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(Re)Connecting spatial literacy with children's geographies: GPS, Google Earth and children's everyday lives

Jarvis, Claire H.^{1*}, Kraftl, P.², Dickie, J.³

¹University of Leicester, Department of Geography, Bennett Building, University Road,
Leicester LE1 7RH, UK.

* Corresponding author chj2@le.ac.uk, +44 (0)116 252 3808

²University of Birmingham

³University of Stirling

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ABSTRACT

This article sets out an agenda for research that (re)connects research on children's geographies and childhood studies with studies of spatial literacy. Research on children's environmental cognition and, latterly, spatial literacy, has been artificially and problematically separated from the majority of research in childhood studies. Our fundamental aim in this article is to argue for – and to evidence – greater attention to how spatial literacy and children's everyday lives are *embedded* in one another. To support our broader call for a synthetic research agenda, we draw on some more focussed, qualitative empirical material taken from a large-scale project about children's mobilities and everyday lives in newly-built urban communities. Our analysis focuses upon children's interpretations of Global Positioning Systems (GPS) tracks of their mobilities, set against a background of Google Earth imagery. In doing so, we showcase one suite of ways in which research on environmental cognition and children's geographies might proceed *together*. We demonstrate that children not only displayed analytical skills (for instance, in relation to scaling effects and pattern recognition) but that many also exercised higher-level, critical analysis, especially in relation to errors on Google Earth outputs. Simultaneously, we interrogate the recursive articulation of a range of *qualitative* indicators of spatial literacy, with children's everyday mobilities, routines, emotions and memories. The paper analyses how new conceptual languages and technologies being propounded by spatial literacy scholars could afford a more enriched understanding of key contemporary concerns for children's geographers, and, recursively, what spatial literacy scholars might gain from engaging with (especially qualitative) research prompted by those concerns.

1. Introduction

There is an expanding literature on the use of virtual globes (e.g. National Research Council 2006; Shultz et al. 2008) and GPS (e.g. Cyvin 2013; Davies et al. 2012) in the teaching of GIS

(Geographical Information Science) and spatial literacy skills (e.g. Baker et al. 2015; Patterson 2007). As Baker et al. (2015) outline, there are still many outstanding questions concerning the triggers for the development of spatial literacy, especially amongst children. Equally, since the mid-2000s, there has been a growing body of research exploiting GPS (Global Positioning Systems) in the context of children's health studies, children's geographies and interdisciplinary, social-scientific childhood studies more generally (e.g. Walker et al. 2009; Mackett et al. 2007; Oliver et al. 2014; Christensen et al. 2011).

However, despite the volume of work on children's geographies and spatial literacy *individually*, these important fields of research have rarely been investigated together. There is a need for research that more rigorously explores the experiences and, especially, qualitative responses of children themselves to the GPS tracks of their own movements *and* that asks questions about their spatial literacy – especially, but not only, in the context of Virtual Globes and other recent technological advances. This observation echoes a broader trend where scholarship on environmental cognition (and environmental psychology) and children's geographies has ostensibly proceeded separately. This separation is surprising given that early, seminal work in what has become subdisciplinary children's geographies developed methods from environmental psychology to use free-recall maps and aerial photography as a research tool *with* children (e.g. Matthews 1984; Morrow 2001; Blaut 1997; Liben and Downs 1997; Plester et al. 2002). Focussed on what was then termed 'spatial cognition' (Matthews 1992), these approaches were one of the key underpinning prompts for contemporary interest in children's mobilities, which interest has become a central feature of children's geographies scholarship (Skelton and Gough 2013). Indeed, somewhat confusingly, some scholars in children's geographies now use the term 'literacy' to refer to children's social, embodied or emotional knowledges of outdoor environments (e.g. Young, 2003; Pyry, 2016), but this term is often used vaguely and in a narrowly metaphorical sense. Of greatest significance to the

present article is that, for various reasons – outlined in the next section of the article – research on children's urban mobilities since the 2000s has rarely asked questions about children's spatial *cognition* as it has been understood in a range of disciplines *beyond* children's geographies and childhood studies. For shorthand, and given the shift in those disciplines towards the term, we refer to a broad range of inter-linked work on environmental cognition, spatial cognition and spatial literacy as '*spatial literacy*'.

Although the possibilities for (re)connecting children's geographies and childhood studies with wider work on spatial literacy are manifold, a pressing concern is that there is little work probing the spatial literacies revealed in 'ordinary' accounts of children's lives. Most research on spatial literacy involves the application of spatial ability or thinking tests following an intervention (Lee and Bednarz 2012; Cyvin 2013), or the careful statistical design of experiments under test conditions (e.g. Möhring et al. 2014; Frick et al. 2014). The major contribution of this article is, in this light, to argue for a research agenda that brings (back) together scholarship on children's geographies and childhood studies with research on children's spatial literacy. We contend that a central part of this should be to focus on *qualitative* approaches that can enrich *both* our understandings of children's everyday lives *and* their spatial literacy. To illuminate our arguments, we draw on empirical material from a large-scale study of children's urban everyday lives, in two ways: to exemplify the *specific* advances to be made from analysing qualitative data in research on the embeddedness of spatial literacy with/in children's everyday lives; as prompts for a *broader* research agenda that encompasses but extends beyond the focus of the empirical research reported here. Our data originate in a major, interdisciplinary four-year project, involving geographers, anthropologists and spatial literacy/GIS experts, which used GPS and "Google Earth" as a significant component of a mixed methods study of children's (aged 9-16) everyday lives (section 3).

