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Attitudes to fluorosis and dental caries by a response latency method

D. M. Williams[1], I. G. Chestnutt[1], P. D. Bennett[2], K. Hood[3], R. Lowe[2] and P. Heard[2]

[1]Department of Dental Health and Biological Sciences, Wales College of Medicine, Cardiff University, Cardiff, [2]Department of Psychology, University of Wales Swansea, Swansea, UK, [3]Department of General Practice, Wales College of Medicine, Cardiff University, Cardiff, UK

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Abstract – *Background:* Understanding socially relevant attitudes to fluorosis and dental caries is important. Previous studies have concentrated mainly on aesthetic implications. *Aims:* To investigate social judgements beyond the aesthetic, made when viewing digitally manipulated extraoral images of dental fluorosis of varying degrees of severity and images of dental caries. *Methodology:* Using a response latency technique, which allowed both the direction and strength of attitudes to be measured, 40 volunteers made judgements on 144 image/characteristic combinations. *Results:* Participants made social judgements which extended beyond the aesthetic to factors such as sociability, reliability and cleanliness. Judgements on mild fluorosis were not markedly different from those made about the same individual with normal enamel, but severe fluorosis had a significant negative impact on social judgements. Untreated dental caries was judged less favourably than normal enamel and mild fluorosis. *Conclusions:* Attribution of characteristics that go beyond the aesthetic are significantly influenced by altered tooth appearance.

Key words: attitudes; dental caries; fluorosis; psychological measures

Dr I.G. Chestnutt, Dental Health and Biological Sciences, Wales College of Medicine, Dental School, Heath Park, Cardiff, CF14 4XY, UK
Tel: 029 2074 6680
Fax: 029 2074 6489
e-mail: chestnuttig@cardiff.ac.uk

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Debate on the role of fluoride as a caries preventive agent must take into account dental fluorosis as a potential drawback and establishing the public's perception of fluorosis is important (1). While severe fluorosis, involving staining and pitting of the teeth, is generally perceived as unattractive and requiring treatment (2), the degree to which milder levels of fluorosis cause concern is uncertain. Indeed, the increased whiteness associated with mild fluorosis may even be considered attractive (3–5). Evidence suggests that dentists and epidemiologists are more sensitive to the aesthetic impact of fluorosis than lay people (6–8). To date, the majority of research has focused on the aesthetic impact of dental fluorosis. While lay observers thought that children with fluorosis were uncaring of their teeth (9), the wider impact of fluorosis has not been investigated.

In addition to perceptions associated with attractiveness, fluorosis may also trigger the attribution of other characteristics. The psychological literature recognizes that attributes linked to appearance and disfigurement go beyond the aesthetic. Rumsey (10) noted that individuals whose appearance deviates from the norm are at greater risk of rejection and being negatively stereotyped, and even minor disfigurement may lead to negative personal appraisals and ridicule (11). A preliminary study has suggested that when viewing photographs of fluorosis, members of the public attributed traits and characteristics such as intelligence, cleanliness and sociability, dependent on the severity of fluorosis (12). However, attributing personal characteristics to other people through explicit and evident judgements is subject to bias. In explicit measurement of attitude, raters

are aware that their attitude is being measured and they may therefore be reluctant to express their actual feelings for fear of seeming rude or impolite. This can be overcome by using an implicit attitudinal measure, whereby the participant is unaware that his/her reaction is being measured.

Response latency provides an implicit measure of attitude strength (13, 14). In this technique, participants are presented with an image on a computer screen. The image is then replaced by a descriptor. The participant is asked to press a 'yes' or 'no' key to indicate if, in their view, the descriptor describes the image – an explicit measure. Unknown to the participant, the time taken to press the response key is also recorded – an implicit measure. Quicker responses are held to indicate greater attitude strength (13, 15). Similar techniques have been widely used in the field of psychology, to measure strength of attitudes in areas such a racial prejudice (16–18).

A 1999 workshop on collaborative research on fluoride (19), suggested that photographs would be useful in reducing variability and ensuring consistency across methods and scores when investigating fluorosis. Using standardized digitally manipulated images, this study aimed, using a response latency technique, to assess attitudes of lay observers to dental fluorosis of varying degrees of severity and untreated dental caries, these conditions being simulated within the same faces. There were two hypotheses. First, that increasingly severe fluorosis would attract more negative judgements. Secondly, that participants would make quicker negative responses to photographs with increasingly severe fluorosis (and slower positive judgements) than they would to the same individual pictured with normal dental enamel. That is, participants would evidence stronger negative stereotyping about people with fluorosis than those with a normal dentition. Images of the stimulus individuals with untreated dental caries were included to allow comparison with fluorosis.

