setting of people's homes. Finally a case study will be presented on the measurement of brushing behaviour following a simulated public health communication campaign.

Key words: Behaviour change, brushing duration, brushing frequency, intervention design, oral health, public health campaign, technology, tooth brushing behaviour

There is little doubt about how people can contribute to good oral health and hygiene through their own behaviour[1]. In essence this concerns brushing teeth twice a day for at least two minutes with a fluoride containing toothpaste[2]. Still this elementary behaviour is not as widely and fully practiced as dentists and health organisations would like it to be in order to achieve a basic health status worldwide. The premise in this paper is that behaviour change and interventions to evoke change are essential to achieve this.

When asked to design a behaviour change intervention that works, the immediate question arises: How? Different theoretical models have identified mechanisms that underpin behaviour change, often each model describing a different facet and emphasising a different mode of action. This can be challenging for designers of interventions as to which is the best route to follow. This paper presents a pragmatic approach rooted in behaviour change theory that provides a framework for the design of behaviour change interventions, these being of a technological nature or in the form of communication. Technology can and should be used to shape behaviour, for example, it can provide insight to the individual about the exact nature of their behaviour which otherwise may remain unknown. It can equally be used to inform the designer of behaviour change interventions of the behaviours subjects (patient or consumer) conduct without having to ask. The type of technology that can be utilised most effectively and efficiently depends on whether the target for behaviour change is an individual, a small cohesive group (e.g. classroom) or a large group of unrelated individuals (e.g. country population). Examples at both ends of this scale, specifically the value of detailed individual feedback and large-scale communication campaigns will be discussed.

Theories of behaviour change

Overview of key concepts

Behaviour change, or more scientifically, behaviour modification is defined as a change in existing behaviour or introduction of a new behaviour[3]. A wide variety of social-cognition theories of health behaviour and behaviour change have emerged since the 1960s; amongst

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others the health belief model[4], the theory of reasoned action[5] which later further developed into the theory of planned behaviour[6,7], and the transtheoretical model or stages of change model[8] (for a comprehensive overview of these and other theories see Abraham and Sheeran[9]). Some of these theories have already been discussed in the paper by Chapple and Hill[3].

The health belief model[4] is characterised by two variables: perceived 'vulnerability' to a health threat, and the severity of such a threat to someone's life. Whether an individual views an action as useful to their health would depend on their beliefs about the benefits versus the cost of such an action, a comparison that operates similarly to an 'economic' cost-benefit analysis. Rosenstock[4] introduced the concept of 'cue to action' as a trigger for an individual to act (this to explain 'inertia', for example in cases where despite a high cost to health, no action is taken).

Fishbein and Ajzen[5] introduced the theory of reasoned action which states that intention is a strong precursor to actual behaviour and depends on the attitude towards and the subjective norm concerning the behaviour. Attitude is determined by beliefs of the likelihood of outcomes caused by the behaviour, and the nature of the outcome as good or bad. The subjective norm is related to beliefs about what others want us to do. Later Ajzen[6,7] added the concept of perceived behavioural control, i.e. someone's belief about how easy or difficult it is to perform the behaviour as well as their individual control over the behaviour.

The transtheoretical model provides a time component to behavioural planning in the form of a series of stages[8,10]. These stages are: precontemplation, contemplation, preparation, action, maintenance and termination. People can go through these stages in a linear fashion, but often will back track as well before they ultimately reach a sustained behaviour change[11].

Despite their differences, together these and other theories have provided a more structured approach to understanding and explaining health behaviours, and the related intervention design to improve behaviour of target groups or societies as a whole[12]. Gollwitzer[13] added a practical element to changing behaviour with the concept of implementation intentions ('I intend to do 'x' when situation 'y' occurs'), by assuming that control of behaviour can be delegated to situational cues. This allows the achievement of goals to be directed by the environment and reduces their conscious regulation. In this way the environment or situation, supports the commitment of an individual who is intending to change.

In 2007 Aunger[14] presented the Norman-Shallice-Cooper model[15] as a framework for understanding tooth brushing behaviour as a routine, based in a situational context. This model postulates three systems; a perceptual system, a cognitive control system and a motivation network. The model assumes that once a behaviour is well-established it is no longer taken care of at the conscious level and runs automatically – hence it is difficult to modify. In his review Aunger concluded that self-regulation is more successful in forming routines, than motivation, which in turn is better than education. This is in line with the role that implementation intentions can play.

From theory to working principles

The theories briefly described above, all have a useful contribution to make to describing and explaining health behaviour. The underpinning models and mechanisms have relevance for a range of health behaviours in different contexts (e.g. condom use, smoking cessation, exercise etc). However the translation of a theoretical model into a practical solution ('design intervention') to actually modify behaviour successfully can still be a challenge. An eclectic approach was taken to look at the theories discussed and distil their key concepts into five working principles for behaviour change (*Figure 1*).

The reasoning behind this approach was to select the best from the theory of behaviour change and utilise this to underpin the design of interventions, which is central to the practical context of industry, health practitioners, and government organisations.

In addition, a structured and user-friendly process was developed to focus multi-disciplinary teams on building insights from observations, and generate tasks that can lead to new routes for behaviour change through product innovation and/ or health communication[16]. The five working principles are called:

Awareness and attitude – prior to behaviour modification, individuals need to be aware that 'behaviour x' is beneficial for them at a personal level, and what that behaviour involves in terms of actions, tools and physical context. Engagement in the behaviour can be stimulated by a positive attitude towards it (in order to form an intention). Knowledge and information play an important part to utilise this principle.

Self and society – our self-image and self-identity determine what behaviours 'fit' with our concept of self and hence how we will behave in order to preserve a stable identity. On the other hand, the social context in which we operate, and the pressure that can be exerted on an individual sets norms to which we adhere (or not).

The principle of self and society can be effected using inspirational *role models* or models close to the target group (peers). In addition social structures and systems (being a member of a club that has certain mores and routines) and social status symbols ('you are what you buy, wear, drive, read, eat etc') are highly relevant.

Easy and difficult – the belief that one is able to perform a behaviour (self-efficacy) despite its real difficulty plays an important part in the ultimate engagement in the behaviour. Ways to facilitate this are: showing how easy a behaviour is through modelling, explaining what skills are required, simplification of a task by breaking it down in elementary steps to make it more achievable step-by-step, simplification of a task through product design, low-threshold availability of products (time and place), and social structures and systems (social facilitation to support the target group).

