Some /l/s are darker than others: Accounting for variation in English /l/ with ultrasound tongue imaging

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1 Introduction

/l/-darkening is the process whereby /l/ is realised with a delayed and/or reduced tongue-tip gesture. It is generally stated that light [l] is found in onsets, e.g., *light, love*, and dark [ɫ] is found in codas, e.g., *dull, fall*. However, previous studies indicate that the situation is more complex than a simple onset/coda distinction, and that different dialects may exhibit different kinds of morphosyntactic sensitivity. Table 1 demonstrates this effect, which can be observed through tokens such as *helix* and *heal*-ing in American English 2. Two /l/s which are in the same position phonotactically may differ phonologically due to their morphological affiliation, with /l/ darkening before a stem-suffix boundary, but remaining light if the following vowel is in the same stem. However, the data in Table 1 are typically based on impressionistic transcription (Received Pronunciation; henceforth RP), judgement elicitation experiments (American English 3,[1]) or acoustic evidence (American English 2), all of which have proved difficult to interpret and may not be reliable for liquid consonants (Gick et al. 2006). Articulatory data are preferred for studies of liquids, but are missing for many dialects.

	light	*helix*	*heal-ing*	*heal it*	*heal*	
RP	[l]	[l]	[l]	[l]	[ɫ]	Cruttenden (2001)
Am. Eng. 1	[l]	[l]	[l]	[ɫ]	[ɫ]	Sproat and Fujimura (1993)
Am. Eng. 2	[l]	[l]	[ɫ]	[ɫ]	[ɫ]	Olive et al. (1993)
Am. Eng. 3	[l]	[ɫ]	[ɫ]	[ɫ]	[ɫ]	Hayes (2000)

Table 1: /l/-darkening in different morphosyntactic environments. Adapted from Bermúdez-Otero (2007).

This paper attempts to investigate the claims of variation in morphosyntactic sensitivity in varieties of English from an articulatory perspective, using ultrasound tongue imaging. The main aim of the paper is to investigate what determines the amount of darkening, as measured by articulatory criteria, that /l/ displays in different morphosyntactic environments in different dialects of English. Moreover, this paper hopes to address an ongoing debate in the literature over /l/ realisations: whether variability involves allophonic variation between light and dark variants, or whether realisations are on a purely gradient continuum of lightness and darkness.

2 Previous Interpretations of /l/-darkening

2.1 Categorical vs. Gradient Processes

Traditional accounts of English /l/-darkening posit two discrete allophones of light [l] and dark [ɫ] (Chomsky and Halle 1968). This is the approach taken in Hayes's (2000) Optimality Theoretic investigation of /l/-

[1]Dark [ɫ] in *helix* in American English 3 reflects an effect of stress, which is not relevant to the varieties discussed in this paper.

darkening judgement data, where 10 speakers of American English were asked to rank the acceptability of pronunciations of light and dark /l/s in several representative forms. Hayes uses the results to argue that acceptability judgements are determined by a variable grammar, and that any variation in /l/-darkening is entirely down to category mixture of discrete allophones. Although he acknowledges there may be low-level duration-driven effects, he argues that the main distributional facts reflect probabilistic application of variable, morphosyntactically sensitive, categorical phonological processes. However, the experiment design inherently elicits scalar responses in judgement, making it very difficult to distinguish between variability at the community level and variability at the individual level, particularly in production. This results in a vast overestimation of the role of categorical variation in the production of individuals. Hayes's account is also unable to control for the finding that duration variance is greater in some environments than others, e.g., phrase-final 'pre-boundary lengthening' (see Lehiste 1980:7).

The categorical nature of a light/dark distinction has been questioned, particularly by studies which focus on articulatory realisation. Sproat and Fujimura (1993) used X-ray microbeam technology to investigate /l/ realisation in 9 phonological contexts. The technology allowed them to monitor gestural phasing, and they found that in light [l]s the coronal gesture precedes the dorsal gesture, and in dark [ɫ]s the dorsal gesture precedes the coronal. However, they do not accept that such categories are the best way of characterising the variation found, and argue that darkening is gradient and is dependent on duration. The categorical-seeming nature of the relative phasing of the coronal and dorsal gestures, they argue, is simply a result of their alignment with the adjacent segments: the dorsal gesture is aligned with the vowel, and the coronal gesture is the consonantal one.

