ABSTRACT

Background Uptake of colorectal cancer (CRC) screening in UK is less than 60%. Geodemographic typologies are useful in describing patterns of individual preventive health behaviour but little is known of their value in assessing uptake of CRC screening, or how this compares to traditional measures of area deprivation.

Methods We used data on CRC screening uptake in the South Central, South-East Coast and South-West England National Health Service regions in multilevel logistic regression to describe the effects of individual composition and contextual factors (area deprivation and geodemographic segments) on non-response to screening invitation. The relative impact of geodemographic segmentation and the index of multiple deprivation (IMD) 2007 was compared. The potential population impact of a targeted increase in uptake in specific geodemographic segments was examined.

Results About 88,891 eligible adults were invited to be screened from 2006 to 2008. Uptake rate was 57.3% (CI: 57.0–57.7) and was lower amongst younger persons, men, residents of more deprived areas and people in specific geodemographic segments. Age and gender were significant determinants of uptake and contextual factors explained an additional 3% of the variation. Geodemographic segmentation reduced this residual contextual variation in uptake more than the IMD 2007 (72% vs. 53% reduction). The three geodemographic types that best predicted non-response were characterized by both ethnic mix and a higher than average proportion of single pensioner households renting council properties. Achieving average uptake in the 2.3% of the study population in these geodemographic segments would only increase the total population uptake rate by 0.5% (57.3–57.8%).

Conclusion Variation in the CRC screening uptake in Southern England is principally explained by characteristics of individuals but contextual factors also have a small but significant effect. This effect is captured in greater detail by geodemographic segmentation than by IMD 2007. This information could be used to inform the design of interventions aiming to improve uptake.

Keywords colorectal cancer, geodemographics, multilevel model, screening

Background

Colorectal cancer (CRC) is the third most prevalent cancer and the second leading cause of cancer death in the UK. Of 30,000 new cases and 20,000 deaths each year in the UK, over 80% are in those aged 60 and over.

The UK National Screening Committee recommended the implementation of a national screening programme for...
colorectal cancer following results from randomized trials showing that screening with faecal occult blood testing (FOBt) results in a 16% reduction in the risk of death from CRC. The programme began by offering screening to 60–69 year olds in England and will be extended in 2010 to people up to age 75. Cost-effectiveness estimates underpinning the rationale for the programme have been based on uptake rates of about 60%. This has not been achieved in many parts of the country, particularly amongst men and minority ethnic groups. Suboptimal uptake in comparison with breast and cervical screening has been documented in other CRC programmes for example in the Netherlands. The response to invitations to attend for screening is governed by a number of individual and contextual factors. Certain individual characteristics such as age and gender show consistency across geographical settings in respect of how they specifically influence uptake of CRC screening. Individual socioeconomic deprivation is associated consistently with lower uptake of CRC screening. Lower uptake rates are also reported for minority ethnic populations even after adjustment for demographic variables and socioeconomic status. As these factors influence the individual response to CRC screening invitation, their distribution in populations might be expected to explain variations in uptake of screening between populations. Indeed, most previous evaluations of CRC screening have examined how individual characteristics explain variations in uptake but few have attempted to examine population-level factors such as those found to influence the uptake of breast and cervical cancer screening.

Studying population-level variation in uptake of CRC screening is a potentially useful way to assess variations in uptake because it recognizes contextual-level impacts such as local programme delivery practices, and also acts as a surrogate for unmeasured and unknown individual factors. One approach to studying population-level variation is the use of composite indices of area deprivation, such as the index of multiple deprivation (IMD). Area deprivation is clearly associated with uptake of most screening programmes but the relationship is complex and there is little evidence to suggest that targeting health promotion or education based on area deprivation increases uptake of screening.