Proof and reward – most behaviour is reward based but the issue here is the time-scale. Positive health-related behaviours often do not have an immediate effect, in other words there is no link to the action and outcome. In some cases adherence to social pressure can be a reward for not performing a positive behaviour. Where the reward remains uncertain, providing proof that the behaviour is beneficial becomes more important. Mechanisms that can facilitate this are: again simplification through breaking down a task in elementary steps to provide an early sense of achievement, the support, encouragement and reassurance from others, and feedback mechanisms.

Permanence – the essence here is to ensure that a new behaviour is not a one-off but becomes a sustained behaviour, a part of the individual's regular repertoire i.e. a habit. In particular, starting positive health behaviours or stopping negative ones is difficult (most readers will have some direct experience with this to a varying degree). At societal level, governments and health organisations have to continuously put effort behind health campaigns. Some UK figures show the cost of this, e.g. £50m for a three-year anti-smoking campaign[17], £50m for a three-year condom awareness campaign[18], £75m for an anti-obesity campaign[19]. Permanence is the most difficult principle of behaviour change and can be enabled by utilising transitional moments, those times in people's lives when important life events unfold, during which there is a general openness to new experiences (e.g. leaving home, marriage, first child, etc). Establishing associations between a new and an existing behaviour can be used to integrate the new behaviour into existing routines. The physical environment can be used as a cue to remind, stimulate or evoke the new behaviour. Stimulating product design features that appeal to the user and make the product use irresistible.

These five principles can work independently as well as in combination, the more that can be utilised the more support an individual will have in conducting a new behaviour.

The process

A process was developed to identify potential routes to facilitating behaviour change in which the five working principles come into action. The steps in this process are:

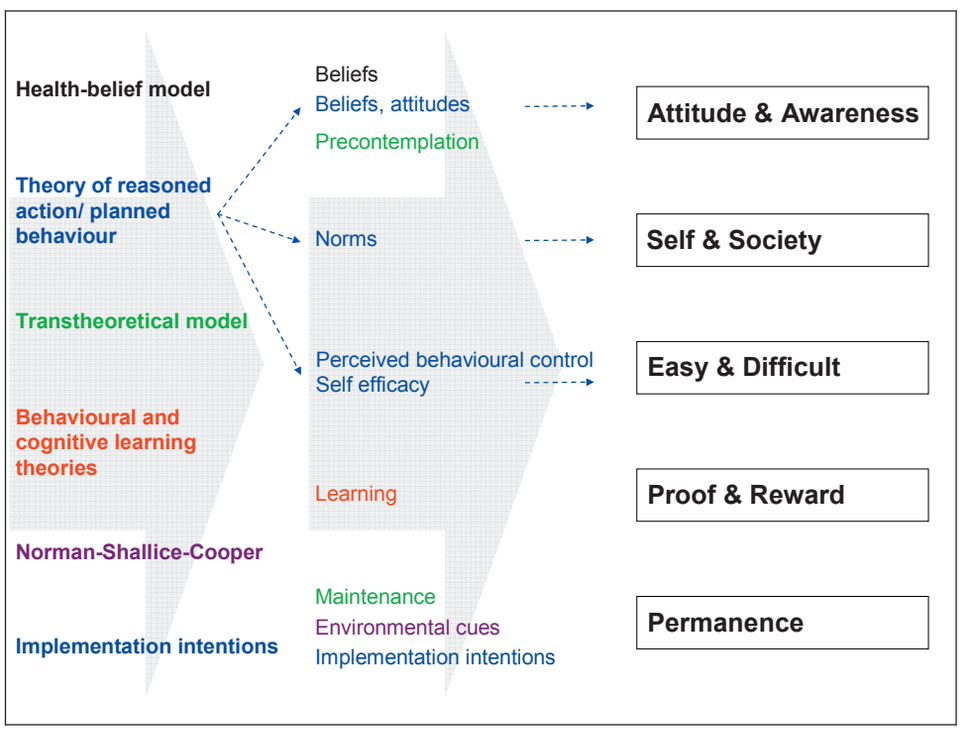

Figure 1. Working principles are theory based.

1. Specify the desired behaviour and target group
↓
2. Establish in-depth understanding of target group and existing behaviour
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3. Map current versus desired behaviour
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4. Identify barriers and benefits of current and future behaviours
↓
5. Identify relevant tasks that can trigger the new behaviour
↓
6. Develop ideas using the five working principles
↓
7. Implement innovation/communication through R&D and Marketing.

A process for behaviour change

The step-wise process described in the previous section focuses designers of behaviour change interventions to consider target group, current and future behaviours, barriers and benefits in detail. Without a holistic and in-depth approach designing a behaviour change intervention might become a quick fix with a minimal impact. This section explains what detailed activities some of the key steps entail.

Fact finding and observation

In order to make an impact to individuals' lives, understanding the target group is essential. Without this knowledge there is little hope of designing a behaviour change intervention that will be understood, that will resonate with the audience and will be implemented by the audience. Different research methods should be employed, amongst others, desk research into habits and attitudes, and socio-economic variables; qualitative interviews with members of the target group, preferably in their habitat; participative observation to understand current behaviour and barriers; and if time allows ethnographic research to develop in-depth understanding of the target group's social structures, environment and behaviours. It is essential here to get first-hand information by those involved in creating and designing interventions, in order to develop an intimate understanding of the target group.

Building insights

Assuming a wealth of information and observations has been obtained, this will serve as input to generate insights. An insight can be defined as 'a clear and penetrating understanding of a complex situation or problem[20], and specifically contains 'a possible explanation for what is going on in the observations – the 'why' behind people's actions and words, based on an emphatic understanding of the target group'. Insights that point to a common theme can be grouped into clusters, so called insight platforms (*Figure 2*).