Yuan and Liberman (2009, 2011) also consider the effect of duration on the realisation of /l/ in their acoustic analysis of the SCOTUS tapes, based on over 20,000 tokens. Although they found a correlation between darkness and duration, this was for dark /l/s only. In fact, as pointed out by Bermúdez-Otero and Trousdale (2012), when inspecting Sproat and Fujimura's (1993:303) own plot, the same seems to be true of their data also. The bottom half of the plot shows /l/s which have a negative tip delay, where the coronal gesture has occurred before the dorsal one (i.e., a light [l]). The top half of the panel shows tokens in which the dorsal gesture precedes the coronal (i.e., a dark [ɫ]). Although the top half of the panel does seem to show a correlation between darkness and duration, the bottom half is more clustered together and shows no such pattern. This suggests an in-between situation: duration does seem to partly correlate with darkness, but cannot fully account for the variation found.

Lee-Kim et al. (2013) also argue that /l/ darkness is on a continuum, but reject the claim that duration solely accounts for /l/ realisation. They used ultrasound to study /l/ in three phonological contexts: /l/ as a part of a suffix (e.g., *flaw-less*), before a stem-suffix boundary (e.g., *cool-est*), and pre-consonantally (e.g., *cool headphones*). Using tongue-body lowering as the articulatory correlate of darkness, they found that /l/ is darkest in the pre-consonantal context, intermediately realised before the pre-boundary /l/, and lightest when part of a suffix. They assume that three categories cannot be a possibility, and thus conclude that darkness must be gradient, not categorical. They opt for an explanation where the morphological boundaries directly affect phonetic implementation. Note that this explanation violates the principle of morphology-free phonetics (Bermúdez-Otero 2010, 2013), the long-held fundamental assumption that morphology and phonetics do not share an interface. Moreover, it is not clear that we can make judgements of gradience or categoricity, based on just three phonological contexts. We need data from the entire spectrum of realisation possibilities in order to make such claims. To summarise thus far, the existing literature provides examples of analyses which tend toward one of two ways of looking at /l/-darkening: one approach underplays the role of categorical phonological variation and the other overestimates it. However, there are compelling arguments for both sides. This paper will attempt to investigate if there is a way of keeping the positive aspects of these analyses whilst overcoming their deficiencies. Is there an approach which can account for

both categorical and gradient effects?

2.2 A Modular Approach

In a modular approach, categorical phonology feeds gradient phonetics. The phonology computes general-isations over discrete features, whereas the phonetics assigns targets to surface feature configurations. The phonology itself is stratified with three levels: stem level, word level, and phrase level. This follows from the ideas behind the life cycle of phonological processes (Bermúdez-Otero 1999, 2011). Phonetically driven innovations enter the grammar as gradient phonetic rules. Later, they may become stabilised as categorical phonological processes at the phrase level. Analogical change results in the new phonological process climbing up to higher levels, which narrows the domain of application of the process. This explains why word-final prevocalic /l/s darken in Sproat and Fujimura's data in phrases such as *Beel equates the actors*. One might expect /l/ to resyllabify into the following syllable and remain light, concluding that /l/-darkening shows overapplication in this environment. However, a modular approach can explain this opacity through word-level darkening. For these speakers of American English, darkening has moved up to the word level, and /l/ darkens prior to resyllabification.

The life cycle also makes predictions about the relative position of diachronically related rules coexisting in the same synchronic system. The life cycle does not merely involve phonologisation, stabilisation and domain narrowing, but also includes rule scattering (Bermúdez-Otero 2013). When a new rule enters a higher component of the grammar, it does not completely stop its application at the lower level. In other words, innovative phonological rules do not replace the phonetic rules from which they emerge, but typically coexist with them. An example of this is present-day English palatalisation, as demonstrated in Zsiga's (1995) electropalatography (EPG) study. Zsiga looked at palatalisation of /s/ plus /j/ clusters, both across word boundaries e.g., *press you*) and within a word e.g., *confession*, (note that Chaucer's *confessioune* would have contained an /s + j/ cluster in Middle English). Zsiga's results show that, although some form of palatalisation is present in both contexts, the articulators are not doing the same thing in *confession* as *press you*. Word-internally, the EPG shows that the palate trace of the /s+j/ cluster is identical to a typical /ʃ/ in word such as *shoe*. However, when palatalisation occurs across word boundaries, the palate traces look identical to an /s/ and a /j/ articulated simultaneously. This is an example of rule scattering. Across word-boundaries /s/ + /j/ clusters produce a /ʃ/-like sound, even though the articulators are still moving towards their separate /s/ and /j/ targets, resulting in gradient palatalisation by gestural overlap. Word-internally, however, the process has been stabilised, giving categorical palatalisation by featural change. Crucially, the idea behind rule scattering is that the two exist in the same grammar.