Materials and methods

Participants

The images were rated by 40 volunteers, aged 18–34 years, recruited via e-mail. Participants were blinded to the fact that the study concerned dentistry and experiments were conducted in a neutral venue outside the Dental School.

Materials

Images

The study stimuli comprised 12 life-size extraoral images of smiling faces with teeth exposed.[1] Of these, eight target images comprised a male or female face, either with normal enamel or digitally manipulated to simulate either mild or severe fluorosis (20) or untreated dental caries. Thus images were produced which varied only in the appearance of the teeth, i.e. tooth shape, form and all extraoral features were identical, within the two faces used. Filler stimuli comprised unaltered pictures of four different faces (two males and two females), photographed under identical conditions to the target images. The original photographs of volunteers, unconnected with or unknown to the student participants, were taken using a Fujifilm Finepix S1 Pro camera (Fujifilm, Tokyo, Japan), a Nikon Macro Speedlight SB-29, and an AF Micro Nikkor 105 mm lens (Nikon, Tokyo, Japan). Digital manipulation was conducted using Adobe PhotoShop version 6.

Characteristics

Participants were asked to assess 18 characteristics (nine positive and nine negative) identified as being relevant to fluorosis in a previous study (12). The characteristics which represented polar opposites of nine themes comprised: attractive, unattractive; careful, careless; clean, dirty; happy, unhappy; healthy, unhealthy; intelligent, unintelligent; kind, unkind; reliable, unreliable; sociable and unsociable.

Hardware

Images were displayed on a laptop computer (Dell Notebook Inspiron 8200: Dell Europe, Bracknell, UK), the liquid crystal display screen of which had a diagonal size of 382 mm and a screen resolution of 1600 × 1200 pixels with a 60-Hz refresh rate. The laptop was placed on its side so that the monitor could display the faces in portrait view. Participants used a Cedrus 6-key serial response box RB-610 (Cedrus, San Pedro, CA, USA) to record their responses.

Software

Response latency was measured using Cedrus SuperLab Pro 2.01 (Cedrus), running on Microsoft Windows XP Pro operating system. This software

[1]Copies of the images are available from the corresponding author

displays stimuli at programmed intervals and for programmed durations and also records responses made by the user, in terms of the length of time taken by respondents to depress the key following display of the stimulus, and which key on the response box is selected. In this way it was possible to record whether each participant felt a stimulus word applied to a stimulus picture (by pressing a 'yes' or 'no' key) as well as the speed of their decision (from which the strength of their evaluation could be inferred).

Procedure

Participants' responses were measured over 432 stimulus presentations, of which 144 related to 'target' images and 288 'filler' images. Thus, participants were asked to rate eight target images – four of the same male and four of the same female. These images comprised life-size extraoral photographs, in which the subjects smiled to expose the teeth. The images were identical except for the appearance of the teeth which showed either normal enamel or had been digitally manipulated to simulate mild or severe fluorosis or dental caries. Each image was rated on the 18 characteristics described above. In addition to the target images, four 'filler' images were rated. These comprised four additional extraoral images of individuals with normal enamel and were included to prevent undue emphasis on the target faces, and thus avoid motivating the participants to deliberately look for variations. Again, each image was followed by presentation of the 18 characteristics which followed the target faces. As is convention in response latency studies, the filler images were not subject to analysis.

Explicit and implicit attitudes to the image/characteristic combinations were assessed as follows. The images were displayed on the computer screen for 2000 ms. The screen then remained blank for 500 ms, except for an orientation cross used to direct participants' attention for the next trial step, when the cross was replaced by one of the 18 characteristic words. Participants pressed either a 'yes' or 'no' key on the response box to indicate whether or not they thought the characteristic described the face. The time the participant took to respond (in milliseconds) was recorded as was the participant's decision (i.e. whether the 'yes' or 'no' key was depressed).

Following 20 practice trials comprising images and characteristics not used in the main study, the participants rated the images. The order in which the images were displayed was randomly generated by the software. It took each participant approximately 1 h to complete the study.