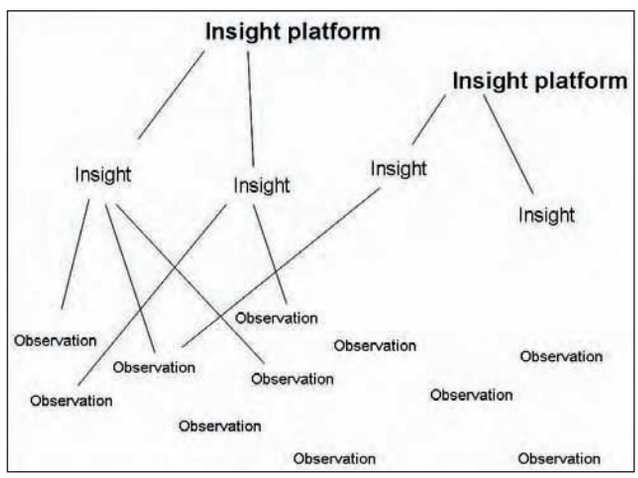

Figure 2. Ladder of observation – insight – insight platforms.

Insight platforms should act to inspire idea generation with the aim of reducing barriers and increasing benefits at a social, functional, emotional or sensorial level. In other words this should lead to ideas that ultimately become the building blocks of a new health campaign, or innovation aimed at changing behaviour.

Use of the working principles

The principles are based on concepts that stem directly from theories of behaviour change. For each platform, ideas will be generated utilising one principle at a time. In this way all principles will be used to create a wide range of potential solutions to initiate a behaviour change. Once completed, combinations of ideas based on individual principles can be made in order to create an intervention with 'maximum effect'.

Intervention design

So far, the route taken has been: Observations ⇒ Insights ⇒ Insight platforms, viewed through Principles ⇒ Intervention ideas. These ideas need to be worked up, using different creative routes via partners with different areas of expertise, e.g. marketing, advertisement agencies, health advisors, and professional bodies in the case of communication campaigns, or RandD design, and engineering in the case of products or technology.

In most cases however, these activities are conducted by mixed teams to maximise complementary strengths.

Three levels of intervention design (and technology)

Behavioural interventions can be considered at three different levels, at an individual level (micro), at cohesive group level (meso), or at mass level (macro). The obvious size difference between the groups at these different levels generates a different closeness between change agent and target, as well as a different level of understanding of the target. Therefore each level requires different approaches for change and provides different opportunities.

For example, at the micro level there exists a relationship between change agent and the target (similar to those found in individual therapeutic sessions). In a clinical dental setting this is often a dentist-patient relationship but in other settings this would be more like coach-trainee relationship (e.g. high performance coaching in a business environment, personal trainer in physical exercise etc). In these cases the relationship forms part of the intervention itself, whereas at the macro level this is completely absent. An intensity dimension also runs across the three levels (e.g. contact time, interaction, and content) with the intervention at micro level the most intense and at the macro level the least intense. Conversely, the size of the target touched by a single intervention is largest at the macro level. This section discusses three practical examples, one for each level.

Micro level: Personalised feedback

In the paper by Chapple and Hill[3] on personalised biofeedback the relationship between health professional and patient is discussed. The authors indicate that health education (in the context of patients suffering from periodontal disease) can be unsuccessful because adequate health behaviour requires specific skills from the patient (e.g. easy and difficult), and a participative style on behalf of the professional which supports empowerment of the patient (e.g. self and society, proof and reward). In fact the health professional has to operate on a tailor-made basis, understand when the patient is ready for change, and what is required to make changes. The interaction between patient and professional is a key enabler, i.e. feelings of respect, plus a coaching versus prescriptive style are deemed necessary to bring about lasting change.

Meso level: School programmes

Pine[21] discussed how schools can be an optimum place for behaviour change intervention (e.g. brushing twice a day with a fluoridated toothpaste) especially for those target groups where this behaviour is not established before school age. In the British Tayside study[22] and French Signaline study[21], both programmes went beyond mere education and involved parents and teachers in the intervention. It was found that those who brushed only once a day gained the largest benefit, providing evidence that these school programmes were highly successful. One can hypothesise that in fact two overlapping groups might have acted as different social contexts, i.e. family and school with the child being at the centre, to facilitate the new behaviour (*Figure 3*). Thereby utilising the principles of self and society (via social structures and systems) and easy and difficult (via skills).

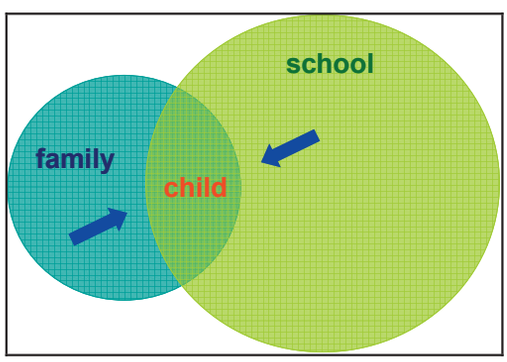

Figure 3. Overlapping groups working together.

Both family and school can be considered as a meso level of small cohesive groups. Aunger[14] suggested that the family unit should be the entry level for brushing teeth that is most successful in creating populations of 'regular tooth brushers', hence supporting the principle of participatory school programmes.

Macro level: Public health communication

Mass-media communication has been a widely used instrument for marketing activities (promotion) as well as social marketing by government agencies and non-profit organisations[23]. With a large reach potential it is a one-way form of informing and influencing but without dialogue (although most global brands have nowadays their own Internet-sites through which interaction can take place). Fast Moving Consumer Goods companies, like Unilever, mainly used the communication media to promote product benefits and to create brand awareness. A new trend however is to communicate about health or healthy options without necessarily talking about a product and its benefits. Examples are: helping consumers to make healthier choices by providing them with clear information (awareness and attitude, easy and difficult). This can be achieved by using a front-of-pack stamp to identify products that are in line with interna-

tionally accepted standards for healthy diets[24,25] (*Figure 4*). Or the 'Eat colour' campaign to encourage consumers to eat more vegetables. This approach is aligned with Unilever's Vitality mission which is 'to add vitality to life and to do this in a sustainable way'[26].

Figure 4. Choices logo used on selected food products.

Each of these levels of intervention (micro, meso, macro) provide different contexts with a range of opportunities for the use of technology to either measure or modify behaviour:

- Personalised biofeedback, in which the Oralinsights® system can be used[3]. This technology allows measurement of the motion (position and orientation) of the toothbrush in the mouth during brushing and the time spent brushing different areas – high tech, to measure and modify behaviour.
- School programme, print and video[21] (which in future might be interactive e.g. DVD) – low tech, to modify behaviour.
- Public health communication, the use of a Sensor brush (a tool to capture time and date of brushing events and their duration) – high tech, to measure behaviour.