Similarly, the process of /l/-darkening may show the cumulative effects of several cognate processes simultaneously overlaid in the grammar. Sproat and Fujimura's data provide evidence for rule scattering, and support the idea that the process of darkening originated as a gradient phonetic process which was sensitive to duration, but over time has been reanalysed by learners and phonologised as a duration-insensitive categorical process. This means that the original duration-sensitive gradient process of phonetic implementation coexists in the grammar on top of the newer morphosyntactically conditioned categorical process.

One final prediction made by the life cycle concerns the idea of lenition trajectories. Successive steps in a lenition trajectory give rise to a series of separate phonological rules entering the grammar one after the other. In the synchronic grammar, the older rules, effecting milder types of lenition, have narrower cyclic domains (i.e., apply at higher levels) than the younger rules, affecting more drastic types of lenition. Take present day post-vocalic /r/ in Standard British English as an example. The majority of dialects in England today are non-rhotic, that is, /r/ is not pronounced word-finally or before a consonant, as in (1). However, when word-final /r/ occurs before a vowel in the following word, it is retained although crucially lenited, as

in (2).

(1) *four pears* [fɔː pɛəz]

(2) *four apples* [fɔːɹ̝ æpl̩z]

This results in a three-way realisation of /r/ in present-day Standard British English, as in (3): word-initial consonantal /ɹ/, the word-final prevocalic lenited variant, and the vocalised variant. Lenition is word level, which exists at this higher level due to it being an older phonological process, and targets /r/ in the coda at the word level. The younger harsher process of complete vocalisation occurs at a lower level, and targets /r/s in the coda at the phrase level. An /r/ in a word such as *four* undergoes lenition at the word level first. In the next round, the /r/ in *four pears* is also in the coda at the phrase level, and is vocalised completely. The /r/ in *four apples*, however, is resyllabified into the onset and avoids complete vocalisation, although lenition has already occurred in the previous cycle.

(3) ɹ >$_{reduction}$ ɹ̝ >$_{deletion}$ Ø

We may also find this kind of distribution for /l/. Many dialects of English are reported as having full-vocalisation of /l/, usually post-vocalically, both in the UK (Johnson and Britain 2007, Scobbie and Wrench 2003, Scobbie and Pouplier 2010) and the US (Ash 1982, Hall-Lew and Fix 2012). In England, /l/-vocalisation is long described as a marker of working-class Cockney English (Wells, 1982:313-315), although more recent studies of British English have shown vocalisation seems to be a change in progress, spreading to many urban centres of the UK, with younger speakers vocalising more frequently than older speakers from the same town or city (Britain 2009, Wright 1988). Note that studies often refer to different ranges of lenition when they use the term /l/-vocalisation; here it is used to describe the process whereby /l/ loses its tongue tip gesture altogether.

3 Methodology

Speakers of various dialects of English were recorded producing /l/ in the phonological contexts shown in Table 2 (henceforth referred to by example token).[2] In this paper, the results from speakers of RP, Manchester English, American English and Essex English are presented. Subjects were recorded reading lists of words and phrases containing the target stimuli five times on a Mindray DP2200 ultrasound machine (frame rate 60 fps deinterlaced), with acoustics recorded through a Audio-Technica ATR-3350 microphone. /l/s were flanked by front high vowels in all contexts. The data were collected using Articulate Assistant Advanced (henceforth AAA; Articulate Instruments 2012). Sound files were exported out for acoustic segmentation in Praat, before being imported back to AAA where splines were hand-drawn for all frames within /l/ boundaries and flanking vowels. Spline coordinates (over 42 points) were extracted for contextual comparison and mean midpoint values plotted in R's `ggplot2` package. Midpoints only are analysed in this paper. The right side of the image shows the tongue-tip, and the left side the tongue-root.