Data analyses

The study data comprised a binary response (whether or not the characteristic applied to the face), and the decisional response latency (time taken to respond). The analysis involved a two-level logistic regression to assess response direction, and a two-level linear regression to explore response latency. Within subject factors (level 1) were: characteristic valence (whether the characteristic viewed was positive or negative in meaning), dental appearance, descriptive theme (i.e. a theme consisted of polar-opposite pairs of characteristic words, e.g. responses to attractive and unattractive were analysed in the same regression), response latency (linear regression only), response direction, and gender of image. Between subject factors (level 2) were, participant gender, and participant age. In the logistic regression the dependant variable was the likelihood of a 'yes' response. The linear regression model was designed to compare the latency of responses to each dental appearance with normal enamel, response times having been transformed to normality using ($\log_{10}$) transformation.

In line with convention (16, 21), responses below 300 ms were discarded as being too rapid to be meaningful and those in excess of 10 000 ms were excluded as outside an acceptable response time (e.g. participant lost concentration). In total, <0.1% of 18 080 responses were discarded on this basis. The responses to the filler images were also removed prior to analysis. The study was approved by the South East Wales Research Ethics Committee.

Results

Attribution of characteristics (explicit measure)

The percentage of 'yes' responses to each characteristic, indicating the *valence* of the attitude, relating to different dental appearances is shown in Table 1. From this, it can be observed that while in response to images where the teeth displayed normal enamel or mild fluorosis, 78.8% and 76.3% of respondents pressed the 'yes' key when presented with the characteristic 'careful' (i.e. they agreed that this characteristic described the image), just

23.8% and 37.5% pressed the 'yes' key when shown images of severe fluorosis and untreated dental caries respectively. The data in Table 1 suggest that while minimal differences were apparent between normal enamel and mild fluorosis, a different pattern of responses were made to severe fluorosis and dental caries. Table 2 summarizes the logistic regression conducted on the entire data set, where the dependent variable was the likelihood of a 'yes' response. This shows that the main effects of characteristic valence (i.e. positive or negative in meaning), the different dental appearances and the interaction between them was significant. That is, participants were significantly least likely to give a 'yes' response to a positive characteristic when viewing dental caries (OR 0.03) and severe fluorosis (OR 0.01), the latter showing the lowest likelihood of a 'yes' response. The logistic regression was used to create a prediction table, (Table 3). This shows that normal enamel and mild fluorosis had a very similar percentage of 'yes' responses to positive characteristics (88% and 85% respectively) and that severe fluorosis was most likely to be attributed with negative characteristics (45%). Logistic regressions were also conducted on individual descriptive themes (data not shown) and participants' judgements on the attributes of attractiveness, carefulness, cleanliness, intelligence, reliability and sociability all showed a significant trend ($P < 0.001$) for severe fluorosis and dental caries to be judged less favourably than mild fluorosis or normal enamel.

Table 1. Percentage of 'yes' responses to each characteristic by dental appearance

Characteristic	*n*	Normal enamel	Mild fluorosis	Severe fluorosis	Dental caries
Attractive	320	61.3	63.8	11.3	31.3
Unattractive	320	21.3	35.0	71.3	63.8
Careful	320	78.8	76.3	23.8	37.5
Careless	318	21.5	19.0	55.0	51.3
Clean	319	83.8	83.8	18.8	32.9
Dirty	319	13.8	8.8	72.5	59.5
Happy	320	90.0	87.5	68.8	76.3
Unhappy	319	7.6	3.8	23.8	12.5
Healthy	319	87.5	86.3	26.3	39.2
Unhealthy	320	12.5	12.5	66.3	46.3
Intelligent	320	85.0	72.5	43.8	51.3
Unintelligent	318	11.3	14.1	36.3	21.3
Kind	320	92.5	88.8	75.0	77.5
Unkind	318	6.3	7.5	9.0	8.8
Reliable	319	87.5	78.8	39.2	58.8
Unreliable	317	8.8	10.3	41.8	23.8
Social	320	86.3	87.5	52.5	67.5
Unsocial	320	1.3	7.5	35.0	17.5

The remaining percentage are 'no' responses.
n varies because of the exclusion of outliers (see text).