An alternative approach to the study of context is geodemographic segmentation. Traditionally, in biomedical disciplines, the notion of segmentation has involved identifying subgroups within a population that may have similar individual- or area-level attributes such as age, gender and socioeconomic status. Geodemographic segmentation has extended this approach to include data on behaviours, beliefs, habits and preferences to provide a more robust understanding of subgroups within the population. It focuses on the distinctiveness of areas and potentially offers an improvement on the use of composite indices of area deprivation. Geodemographic segmentation systems use a range of carefully selected demographic and contextual indicator variables to classify small geographical areas by the predominant characteristics of the locality and its residents. A number of geodemographic segmentation systems are in use, including ACORN, MOSAIC, output area classification and people and places (P²) system. Most systems incorporate both census and non-census data, for example including information on house prices, unemployment, share ownership, product purchases and council tax band. It has been argued that the different combinations of these variables summarized as geodemographic segments provide an enhanced understanding of local conditions that is not routinely captured by traditional composite deprivation indices such as the IMD.

Geodemographic segmentation systems are increasingly being used in health settings to describe variations in health service use, design tailored interventions for specific groups in the population and assess the penetration of policy implementation. This trend is closely linked to the growing emphasis on social marketing principles and techniques, which are becoming key components of national public health policy to improve health and reduce health inequalities. The approach builds on private sector target marketing techniques and conceptualizes a social intervention (in this case screening), as a product being promoted and subsequently delivered to target customers in target locations. The proponents of social marketing techniques in health care argue that intelligence gleaned from the geodemographic segmentation of a population can be combined with other threads of social marketing, such as consumer insights and motivations, to establish robust consumer profiles. These profiles can in turn inform promotional activities aimed at enhancing the social acceptability of a health-care intervention amongst the target audience. Enhanced knowledge of the characteristics of the customer enables ‘smart’ targeting and, potentially, raised product uptake. The success of such social marketing in the context of screening will thus rely both on how well geodemographic segmentation systems can identify and quantify variations in the population characteristics associated with screening and their effectiveness in targeting health promotion campaigns, which are informed by such findings.

This paper aims to assess how the level of information that can be gained from geodemographic segmentation compares with the use of the IMD. More specifically the paper (i) investigates the contribution of both individual and
contextual factors to total variation in CRC screening uptake and (ii) compares the relative contributions of area deprivation and geodemographic segmentation to this variation.

**Methods**

Data on the uptake of colorectal cancer screening from 2006 to 2008 were obtained from the southern hub of the National Bowel Cancer Screening Programme and included data from the South-East Coast, South Central and South-West Strategic Health Authorities of England. This data set comprised 88,891 records with unique subject identifiers, age, gender, postcodes of residence and response to screening invitation.

Postcodes in the data set were linked to 2001 census lower super output areas (LSOAs) using the geocover online facility freely available to UK academics and thence to (i) continuous deprivation scores in the IMD 2007 and to (ii) the P² geodemographic segmentation system commercially available from Beacon Dodsworth.

P² was constructed using 2001 census data (age, household information, transport, education, employment, housing tenure, affluence and ethnicity) and other non-census information. Figure 1 shows how the UK and our study populations are relatively distributed across P² segments. P² was selected for analysis because it is freely available to the National Health Service and has been used in a number of health-related applications. Users include the North West Public Health Observatory. The construction of P² follows the general principles evident to all geodemographic segmentation systems and it serves as a general exemplar of their utility.

The linked data set was imported into MLwiN 2.10 Beta for multilevel analyses. To identify potential non-linear effects, four age categories (60–62, 63–65, 66–68 and 69–71) were created and continuous deprivation scores were converted to deprivation quartiles with deprivation worsening from quartile 1 through to 4 (Table 1).

**Multilevel analysis**

The multilevel structure of the data set comprised individuals (level 1; n = 88,891) nesting within LSOAs (level 2; n = 1412). We developed a two-level model with a binary outcome (‘non-response’ to invitation for CRC screening) for persons i living within LSOAs j. The likelihood of non-response was related to a number of categorical predictor variables (age, gender, deprivation and geodemographic segmentation type) as well as to a random effect for each of the two levels.

For gender, age and deprivation, we used female gender, age 60–62 and the ‘least deprived’ category, respectively, as the reference categories in the models. For the P² geodemographic segmentation, we used the modal Tree (‘mature oaks’) as the reference category. Thus, the reference category for the model was a 60–62-year-old woman living in a lowest quartile IMD LSOA with a ‘Mature Oaks’ P² tree type.