Significant differences are shown through non-overlapping confidence intervals in the plots. The confidence intervals and are constructed using the LOESS method, which is similar to the SS ANOVA methods used by Davidson (2006).

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[2]For the first two speakers, pre-consonantal contexts were not collected (this was not considered part of the scope of study at the time, but has since been corrected).

Context	Environment	Example
initial	[$_{—word}$	*leap*
stem-medial,V__V	[$_{stem}$V__V]	*helix*
stem-final,V__V	V$_{—stem}$][$_{suffix}$ V	*heal-ing*
word-final,__V	V$_{—word}$][$_{word}$V	*heal it*
phrase-final	V$_{—phrase}$]	*heal*
word-final,__C	V$_{—word}$][$_{word}$C	*peel bananas*

Table 2: Phonological contexts and their reference words and phrases.

4 Results

4.1 RP

Cruttenden's (2001) description of RP is corroborated by articulatory evidence from spline data: the backed tongue body, reduced tongue-tip gesture, and retracted tongue root typical of dark [ɫ] is only found non-prevocalically, as shown in Figure 1. Note the sharp distinction between the two realisations, and the lack of gradience in the in-between phonological contexts, such as word-final prevocalic. This pattern is consistent with the first stage of the life-cycle. As represented in the first row of Table 1, darkening occurs in coda-position at the phrase level, meaning that any word-final codas which occur prevocalically (e.g., *heal it*), are resyllabified into the onset at the phrase level and escape darkening. This is in contrast to the pattern found by Sproat and Fujimura (1993), where the equivalent *heal it* tokens are dark.
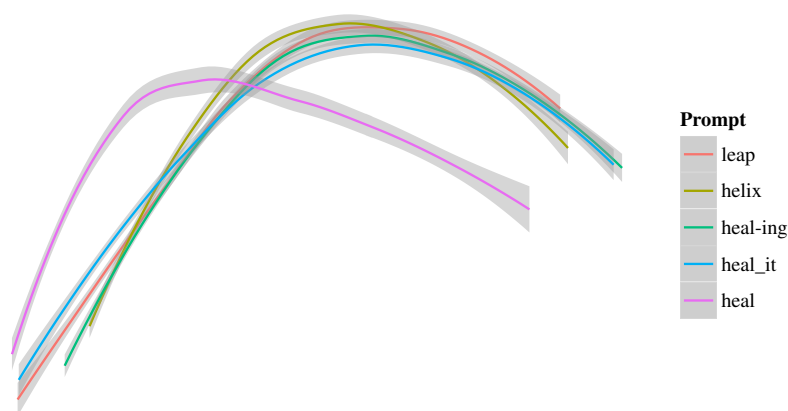

Prompt
— leap
— helix
— heal-ing
— heal_it
— heal

Figure 1: RP splines at /l/ midpoint across phonological context.

4.2 Manchester

The variety spoken in Manchester (North-West England) is of interest, as the existing literature tends to conclude that Manchester /l/s are dark in all positions (Cruttenden 2001, Kelly and Local 1986), although there is acoustic evidence of a small difference between initial and final position (Carter 2002). At first glance, the Manchester splines in Figure 2 seem to corroborate the claims of only one category in this dialect. However, note the small difference and the lack of confidence interval overlap in tongue-root backing between phrase-final *heal* tokens and the other contexts. Although *phonetically*, the Manchester distribution is in contrast to the clear light/dark dichotomy found in RP, it is interesting to note that the *phonological* contexts pattern together, in that phrase-final *heal* is more retracted than the other five contexts. However, it is not clear from this picture that Manchester has the categorical distinction so convincingly displayed by RP, or whether this is a gradient effect of phrase finality, perhaps conditioned by duration for this speaker. Although the effects of gradient durational differences are not addressed here, they are discussed extensively in Turton (2014).
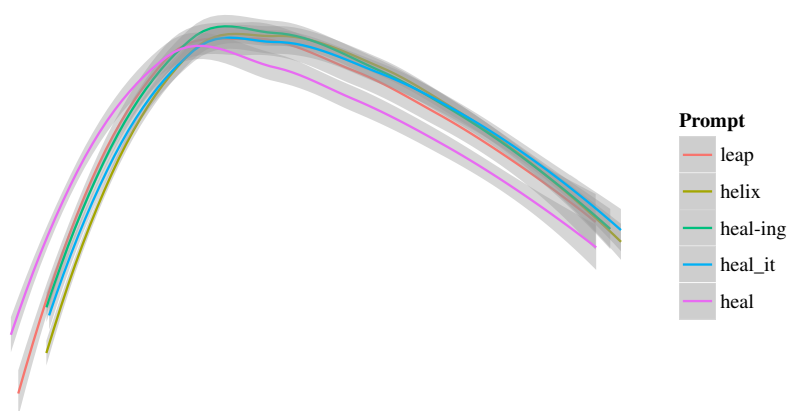