The use of technologies like Oralinsights and Sensor brush forms part of the next section.

Technology to shape and measure behaviour

Changing tooth brushing behaviour using personalised feedback via Oralinsights®

The study reported here was conducted in collaboration with Liverpool University Dental Hospital (C. Pine, A. Gillett, G. Burnside). The aim was to determine the effect of an oral hygiene instruction (OHI) session using verbal and visual feedback from a toothbrush tracking device (prototype Oralinsights system), upon tooth brushing behaviour and plaque scores. The Oralinsights system has been described by Chapple and Hill[3].

Design

Seventeen adult volunteers in good general dental health and having at least 20 natural teeth participated in the study, using standard commercially available fluoride toothpaste and flat trim toothbrush as part of their normal oral hygiene routine throughout, both at home and at the study site.

Subjects attended the study site for baseline assessment, following a minimum of 12 hours since last brushing their teeth. Plaque scores were assessed using modified Quigley and Hein plaque index[27] and subjects were then asked to brush 'as they would do at home' but using the Oralinsights system. The system measured brushing time, defined as the time between the first and the last brushing stroke; contact brushing time, defined as the time that the toothbrush was actually in contact with the teeth and also identified areas in which the toothbrush spent the least amount of time. Data from Oralinsights were combined with post-brushing plaque score data to identify one or two distinct 'hotspot' areas for each subject individually. 'Hotspots' were defined as areas with low toothbrush dwell time and high plaque levels.

Subjects attended a subsequent OHI session with a dental hygienist. In this session they were given a brief description of dental plaque, verbal and visual feedback regarding their individual 'hotspots' and instruction on to how best to brush these areas. Subjects also received a personalised feedback chart to take home, clearly showing the 'hotspot' area (*Figure 5*).

The effect of the personalised OHI intervention in altering brushing behaviour and pre- and post-brushing plaque levels was measured at 1, 2, 6 and 12 weeks after the OHI intervention session. Subjects were recalled for assessment one year after the intervention. Two-tailed t-tests were used to compare the data generated at different visits.

Results

Out of the 17 subjects, 15 were female, 15 were right handed, and 16 had visited the dentist in the last year. Not all subjects attended all visits therefore some data were missing.

In total 27 sites were identified in the 17 subjects as areas for improvement. For some subjects several poorly brushed adjacent sites were combined to form one 'hotspot'. Each subject was allocated one or two 'hotspot' areas depending on baseline data. Predominantly the whole of the lower lingual area and the upper molar buccal areas were identified as poorly brushed with associated high post-brushing plaque scores. These sites accounted for 87% of the 'hotspot' areas.

Brushing time - Brushing times before intervention ranged from 24 to 190 seconds and after intervention (at 1 week) from 44 to 199 seconds. The overall brushing time increased by 28% from baseline following the OHI intervention and all subjects increased brushing time

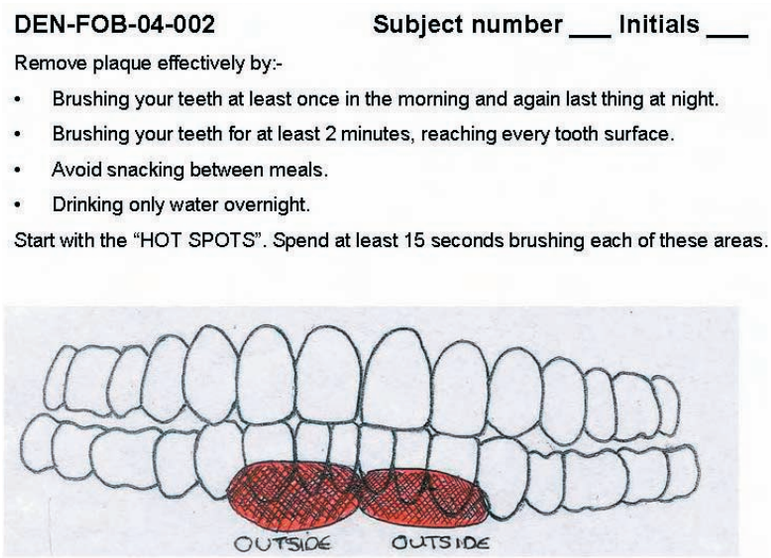

Figure 5. Individual feedback chart showing 'hotspot' areas.

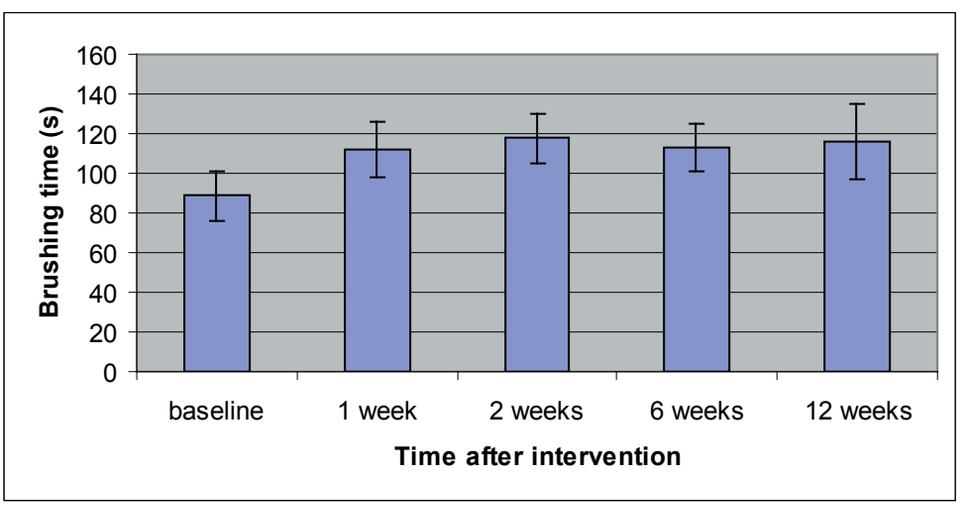

Figure 6. Mean brushing times.

(p<0.001, *Figure 6*) on at least three out of four visits. Overall, subjects spent significantly more time brushing the anterior teeth compared to posterior (p=0.002).