We start by outlining the two fields of geographical scholarship that we contend should be (re)combined: children's geographies and spatial literacy. We do not only review those literatures, but begin to outline key, focussed elements of a more synthetic research agenda. Section 3 outlines contextual information about the research project on which this article is based, including the project's methodology. The bulk of the paper analyses findings from over 100 semi-structured interviews conducted with interactive, dynamic views of Google Earth overlain with the GPS tracks of each child's movements over one week. We tease out children's responses to the maps, their ability to interpret the maps and individual features, their commentaries on the routes they took, and their ability to identify errors or omissions in the data. In order to offer some thematic specificity, and in order to exemplify the many possibilities of the conjoined research agenda we advocate, we deliberately move away in our analysis from questions of independent *mobility* that have been so popular in children's geographies scholarship. Instead, we interrogate questions around *emotion* and *memory* that have been a less common (although increasingly important) focus of children's geographies scholarship in recent years (e.g. Kraftl 2013a; Jones 2008). In conclusion, we draw together the *specific* and the *broader* implications of our analysis, towards a research agenda for understanding the embeddedness of spatial literacy with/in children's everyday lives.

2. Literature Review

2.1 Children's Geographies: mobilities, digital methodologies, emotions and memory

Children's geographies has become a well-established subdiscipline of human geography. With diverse origins, the subdiscipline has grown into a broad field of scholarship difficult to capture in a brief review (see, for instance, Kraftl et al. 2012; Holloway 2014). Nevertheless, three issues are pertinent to this article: mobilities; the use of GPS and other digital technologies; emotions and memories.

Firstly, as scholars have sought to uncover children's experiences of (especially urban) places, they have, increasingly, focussed on their everyday mobilities (Barker et al. 2009; Skelton and Gough 2013). A critical concern – unlike the majority of work on children's environmental cognition – has been a shift to viewing children as competent research participants, able to articulate their own experiences of their mobilities. This has enabled scholars to construct a sense not only of children's movements through outdoor spaces, but the contextual power relations, materialities and subjectivities that are recursively entangled with them.

On one hand, research has repeatedly shown that children's independent mobilities – unaccompanied by adults – have decreased in a range of contexts (e.g. O'Brien et al. 2000), with diverse contextual factors at play including parental conceptions of risk and the 'walkability' of neighbourhoods (Witten et al. 2013; Nansen et al. 2015). On the other hand, questions have been asked about the relative validity of focussing on children's *independent* mobilities as an indicator of the health (or otherwise) of both children and their environments (Kullman 2012). As Mikkelsen and Christensen (2009) argue, academics need to pay far greater attention not only to local, contextual factors affecting mobility but to the variety of inter-dependent relationships (human and non-human) through which children's mobilities are afforded (Ross et al., 2009).

We agree with the latter, critical perspective on independent *mobilities*; however, we also argue that early work on environmental cognition (e.g. Hart, 1979) was a key, underpinning tenet for children's geographies, including many of the above studies – even if this influence is rarely acknowledged today. For instance, Matthews' (1992) pioneering work with younger children sought to gauge children's perceptions of large-scale, urban environments, through a series of mapping activities. However, his work also involved some investigation into children's urban experiences – their movements, their fears and their

knowledges of local places. This approach was fundamental to the development of what became 'children's geographies' – albeit wherein a focus on environmental cognition was virtually lost in favour of methods that allowed children to 'voice' their experiences of urban places (e.g. Matthews et al. 2000). A major reason for this 'split' has been a political one: contemporary children's geographies scholarship (and that in wider interdisciplinary childhood studies [see James et al., 1998]) has, since the 1990s, been premised upon a stinging critique of psychological approaches to studying childhood, and especially developmental models (Kraftl, 2013a). With very few exceptions, a deep suspicion of psychological approaches remains prevalent within children's geographies and childhood studies. Thus, whilst there remain innumerable studies of children's mobilities, and despite their keen emphasis on notions such as children's 'place attachment' and their 'knowledge' of/about local places, such studies rarely, if ever, involve the languages, methods or analytical techniques offered by scholarship on environmental cognition and spatial literacy (e.g. Young 2003; Porter et al. 2012; Walker et al. 2012; Pyyry 2016). Our intention is not to single out particular studies for a dressing down; rather, to merely indicate that they are symptomatic of a wider (and now simply assumed) divide between. Our argument is, therefore, in part a call to (re)turn to a research agenda – if not the same nomenclature and methods – that *combines* attention to children's environmental cognition *with* their experiences of mobilities. We ask – given that there will have been advances in both fields over the past twenty years, and not least in the field of spatial literacy – what might be gained from a more synthetic research agenda.