Prompt

— leap
— helix
— heal-ing
— heal_it
— heal

Figure 2: Manchester splines at /l/ midpoint across phonological context.

4.3 American English

The first thing to notice about the American speaker[3] in Figure 3 is that the splines are mostly overlapping, with the exception of the tongue root in the phrase-final *heal* spline, which is clearly more retracted[4]. However, the confidence intervals indicate a small but significant difference between tongue shapes, this time with a three-way distinction: the *leap* and *helix*-type tokens have significantly advanced tongue-tips than the

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[3]The American speaker is from Texas, but has a standard Western US accent, rather than a typical Texan one.

[4]The additional tongue-root retraction of the mean word-initial *leap* is due to one token which was articulated with a drawn-out run-up to the word. For future study, participants will be given *leap* tokens which are non-initial in the utterance, because of the risk of this happening in utterance initial position.

other environments. In addition, the phrase-final *heal*-type tokens have an extra amount of tongue-root retraction. In the pre-consonantal cases, we do not find the extra tongue-root retraction present in phrase-final *heal*-type tokens, and the tongue tip is not as low. Further analysis comparing durational effects may shed light on the patterning of these tokens.
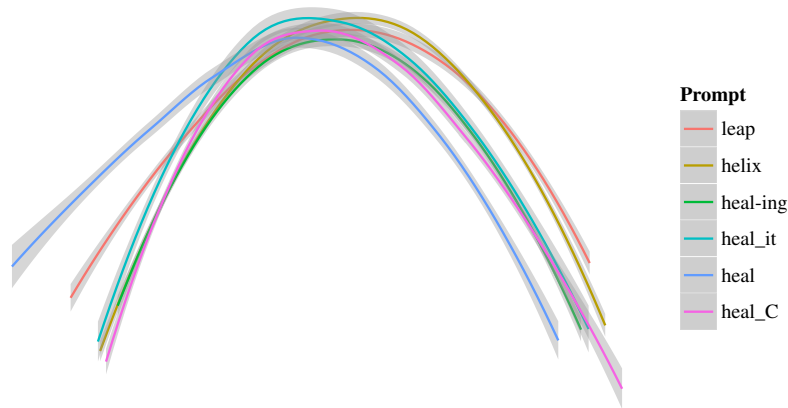

Figure 3: American splines at /l/ midpoint across phonological context.

4.4 Essex

As discussed previously, Essex is a variety of English spoken in the South-East of England where most dialects show vocalisation in word-final or phrase-final position. The first thing to note is that the Essex speaker, who was selected for her non-variable vocalisation pre-consonantally in natural speech, produces highly unnatural tokens in this environment when monitored by ultrasound. This can be observed in Figure 4 where these tokens are even more advanced than canonical onset position. This is interesting from a sociolinguistic viewpoint: speakers do not style-shift their darkening, the older stage of the lenition trajectory which is completely below the level of awareness, but they do shift their vocalisation. This is also reported in sociolinguistic studies of speakers producing unnatural /l/ tokens in word-list style (Hughes et al. 2012). Because of the unnatural realisation, these tokens are excluded from further analysis, but indicate a fruitful topic for future studies in style-shifting and sociophonology.