Contact brushing time - this was significantly lower than the overall brushing time (p<0.001). The contact brushing time increased significantly for the whole mouth at all visits following the intervention visit (1 week p=0.0088, 2 weeks p=0.0003, 6 weeks p=0.0003, 12 weeks p=0.0016). For 'hotspot 1' a significant increase in contact brushing time was observed at 2, 6 and 12 weeks (p=0.0038, p=0.0027, p=0.0035 respectively). A significant increase in contact brushing time was not noted for 'hotspot 2' except at the 2 week visit (p=0.0248) (*Figure 7*). Following intervention a larger increase in contact brushing time was noted for the mandibular teeth (26%) than for the maxillary (13%).

Overall for 'hotspot 1' a significant 3% increase in contact time was noted over the 12 week period (p=0.0048), but for 'hotspot 2' there was no significant difference from baseline (p=0.2135).

Plaque assessment

Pre-brushing plaque scores - The mean whole mouth baseline plaque score before intervention was 2.3 compared to 'hotspot 1' and 'hotspot 2' with scores of 3.6 and 3.3 respectively. All whole mouth pre-brushing mean plaque scores were significantly reduced at 1, 2, 6 (all p<0.001) and 12 weeks (p=0.007) following the intervention visit (*Figure 8*). Mean pre-brushing 'hotspot' scores were also significantly reduced at 1, 2, 6 and 12 weeks following the intervention visit (the largest p value was p=0.023 from all eight baseline comparisons for both 'hotspots' 1 and 2), (*Figure 8*).

Post-brushing plaque scores - All mean whole mouth post-brushing plaque scores were significantly reduced at 1, 2, 6 and 12 weeks (all p<0.001) following the in-

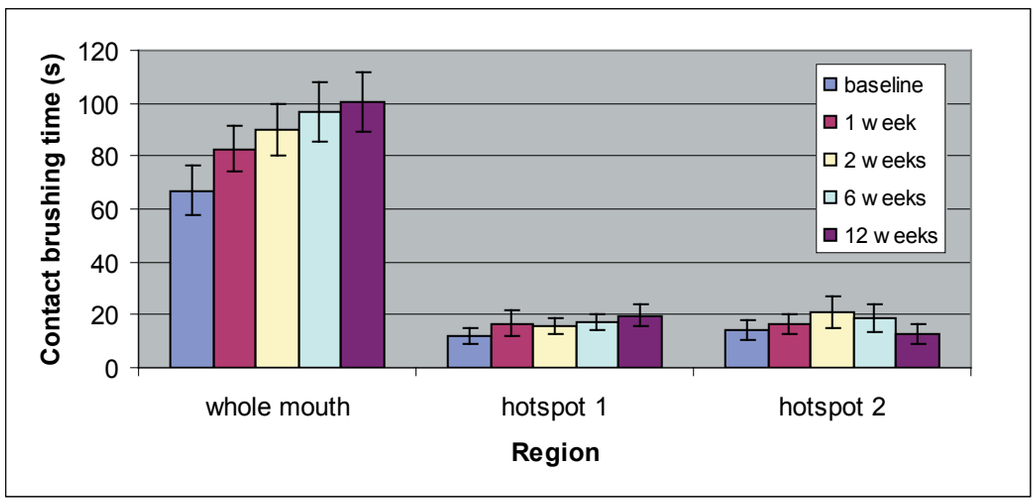

Figure 7. Mean contact brushing times.

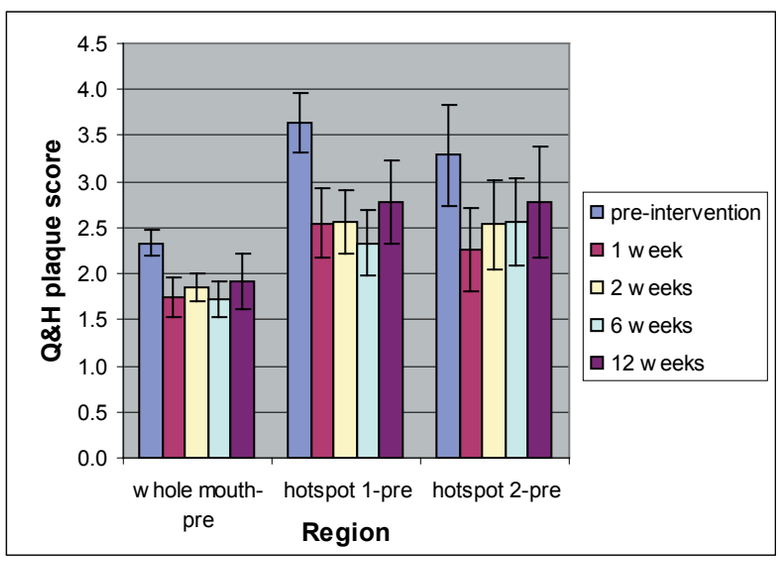

Figure 8. Pre-brushing plaque scores.

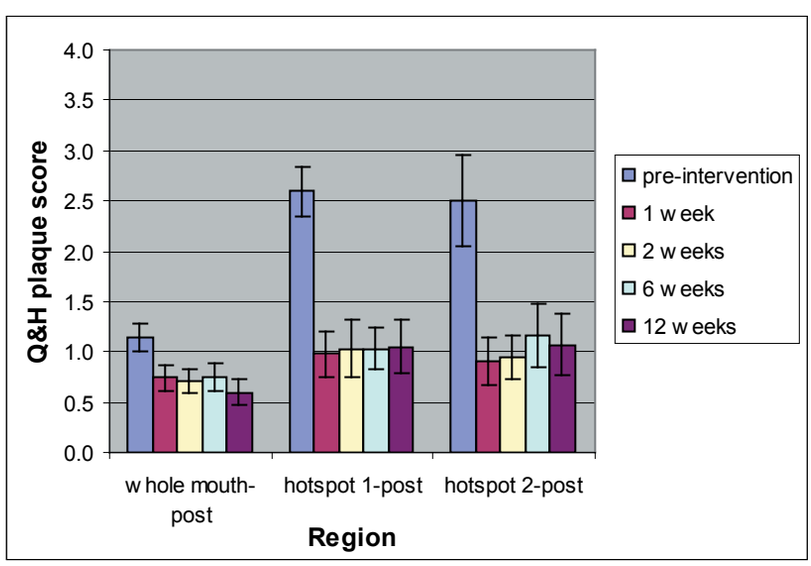

Figure 9. Post-brushing plaque scores.

tervention visit. Mean post-brushing 'hotspot' scores were also significantly reduced at all assessments up to 12 weeks following the intervention visit (the largest p value was p=0.003 from all eight baseline comparisons for both 'hotspots' 1 and 2), (*Figure 9*).