Response latency (implicit measure)

Descriptive statistics of the untransformed response latencies, which measured the *strength* of attitude regardless of its valence, for the entire data set are shown in Table 4. So by way of example and

Table 3. Prediction table for likelihood of a 'yes' response to positive and negative characteristics by dental appearance

	Percentage likelihood of a 'yes' response	
Dental appearance	Positive characteristics	Negative characteristics
Normal enamel	88	8
Mild fluorosis	85	10
Severe fluorosis	37	45
Dental caries	52	30

Table 2. Two-level logistic regression model of response direction for all characteristics

	Odds ratio (95% confidence interval)	Significance (*P*-value)
Valence of characteristic[a]	79.76 (39.62–160.57)	<0.001
Dental appearance		
Normal enamel	1[b] (R)	<0.001
Mild fluorosis	1.17 (0.84–1.65)	
Dental caries	4.92 (3.63–6.68)	
Severe fluorosis	9.03 (6.66–12.23)	
Valence of characteristic * dental appearance		
Normal enamel	1[b] (R)	<0.001
Mild fluorosis	0.66 (0.42–1.05)	
Dental caries	0.03 (0.02–0.05)	
Severe fluorosis	0.01 (0.01–0.01)	

[a]Valence means whether the characteristic is positive or negative in meaning (e.g. clean = positive valence, unclean = negative valence).
[b]Normal enamel is the reference category.

Table 4. Response latencies (milliseconds), by dental appearance for all characteristics combined

Valence of characteristic	Response direction	Normal enamel		Mild fluorosis		Severe fluorosis		Dental caries	
		Median	Range	Median	Range	Median	Range	Median	Range
Positive	Yes	1001	341–7631	1012	350–6259	1342	490–9884	1291	501–9904
	No	1387	521–6570	1292	521–7361	1132	520–5848	1182	491–9244
Negative	Yes	1622	350–6710	1583	561–6769	1282	531–8682	1241	420–5929
	No	1102	350–7241	1132	451–7561	1312	430–8823	1202	490–8232

Table 5. Two-level linear regression model showing the differences in response latency for all characteristics combined

	Coefficient (95% confidence interval)	Significance (*P*-value)
Dental appearance		
Normal enamel	0[a] (R)	<0.001
Mild fluorosis	0.007 (−0.014, 0.028)	
Dental caries	0.036 (0.014, 0.060)	
Severe fluorosis	0.073 (0.049, 0.097)	
Response direction[b]	0.137 (0.092, 0.181)	<0.001
Valence of characteristic[c]	0.058 (0.020, 0.096)	<0.01
Valence of characteristic * response direction	−0.233 (−0.292, −0.175)	<0.001
Dental appearance * valence of characteristic		
Normal enamel	0[a] (R)	ns
Mild fluorosis	−0.008 (−0.060, 0.043)	
Dental caries	−0.048 (−0.095, −0.002)	
Severe fluorosis	−0.111 (−0.016, −0.065)	
Dental appearance * response direction		
Normal enamel	0[a] (R)	<0.01
Mild fluorosis	−0.024 (−0.085, 0.036)	
Dental caries	−0.128 (−0.181, −0.075)	
Severe fluorosis	−0.143 (−0.195, −0.090)	
Dental appearance * valence of characteristic * response direction		
Normal enamel	0[a] (R)	<0.001
Mild fluorosis	0.038 (−0.042, 0.118)	
Dental caries	0.229 (0.158, 0.300)	
Severe fluorosis	0.277 (0.206, 0.348)	

[a]Normal enamel is the reference category.
[b]Response means whether the participant pressed the 'yes' or 'no' key when linking the characteristic to the image.
[c]Valence means whether the characteristic is positive or negative in meaning (e.g. clean = positive valence, unclean = negative valence).

to help in interpretation, the median response time to press the 'yes' key in response to a positive characteristic (such as careful) when viewing normal enamel was 1001 ms, compared with a median time of 1662 ms to press the 'yes' key when attributing a negative characteristic (such as careless) to the images displaying normal enamel. Conversely, the median time to reject a negative characteristic (i.e. press the 'no' key) when viewing normal enamel was 1102 ms. The response latency data were analysed using linear regression where the dependent variable was the transformed ($\log_{10}$) response latency (Table 5). The basic model of the linear regression shows response latencies for 'no' responses to negative words: for normal enamel, therefore, the value in this cell is 0 (Table 6). This shows that when judging faces with normal enamel, or with mild fluorosis, the fastest latencies −0.039 and −0.02, (i.e. the strongest attitudes) were for 'yes' responses to positive characteristics and the slowest responses, or weakest attitudes, related to the endorsement of negative characteristics, at 0.137 and 0.119 respectively. In contrast, when viewing images of severe fluorosis, the shortest response times where when rejecting positive characteristics (0.02). This means that the participants' felt strongly when rejecting positive descriptions of severe fluorosis. In contrast, their response times were longest when endorsing a positive characteristic to describe severe fluorosis, indica-