Combining auditory and articulatory evidence from the remaining tokens, it seems that the Essex speaker shows a three-way lenition trajectory in /l/ realisations. There are similarities with the American speaker: both have a three way distinction between *leap*-type and *helix*-type tokens, *healing* and *heal it* type tokens, and *heal*-type tokens. The question is whether or not the data here can be claimed to show three categories. It is worth noting that Lee-Kim et al. (2013) see three categories as problematic, but our Essex speaker provides support for this possibility. However, the American pattern is much less distinct phonetically and conclusions of categoricity and gradience can not be made from these data alone. Section 4.4 suggests one interpretation of the data. The Essex pattern could reflect the operation of two overlaid categorical phonological processes: one controlling tongue-root retraction, the other linguo-alveolar contact. The
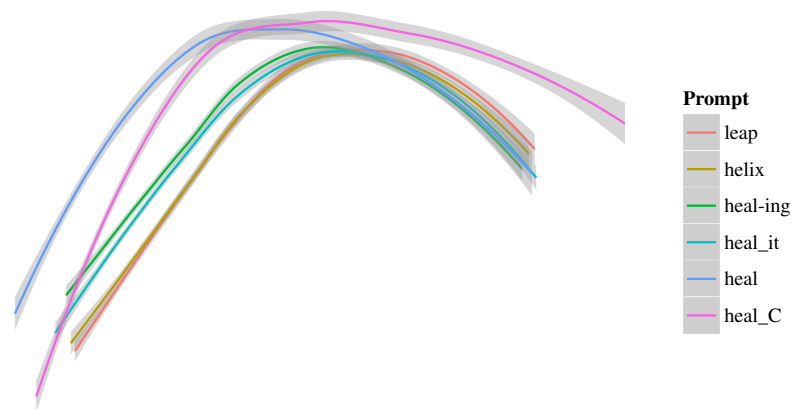
Figure 4: Essex splines at /l/ midpoint across phonological context.

American pattern may be down to categorical darkening, superimposed on a gradient duration-driven adjustment in final position. In both scenarios, we have two processes synchronically overlaid in the grammar. This pilot study has the same problem as Lee-Kim et al.'s: such a coarse sample of the possible phonological environments means we are unable to distinguish between categorical and gradient effects reliably, at least in dialects whereby the articulations are so similar. It could be the case that there are three categories for my American speaker also. Future work with more data will allow us to draw more solid conclusions.

	leap	*helix*	*healing*	*heal it*	*heal*
American English 2	[l]	[l]	[ɫ]	[ɫ]	[ɫ]
Essex	[l]	[l]	[ɫ]	[ɫ]	[ɤ̈]

Table 3: Possible interpretation of Essex and American English patterns.

5 Conclusion

The present paper has demonstrated that different dialects show evidence of different kinds of /l/-darkening processes, from the perspective of morphosyntactic sensitivity, phonetic implementation and phonological realisation. An additional point which this paper seeks to make is that it is not helpful to dismiss categoricity, particularly when the opportunities to observe such patterns are overlooked. A full analysis of a wide range of phonological contexts is needed, but even then, fine-grained phonetic differences may make it difficult to diagnose the true pattern. One glance at the stark difference between initial and final /l/ realisations in dialects such as RP may be a convincing enough an argument for categoricity, but the issue becomes trickier when observing small phonetic differences such as the American English pattern. Do we want to claim that small phonetic differences are evidence of gradience? In the case of the Manchester speaker, the difference between dark and "even darker" is consistent, whereas the American speaker shows a more gradual pattern

between darkest and lightest. However, the Sproat and Fujimura data also shows gradual variation over a small scale, but the tip delay data allows us to observe more intricate patterns. The introduction of statistical techniques such as Principle Components Analysis of tongue spline data (Slud et al. 2005, Stone 2005) and Optical Flow (Moisik 2013) are planned for future research, but more phonological environments and more recorded tokens are required for a reliable diagnosis of categorical vs. gradient effects.

This paper has shown that dialectal diversity has been vastly underestimated in the existing literature on /l/-darkening. The effects of differing sensitivity to morphosyntax demonstrate that we need a theory that can account for the evidence that categorical darkening domains may differ in size between dialects. A modular approach can make sense of such facts, with rule scattering and domain narrowing accounting for the coexistence of categorical and gradient effects, and lenition trajectories such as /l/-vocalisation. The wide range of dialectal diversity, for which this paper provides only a small subset, shows a great deal of orderliness if considered from the viewpoint of the life cycle.

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