Data at 12 months - One year after the intervention, subjects were recalled and 8 attended for assessment. Brushing time and contact brushing time were not significantly different from baseline. However, plaque scores were significantly reduced compared to baseline: mean whole mouth plaque score pre-brushing was 1.6 ($p<0.001$) and decreased to 0.6 ($p=0.010$) post-brushing. A significant reduction in plaque score in comparison to baseline was also found in 'hotspot' 1 ($p=0.004$ pre-brushing; $p<0.001$ post-brushing), but there was no significant difference in plaque score for 'hotspot' 2.

Discussion and conclusions

For this group of subjects a wide range of brushing styles was observed and captured by the Oralinsights system. Brushing time recorded showed a wide range and is consistent with findings from previous studies where time has been measured using a stopwatch. The increase in brushing time seen over 12 weeks indicates a significant change in behaviour following the Oralinsights-based OHI intervention. The larger increase in brushing time seen for the mandible in comparison with the maxilla is likely due to 18 out of 27 'hotspot' sites being in the mandible, as it was shown that overall brushing times within the primary 'hotspot' area increased significantly following intervention.

Most importantly, the plaque data also indicated that the change in tooth brushing behaviour had resulted in improved plaque removal. Plaque scores after brushing were significantly lower both within whole mouth as well as 'hotspot' areas indicating improved brushing efficacy whilst under observation. Furthermore, at each visit following the intervention, plaque scores pre-brushing were significantly lower than at baseline, suggesting an improvement in habitual plaque removal outside the study sessions. This improvement was sustained up to one year after intervention. Greater improvements were observed in those subjects who were allocated only one 'hotspot', which seems logical as subjects only had to concentrate on one area.

In conclusion, a combination of verbal and visual feedback, based upon the Oralinsights system was found to effectively increase the length of brushing time within this group (through utilisation of information from Awareness and attitude, feedback from Proof and reward, and skills from Easy and difficult) and this change in behaviour significantly reduced plaque levels both pre- and post-brushing with sustained effects up to one year. Oralinsights® OHI system can provide the basis for an effective behaviour change intervention package for delivery to individuals and can also be used for continued monitoring of tooth brushing behaviour at subsequent visits.

Sensor brush (data logger) to measure tooth brushing behaviour

Self-report and observation have been widely used in medical, psychological and market research to understand behaviour. Both methods have disadvantages. For example, self-report can be skewed because of 'inaccurate introspection' by the individual or by simply not having access to one's own behaviour, and therefore providing an inexact description. Another disadvantage is that 'social desirability' might influence the individual's report of what he or she thinks the researcher would like to hear or see. This latter effect might play a role as well when the individual is being observed. In addition the Hawthorne effect[28], showed that people perform differently when taking part in a study. So the more the 'study feel' can be limited to normal circumstances and habits, the better.

In order to capture brushing behaviour of individuals without having to revert to self-report or observation a novel device has been developed, called the Sensor brush (*Figure 10*). The Sensor brush is a toothbrush with a compartment in the handle which contains a data logger (3-axial accelerometer, including memory and battery). This device responds to changes in movement which are used to record when a brushing event occurs (date and time) as well as the duration of the brushing event. The validity and reliability of this novel technology has been established in a number of studies[29], which all indicated that the Sensor brush correctly identifies time and date of brushing events, brushing duration, and does not influence brushing duration when compared to a standard marketed toothbrush. This tool helps to increase understanding of patient and consumer behaviours, and allows for more appropriate interventions and products to improve health.

Evaluating effectiveness of a public health communication to promote night brushing

In line with the recommendation to brush twice a day[2] and the knowledge that this behaviour is still not practiced widely on a large scale[30] the process for designing behaviour change interventions was used (as above). The objective here was to target people who were already brushing their teeth but mainly once, and to expand their brushing behaviour to a second time before bedtime. During this process the following insights were discovered: e.g. parents play different roles at different times of the day; parents are more inclined to 'give in battles' towards the end of the day (having had to fight quite a few throughout the day), this leads to tooth brushing 'falling off the agenda', and children copy their parents' behaviours (negative as well as positive ones).

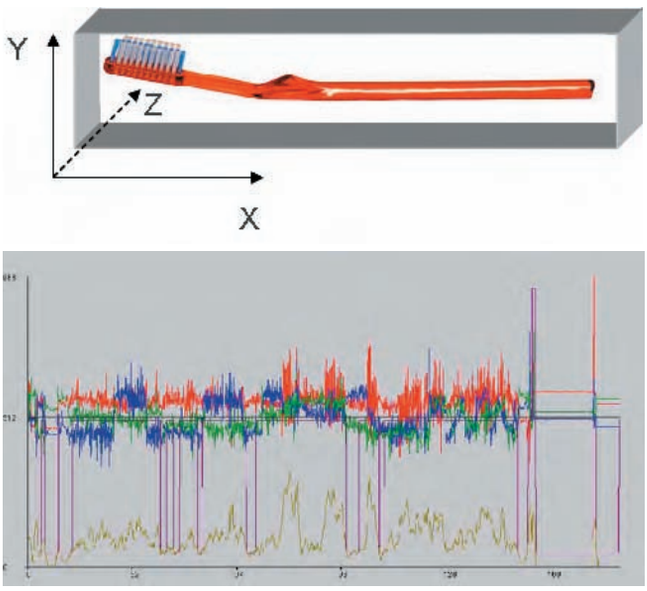

Figure 10. Sensor brush 3-axial measurement and signal.

Figure 11. Night brushing TVC screen shot.

As a result Unilever Oral Care developed a public health communication in the form of a television commercial. This advert utilised the following working principles: Awareness (via information), Self and society (via modelling), Easy and difficult (via skills and simplification). The central messages that were conveyed are:

- 'Children copy all sorts of habits from you -the parent- including late night snacking'
- Given this, 'You -the parent- can be an excellent role model'
- 'You can show your children that brushing your teeth before bed time is easy and not an ordeal'.