Analysis involved fitting five models. The intercept-only (null) model included no predictor variables and only described area (LSOA) components of variation in non-response to screening invitation. In Model 1, we included age and gender (individual-level variables) to adjust for age- and gender-related differences in non-response to screening invitation. Model 2 extended Model 1 by adding deprivation alone to age and gender; Model 3 added only...
geodemographic types whereas Model 4 added both deprivation and geodemographic type. This enabled us to assess multicollinearity and the relative importance of deprivation and geodemographic segmentation.

We computed the extra-binomial variation in the probability of non-response to a screening invitation between individuals within LSOAs as well as the level-two variance (variation across LSOAs). Measures of association (fixed effects) were expressed in the models as beta coefficients and standard errors, which were used to derive odds ratios (ORs) and 95% confidence intervals (CIs). Measures of variation (random effects) were expressed as the variance partition coefficient (VPC) and percentage change in variance from the intercept-only model for each subsequent model.

The VPC expresses the extent to which members of one LSOA resemble each other more than they resemble members of other LSOAs with respect to non-response to screening invitation. It is a useful indicator of how much of the variation in non-response to screening is explained by contextual factors. The latent variable approach described by Snijders and Bosker was used to estimate the VPC for the binary response multilevel model. A large VPC would suggest that differences in LSOA populations are responsible for a large part of the variation in non-response to screening invitation between persons in the study. Alternatively, a near-zero VPC would suggest that LSOA-level characteristics exert little effect on variations in non-response in the study population.

### Increasing uptake in low-uptake geodemographic groups

We examined what might be the consequence of using P² geodemographic segmentation to target efforts to increase uptake of CRC screening in our study population. To do this, we estimated the impact of increasing to the study population average the uptake rates in the three geodemographic trees with the lowest uptake rates, whilst keeping the rate in other trees unchanged. The effect of this increase on the total number of people taking up CRC screening was observed and a new population uptake rate under this scenario calculated (with 95% CIs).

### Results

The average uptake rate of bowel cancer screening invitation over the period was 57.3% (CI: 57.0–57.7) and women had a higher uptake rate than men (Table 2). There was a statistically significant trend for the uptake rate to increase with age ($\chi^2$ test for trend $P < 0.0001$) and to decrease with increasing deprivation ($\chi^2$ test for trend $P < 0.0001$).

### Multilevel models

The results of the multilevel modelling are shown in Table 3. The intercept-only model suggests there is significant variation in the likelihood of non-response to colorectal cancer screening invitation across LSOAs in the population studied ($\tau = 0.098$). The VPC indicates that about 3% of the total variation in the probability of non-response to CRC screening invitation is attributable to population-level factors. After accounting for individual-level characteristics, this variation remained unchanged (Model 1). Unexplained residual variation in non-response remained even after accounting for both individual and LSOA-level characteristics (Model 4).

From the proportional changes in variance estimated, it is observed that deprivation explained 53% of the variation at
the LSOA level and P² geodemographic segmentation explained 72% of the LSOA-level variation in uptake of CRC screening. Inspection of the reductions in LSOA-level variance reveals that the P² geodemographic segmentation achieves a greater variance reduction over the individual-only model than the IMD. Thus, it can be inferred that the set of contextual factors captured by P² geodemographic segmentation types (or ‘trees’) is more effective at capturing LSOA variation in non-response to CRC screening invitation than the IMD.

Figure 2 shows a plot of P² trees and predicted values (with 95% CIs) of their probability of non-response from Model 4. It suggests that individuals in segments described by the terms ‘urban challenge’, ‘disadvantaged households’ and ‘multicultural centres’ had the highest probabilities of non-response to CRC screening invitation. The probability of non-response was however significantly different from other segments (excluding the above three) only for ‘multicultural centres’, although the overlap of CIs amongst the three ‘trees’ is marginal partly due to the width of the CIs for the small population in those groups. There is significant overlap between the other ‘trees’ but with some indication of discrimination between high and low responding segments.

Gender, age and area deprivation as predictors of non-response
After adjusting for the effect of age (Table 3), men were more likely than women to fail to take up invitation to CRC screening (OR: 1.21; CI: 1.19–1.24). Addition of the population-level variables did not have any effect on the contribution of gender to non-response to CRC screening invitation.