Table 6. Change in logged response latency (milliseconds) associated with dental appearance, valence of characteristic and response direction

Response direction[b]	Dental appearance by valence[a] of characteristic							
	Normal enamel		Mild fluorosis		Severe fluorosis		Dental caries	
	Negative	Positive	Negative	Positive	Negative	Positive	Negative	Positive
No	0	0.058	0.007	0.057	0.073	0.020	0.036	0.046
Yes	0.137	−0.039	0.119	−0.020	0.067	0.131	0.045	0.087

[a]Valence means whether the characteristic is positive or negative in meaning (e.g. clean = positive valence, unclean = negative valence).
[b]Response means whether the participant pressed the 'yes' or 'no' key when linking the characteristic to the image.

ting weaker opinions. This also held true when endorsing positive descriptions of dental caries where the logged response latency was 0.087 ms.

Discussion

The views of the public on the impact of fluorosis, in informing the debate on the merits of fluoride as a caries preventive agent are important. To date, this has focused almost exclusively on the cosmetic impact of fluorosis. This study has shown that the public are willing to ascribe characteristics and make personal judgements beyond the aesthetic when presented with images of fluorosis and untreated dental caries.

Previous studies investigating the aesthetic impact of fluorosis have used a number of different methods. These include asking lay people to rate the teeth of patients with fluorosis (6, 9), asking lay people to rate intraoral slides or photographs of fluorosis (3, 4, 22), and asking participants to compare computer-generated intraoral images of fluorosis and other dental conditions (5, 8).

While these techniques may be appropriate for consideration of aesthetics, they are inappropriate for consideration of wider social and psychological factors. The use of standardised extraoral images eliminated variability associated with factors such as varying facial features, physical attractiveness, height, weight, etcetera. In contrast to intra-oral images used in most previous studies of fluorosis, the use of extraoral images, showing the teeth in the context of a full face, more closely simulates the situation in a typical social interaction. In addition, the use of unaltered filler images, which are designed to prevent subjects deliberately searching for variations in the study-critical images, again better simulates conditions of everyday interaction.

We believe that this is the first study to apply an implicit response latency measure in dentistry. Our findings suggest that the participants' attitudes to mild fluorosis and the strength of these attitudes did not differ markedly from those held about normal dental enamel. In contrast, the techniques employed in this study showed that participants were much less favourably disposed to severe fluorosis or untreated dental caries. That is, they held both more negative attitudes (as judged by response direction) and held then more strongly (as judged by response latency), than they did to either no or mild fluorosis. These results could be interpreted to suggest that members of the public are more favourably predisposed to mild fluorosis than untreated dental caries. However, in this study, caries was presented as untreated cavitated lesions, with three interproximal lesions per subject and an area of decalcification at the cervical margin. A further study using images with simulated restorations, perhaps of varying quality, would counter the argument that most caries in anterior teeth is treated and may provide a more realistic representation of the outcome of dental caries.

A further consideration is the mechanism whereby the altered tooth appearance has resulted in the attribution of characteristics that go beyond the aesthetic. Whether this is the result of the direct influence of the altered appearance of the teeth, or whether this led to a more general appraisal of altered facial appearance is not possible to determine from this study. However, there is consistent evidence that attitudes towards individuals are constructed from, and based on, single salient characteristics of that individual (23). Accordingly, it is possible to hypothesize a direct effect of the appearance of teeth on the attitudes respondents expressed.

The study participants were students and hence not representative of the population in general. However, the images being rated were of people of similar age and therefore the resultant peer to peer

ratings are of value. A study involving a wider age range would be beneficial.

In conclusion, these findings provide evidence that participants made social judgements that extend beyond the aesthetic when viewing images of fluorosis and untreated dental caries. The judgements made about mild fluorosis were not different to those made about the same individual with normal dental enamel. However, severe fluorosis and, to slightly lesser degree, untreated dental caries, had a significant negative impact on social judgements over a range of characteristics. This was true both in terms of the direction of judgement (whether a person was or was not thought to possess a certain characteristic) and in the strength of the judgement as measured by the length of time taken to respond. Whether the negative stereotypes attributed are sufficiently strong to influence behaviour requires further investigation.

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