In this advert (*Figure 11*), attention was given to the following issues: late night snacking is something we all do, your children will copy you which is difficult to avoid, and brushing before bedtime is important to retain healthy teeth. It addresses that there is something very important that parents can do themselves, i.e. being a positive role model who brushes before bedtime and teaches this behaviour to their children. In addition, role modelling from parent to child is being suggested as an easy and enjoyable way of adopting new health behaviours.

In preview ratings of this advert people rated it very high in terms of liking, and indicated that their intentions to change their behaviour were high[31]. Despite these positive messages regarding the intentions, a crucial factor in the success of any behaviour change intervention is to measure whether actual behaviour has changed. Therefore a study was conducted in China (Xian, Jinzhou) in collaboration with Liverpool University Dental Hospital (C. Pine, G. Burnside) in 2007, with the aim of evaluating the effectiveness of this purposely designed public health communication.

Study design

A randomised controlled trial was conducted comparing a test and control group. The test group was shown the night brushing communication, whereas the control group received a general anti-caries advertisement. Subjects (families consisting of mother, father, and child) were visited in their homes and were shown the advert on their own TV using a DVD player. During each session the advert was shown twice. At the start of the study all those involved were given a questionnaire to capture brushing attitudes and behaviours; this was repeated at the end of the study. All subjects were given a personal colour-coded Sensor brush which replaced the brush they had used until the start of the study. The frequency of their brushing events was measured using the Sensor brush over a 3-week period, as follows:

Day 1-7:	baseline
Day 8:	ad exposure 1 (two repeated viewings of the commercial)
Day 8-14:	measurement 1
Day 15:	ad exposure 2 (two repeated viewings of the commercial)
Day 15-21:	measurement 2

Figure 12 shows the study schedule in more detail. Individuals were fully informed about the Sensor brush and its measurements upon completion of the study, at which point permission to use their data was sought.

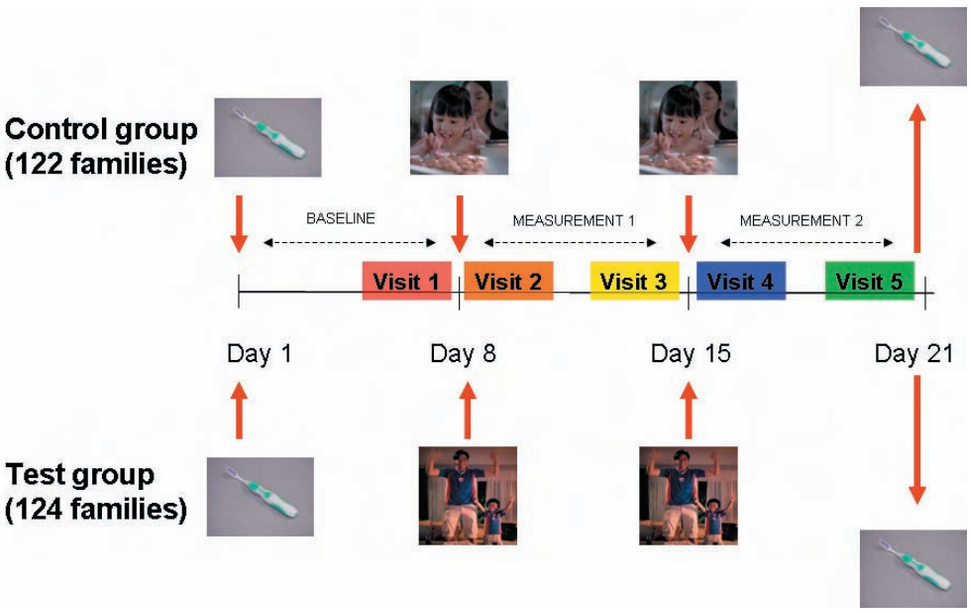

Figure 12. Overview of study design, schedule and visits (3-day clusters).

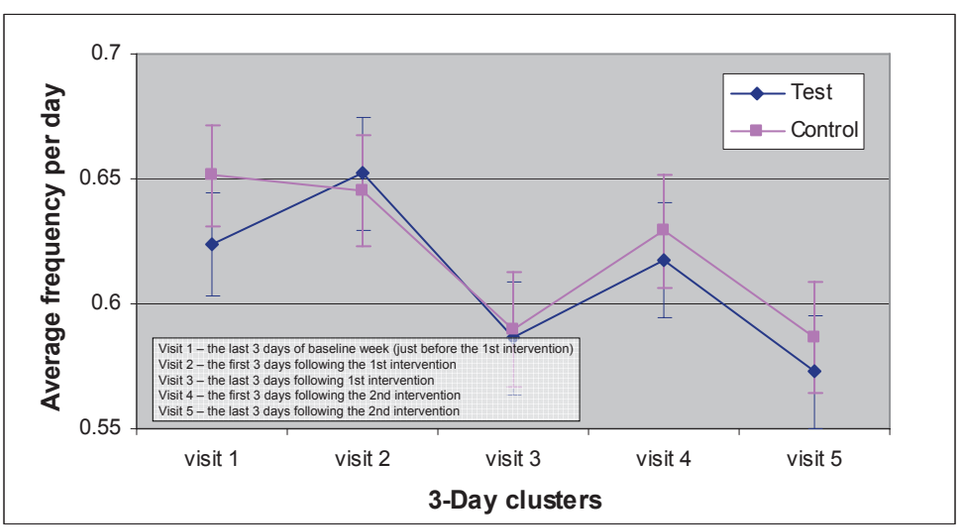

Figure 13. Morning brushing events.