Table 2 Uptake of screening by category of age, gender and deprivation

<table>
<thead>
<tr>
<th>Variables</th>
<th>Total invited (n)</th>
<th>Accepted</th>
<th>Did not respond</th>
<th>Percentage uptake (CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>44 999</td>
<td>26 839</td>
<td>18 160</td>
<td>59.6 (59.2–60.1)</td>
</tr>
<tr>
<td>Male</td>
<td>43 892</td>
<td>24 129</td>
<td>19 763</td>
<td>55.0 (54.5–55.4)</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60–62</td>
<td>16 341</td>
<td>9162</td>
<td>7179</td>
<td>56.1 (55.3–56.8)</td>
</tr>
<tr>
<td>63–65</td>
<td>19 207</td>
<td>10 871</td>
<td>8336</td>
<td>56.6 (55.9–57.3)</td>
</tr>
<tr>
<td>66–68</td>
<td>26 435</td>
<td>15 285</td>
<td>11 150</td>
<td>57.8 (57.2–58.4)</td>
</tr>
<tr>
<td>69–71</td>
<td>26 908</td>
<td>15 650</td>
<td>11 258</td>
<td>58.2 (57.6–58.8)</td>
</tr>
<tr>
<td><strong>Deprivation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Top imd</td>
<td>22 272</td>
<td>13 977</td>
<td>8295</td>
<td>62.8 (62.1–63.4)</td>
</tr>
<tr>
<td>Mid imd</td>
<td>22 204</td>
<td>13 422</td>
<td>8782</td>
<td>60.4 (59.8–61.1)</td>
</tr>
<tr>
<td>Bottom imd</td>
<td>22 250</td>
<td>12 771</td>
<td>9479</td>
<td>57.4 (56.7–58.0)</td>
</tr>
<tr>
<td>Worst imd</td>
<td>22 164</td>
<td>10 797</td>
<td>11 367</td>
<td>48.7 (48.1–49.4)</td>
</tr>
</tbody>
</table>

**P² geodemographic segmentation**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Total invited (n)</th>
<th>Accepted</th>
<th>Did not respond</th>
<th>Percentage uptake (CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mature oaks</td>
<td>17 289</td>
<td>11 015</td>
<td>6274</td>
<td>63.7 (63.3–64.1)</td>
</tr>
<tr>
<td>Country orchards</td>
<td>8155</td>
<td>4911</td>
<td>3244</td>
<td>60.2 (59.7–60.8)</td>
</tr>
<tr>
<td>Blossoming families</td>
<td>4448</td>
<td>2683</td>
<td>1765</td>
<td>60.3 (59.6–61.1)</td>
</tr>
<tr>
<td>Rooted households</td>
<td>15 305</td>
<td>9159</td>
<td>6146</td>
<td>59.8 (59.4–60.2)</td>
</tr>
<tr>
<td>Qualified metropolitanians</td>
<td>13 690</td>
<td>8137</td>
<td>5553</td>
<td>59.4 (59.0–59.9)</td>
</tr>
<tr>
<td>Senior neighbourhoods</td>
<td>1279</td>
<td>708</td>
<td>571</td>
<td>55.4 (54.0–56.7)</td>
</tr>
<tr>
<td>Suburban stability</td>
<td>13 998</td>
<td>7706</td>
<td>6292</td>
<td>55.1 (54.6–55.5)</td>
</tr>
<tr>
<td>New starters</td>
<td>3055</td>
<td>1394</td>
<td>1661</td>
<td>45.6 (44.7–46.5)</td>
</tr>
<tr>
<td>Multicultural centres</td>
<td>226</td>
<td>70</td>
<td>156</td>
<td>31.0 (27.9–34.0)</td>
</tr>
<tr>
<td>Urban producers</td>
<td>6720</td>
<td>3192</td>
<td>3528</td>
<td>47.5 (46.9–48.1)</td>
</tr>
<tr>
<td>Weathered communities</td>
<td>2868</td>
<td>1268</td>
<td>1600</td>
<td>44.2 (43.3–45.1)</td>
</tr>
<tr>
<td>Disadvantaged households</td>
<td>1232</td>
<td>488</td>
<td>744</td>
<td>39.6 (38.2–41.0)</td>
</tr>
<tr>
<td>Urban challenge</td>
<td>585</td>
<td>213</td>
<td>372</td>
<td>36.4 (34.4–38.4)</td>
</tr>
<tr>
<td>Total</td>
<td>88 891</td>
<td>50 968</td>
<td>37 923</td>
<td>57.3 (57.0–57.7)</td>
</tr>
</tbody>
</table>

*Forty-one persons with unclassified P² trees.*
Similarly, compared to people aged 60–62 years, after accounting for the effect of gender, older subjects were less likely to fail to attend for screening (OR: 0.92; CI: 0.88–0.96 for age group 69–71 years). Although subjects aged 69–71 years were more likely to accept screening invitations, their uptake was not significantly different from those aged 63–68 years. The addition of the population-level variables did not affect the contribution of age to non-response to CRC screening invitation.

Model 2 in Table 3 indicates that after controlling for the influences of gender and age, compared with the least deprived invitees in the population, people in more deprived LSOAs were less likely to take up screening invitation (OR: 1.83; CI: 1.78–1.89 for the most deprived quintile). There was also a significant trend for non-response to be more likely with increasing deprivation.

Collinearity of deprivation and geodemographic types
As shown in Table 3, when Pi geodemographic segmentation types were added to the gender–age deprivation model, the ORs for the deprivation categories were changed but the ORs for age and gender remained unchanged. Similarly, the exclusion of deprivation from the gender–age deprivation P2 model changed the ORs for the P2 categories. These changes in the ORs with the addition of P2 geodemographic type or...
exclusion of deprivation indicate the presence of some collinearity between those variables, suggesting that deprivation (measured by the IMD 2007) and geodemographic segmentation types, measure similar constructs. If the collinearity were perfect, both variables might be expected to explain LSOA variability in non-response to similar extents. However, as seen from a direct comparison of models adding P2 geodemographic type as the only population-level variable explains more variability in non-response than does the model adding deprivation as the only population-level variable.

**Geodemographic types associated with non-response**

Although there was no inherent ordering of the categories, the P2 geodemographic segments with the highest significant odds of non-response were identified. As shown in Table 4, people belonging to three P2 geodemographic types were most likely to fail to take up CRC screening invitation. Key demographic and neighbourhood characteristics of these segments are included in Table 5.

Table 4 shows that subjects in the three P2 geodemographic segments with the lowest uptake rates (n = 2043) represent just 2.3% of the study population. If the uptake rate in these P2 geodemographic segments were hypothetically increased to equal the rate for the study population (57.3%), there would be 400 more subjects in the study population taking up invitation for screening (difference of total 'new uptake' and total 'observed uptake' in Table 5).

For the study population, this would result in a non-significant increase of 0.5% in the uptake of CRC screening to 57.8% (CI: 57.5–58.1).

Using the same method, if targeting were based on gender, such that the uptake rate in men was increased to equal that in women, the wider study population uptake would increase by 2.3 to 59.6%.

**Discussion**

**Main findings of this study**

We have used a multilevel analytical framework in this study to demonstrate that in the absence of information on individual-level socioeconomic status, both area-level geodemographic segmentation and composite indices of deprivation can add explanatory power to age and gender in
explaining area variations in the uptake of CRC screening. We found that geodemographic segmentation of the population studied using the P² system was better than the IMD (2007) to the extent that it explained more of the variation in the uptake of CRC screening across LSOAs in the study population.

The multilevel models also suggest that the likelihood of failing to take up invitation for CRC screening in the study population increased with younger invitee age, male gender and, after controlling for age and gender, higher deprivation and belonging to specific P² geodemographic segments. P² geodemographic segments whose presence in a population predicted lower CRC screening uptake were characterized by a higher than average concentration of single pensioner households renting council or housing association properties and were principally of a broad ethnic mix. These are uncommon segments in the study population and a focus on them would offer only limited improvements to uptake.