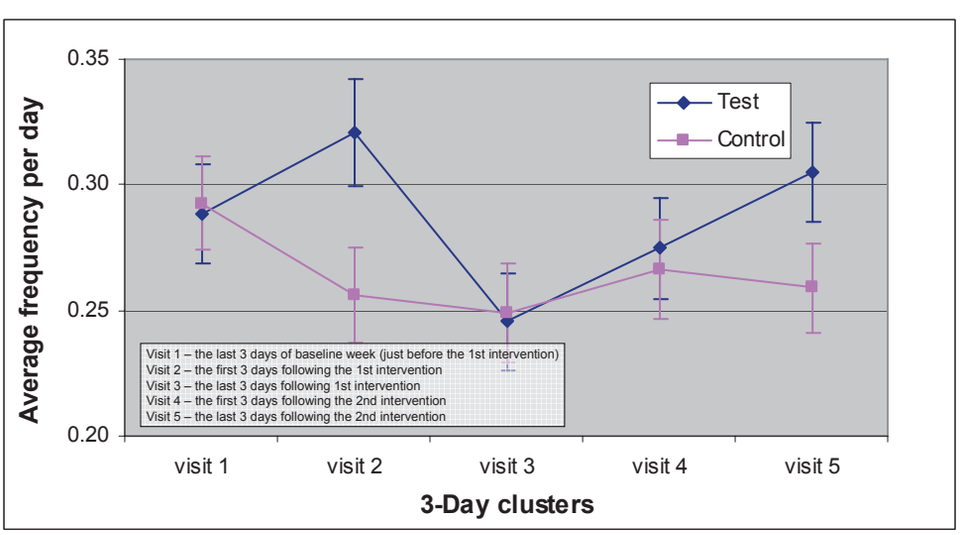

Figure 14. Evening brushing events.

At the end of the study Sensor brush data were downloaded, cleaned, filtered and converted into a matrix containing subject information, group and brushing frequency. This formed the basis for the analysis reported here.

Analysis

Brushing events were split into morning and evening brushing events (the latter defined as activity from 16.00 hrs onwards) and for each of these sets comparisons between test and control group were conducted separately. An overall analysis was performed looking at differences between test and control group before and after baseline. In addition a detailed analysis was conducted to compare three-day clusters just before and after the advert exposures, this to capture small fluctuations in behaviour in case this would have a more 'volatile' character. For example work by Tellis *et al.* [32] indicated that the effect of advertising rapidly decays within eight hours after viewing, in which case effects can only be detected shortly after exposure.

Results

Brushing frequency

The sample that took part in this study can be predominantly characterised as a 'once-a-day' brusher group as measured via the Sensor brush. During the 1st week (baseline) the ratio of brushing events for once versus twice a day was 3.4 : 1. However the ratio of once a day versus not brushing at all was 1.1 : 1. This indicates a 'patchy' behaviour, i.e. there were many occasions when subjects did not brush. The average frequency of brushing was 5-6 times per week, so approximately once-a-day. The questionnaire data at study start revealed a figure of 9.6 times per week as reported by the subjects, which equates to 1.4 times a day.

Intervention effect

An overall effect of sample time was found and both groups showed an increase in week 2 and 3 compared to baseline ($p<0.001$) with no difference between the groups. This effect is very likely to be a demand characteristic of the study. Although the control group received a non-behaviour change advertisement this was still an oral care related form of communication which might have prompted an awareness of oral care health behaviours and hence stimulated brushing action.

Analysis of 3-day clusters for brushing events in the morning and the evening indicated different results. The 3-day clusters were:

Visit 1 – the last 3 days of baseline week (just before the 1st intervention)
Visit 2 – the first 3 days following the 1st intervention
Visit 3 – the last 3 days following 1st intervention
Visit 4 – the first 3 days following the 2nd intervention
Visit 5 – the last 3 days following the 2nd intervention.

Figures 13 and *14* depict the average brushing frequency per day for morning and evening events respectively. There were no significant differences found between test and control group for the brushing events in the morning. In addition, there was no overall effect between the two groups in the evening. Looking in more detail however, there was a significant difference for the test group showing a higher frequency following the 1st intervention at 'visit 2' ($p<0.05$). However this effect disappeared a few days later, at 'visit 3'. There was no effect following the 2nd intervention (at 'visit 4'), but instead the cluster at 'visit 5' showed a directional difference. It might have been that the communication message has an immediate effect but tails off and then reappears with a delay following repeated exposure.

Conclusions and discussion

In this study a behaviour change advertisement was compared against a standard oral care advertisement measuring actual behaviour using a Sensor brush. The baseline measurement using the Sensor brush revealed a difference between self-report statements and actual brushing behaviour; these were 9.6 versus 5.5 times per week respectively. Findings reported by Zhu *et al.*[33] from a study conducted in urban China indicated a frequency across their sample of 10 times per week which is in line with the self-report data in the study reported here. The discrepancies found between the two independent questionnaire data on one hand and the Sensor brush data on the other, might be due to the self-report nature of the questionnaire methods.

Although only a small and short-lived effect on night brushing activity was found, this result should be considered as very promising. Only the brushing events in the evening were affected in the test group, and both groups showed a similar pattern for the morning events. This suggests that only night brushing was affected which formed a key message in the television advertisement shown to the test group.

The fact that there were no substantial differences found between the groups might be due to a limited exposure (two viewings at two occasions which equals to 120 seconds in total). Changing behaviour following such a short message would be highly desirable but unlikely. It would have been interesting to see what would have happened had exposure continued, as Agha[34] has indicated that higher exposure intensity in an AIDS prevention campaign led to a more positive outcome. Another relevant factor might be that both groups were exposed to oral care commercials which might have 'favoured' the control group.

The fact that a small but positive effect was found is in line with a review by Noar[35] who concluded in 2006

that *"…health mass media campaigns can have small-to-moderate effects not only on health knowledge, beliefs, and attitudes, but on behaviors as well, which can translate into major public health impact given the wide reach of mass media"*. Further research should therefore continue in this area and consider exposure, combinations of TV communication with other communication channels for maximum effect, and explore social diffusion of health messages into populations[36], a mechanism that requires sufficient time to understand its longer term effects.

General conclusions

In this paper the focus has not been on the 'why' but predominantly on the 'how' of designing behaviour change interventions. In summary, an approach has been outlined that is based on theory and utilises principles of behaviour change in an eclectic and pragmatic way. Different levels of description have been introduced that can act as a guide when designing interventions, and can help defining the type of intervention required. The use of technology, to measure and change behaviour, is needed as much as a thorough understanding of behaviour. Understanding behaviour is a prerequisite for the design of interventions and measurement of behaviour using unobtrusive technology in field contributes to insight into the real behaviour as opposed to observed or self-reported behaviour. This ultimately will help designing interventions that can make a difference to oral health and hygiene for a wide variety of target audiences around the world.

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