**What is already known on this topic**

Individual attributes such as age, gender, ethnicity and individual socioeconomic status are known determinants of screening behaviour but little is known of the contextual variables that particularly influence CRC screening behaviour. When such variables have been studied,11 much focus has been on area deprivation but it is not clear that using area deprivation to target health education interventions aimed at changing screening behaviour is effective. There have been suggestions that geodemographic segmentation systems offer added value, through more detailed elucidation of social context.26

**What this study adds**

It has been suggested that the use of geodemographic segmentation systems, which supplement census level data with up-to-date demographic and lifestyle data, would give a finer resolution to investigations of the determinants of colorectal screening uptake.27 Our study is the first to explicitly employ a geodemographic segmentation system to describe the effects of individual composition and contextual factors on colorectal screening uptake. The geodemographic characteristics of subjects from segmentation types more likely to decline a screening invitation highlight specific personal and population attributes. This study has shown that geodemographic segmentation is more effective than a composite index of deprivation as a measure capturing contextual variation but also that internal discrimination between geodemographic segments can be limited.

**Limitations of this study**

There are important limitations of the analysis in this study. In a general sense, it must be recognized that the conclusions derive from an analysis of the P² geodemographic segmentation system. Other segmentation systems may behave differently, however, as noted earlier, geodemographic segmentation systems tend to be built in similar ways and P² serves as an exemplar. More specific limitations are 4-fold. First, the three geodemographic segments significantly associated with lower uptake of CRC screening in the study population are attributable to only a small proportion of the total population. Substantial improvements in screening uptake in these geodemographic segments may not therefore have a significant impact on total population uptake rates though the relative mortality benefit for people in these groups may be considerable. Second, the small size of the population-level effect in the study (VPC 3%) may relate to the fact that the invitees in the study population, who represent only 1% of the UK population aged 60–74, live within a region that lacks the extremes of contextual variability. Additionally, the small magnitude of the population effect may also point to screening uptake decisions being a consequence of the characteristics of individuals rather than places. To this end, a third and common limitation for studies of this nature is the absence of individual socioeconomic data on the study population; our analysis could not control for individual socioeconomic or other

<table>
<thead>
<tr>
<th>P² trees</th>
<th>Total in segment</th>
<th>Percentage of total population (88 891) in segment</th>
<th>Observed uptake (n)</th>
<th>New uptake (n)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>'Urban challenge'</td>
<td>585</td>
<td>0.66</td>
<td>213</td>
<td>335</td>
</tr>
<tr>
<td>'Disadvantaged households'</td>
<td>1232</td>
<td>1.39</td>
<td>488</td>
<td>706</td>
</tr>
<tr>
<td>'Multicultural centres'</td>
<td>226</td>
<td>0.25</td>
<td>70</td>
<td>130</td>
</tr>
<tr>
<td>Total</td>
<td>2043</td>
<td>2.30</td>
<td>771</td>
<td>1171</td>
</tr>
</tbody>
</table>

*aif uptake rate in segment was equal to average for population (i.e. 57.3%).
characteristics associated with uptake. Finally, a more con-
tceptual limitation in the analysis relates to the fact that the
characteristics of persons and the contexts in which they live
are tightly interrelated and these tight interrelationships
are often difficult to capture in quantitative studies such as this.

Implications for future research
Work is underway to investigate the potential of geodemo-
graphic segmentation for describing characteristics of
responders and non-responders in a target population with
greater contextual variation than those living in the area
covered by the southern hub. Further research will assess
the cost-effectiveness of health promotion interventions
designed using the information gleaned from geodemo-
graphic segmentation of non-responders to colorectal
screening invitation. Such interventions may, for example,
involve tailored invitations to screening or invitation delivery
in specific settings. Further research is also needed to under-
tand and target the significant gender differences in uptake.

Conclusion
We found significant variations between LSOAs in our study
population in the likelihood of non-response to CRC screen-
ing invitation. Younger age, higher area deprivation and
male gender were associated with a greater likelihood of
non-response to screening invitation. Age and gender did
not fully explain the variation in non-response to screening
invitation between LSOAs; geodemographic segmentation
added a small but significant amount of explanatory power.

People in LSOAs with a more diverse ethnic mix and
single pensioner households living in public rented flats
appeared to have a higher probability of failing to take up
invitation for colorectal screening in our study area. Further
work is needed to assess the full potential of this approach
in areas of the country with greater heterogeneity of social
and geodemographic context.

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