Secondly, notwithstanding these critiques, we would highlight increased interest in the entanglements of digital technologies with/in children's lives (Ergler et al. 2016) and, of particular relevance to this paper, in digital-methodological advancements in studying children's everyday lives. Although none uses approaches from spatial literacy, several studies are indicative of this trend. One of the earliest, by Mackett et al. (2007), reported on the degree

of independent movement and physical activity of children. Four days' worth of GPS tracks were mapped against Ordnance Survey Mastermap™ background data; however, young people themselves did not see or comment on the tracks. A more recent study by Oliver et al. (2014) focussed on the efficacy of the travel diary as an accurate method of evaluating children's travel behaviours, finding that a combination of travel diaries and GPS tracks was ideal, particularly in regard recounting individual 'trips' and their ordering (a topic we pick up below).

Significantly, however, it is only in somewhat more exceptional studies (e.g. Walker et al. 2009; Cope and Elwood 2009; Christensen et al. 2011), that children have been involved *directly* in the analysis of GPS data. On this front, and based within the same premise, a recent special issue of *Children's Geographies* on digital technologies has been particularly instructive (Ergler et al., 2016). Several of the papers explicate how digital technologies might be involved in detailed research *with* children. Indeed, Ergler et al. (2016: 131) note that there is a dearth of considered reflection upon the integration of digital technologies into research methods that do not "too readily [reduce children's lives] to simple spatial coordinates". Thus, Plowman (2016) neatly demonstrates how greater attention to digital devices – especially via the Internet of Things – can blur the boundaries of the spaces in which our research takes place, and especially the notion of the 'home'. With a methodology that overlaps with our current paper, Danby et al. (2016) explore children's capabilities in navigating Google Earth, exploring how interactions with maps can be understood as social processes. As Danby et al. note, their study is original for its emphasis upon children's *active* engagements with the technology, an emphasis sorely lacking in the (scant) previous published studies on children's use of Google Earth. However, whilst rich in detail, their paper's contribution is somewhat tempered on three fronts: by a very small sample set (recounting just one extended vignette with two children, compared with over 100 in our study); given that the vignette itself was part of a wider study of digital technologies in the classroom, and not a systematic investigation using Google Earth

as a central methodological tool (as per our study); and given only scant reference to prior work on the spatial literacies of children. Again with a similar methodology to our own, Freeman et al. (2016) used GPS techniques to examine children's engagements with nature in their locales. They uncover aspects of children's spatial *knowledges* about their environment. However, they (and Ergler et al. 2016: 136) note a key concern: that these knowledges are still couched in and directed by "adult observations of children's interactions with digital technologies". To this critique we add the observation that, although the current paper does not necessarily remedy this situation, greater, more creative interdisciplinary engagements between children's geographers and spatial literacy scholars might open out, rather than preclude, some possibilities to broach Ergler et al.'s concern. This is, we argue, just a part of a wider research agenda if researchers are to meaningfully embed children's spatial literacy with/in their everyday geographies.

Thirdly, we also seek in our analysis to move *beyond* our fundamental contention that spatial literacy is embedded in and of children's everyday lives and, especially, their mobilities. In outlining and beginning to evidence the potential of a synthetic research agenda, we ask what might be the more *specific* empirical, analytical and conceptual gains to be made. Our focus – which we suggest could be a significant, but far from a guiding one for other studies – is upon *emotions* and *memories*. To an extent, our article empirically extends a burgeoning corpus of work about children's emotional geographies (for critical reviews, see Blazek and Windram-Geddes 2013; Kraftl 2013a). In particular, it demonstrates both how engagement with Google Earth tracks during the interviews was itself already an emotional endeavour (also Hadfield-Hill and Horton, 2014) and how spatial literacies were embedded within and productive of the senses of belonging in place that other children's geographers have vividly articulated (Bartos 2013). It could be argued that select work within children's emotional geographies has, to an extent, also engaged with children's spatial literacies. For

instance, recent work by Pyyry (2015, 2016) demonstrates how young people's emotional engagements with/in a city lead to multisensuous forms of learning that are inextricably linked with their dwelling. Pyyry (2016: 104, original emphasis) charts how forms of 'enchantment' create more-than-verbal learning situations that constitute "*a moment of hesitation* when one thinks the world somehow differently" – from being street-wise to the acquisition of "embodied capacities of performance in everyday situations" (ibid.: 107). More widely, a range of work has called for attention to the often-overlooked spatial knowledges of children, which could be instrumental in dealing with pressing social and environmental issues (see Porter et al., 2012, for a helpful overview).

However, in extending and specifying our argument (and indeed extending and specifying children's emotional geographies), we would make two key observations. On one hand, despite a welcome emphasis upon diverse forms of learning and knowledge, those forms of learning and knowledge remain bracketed within the concerns of childhood studies. They do not engage with the equally if not more diverse languages, approaches and analyses of 'spatial literacy' and, indeed, any direct mention of that term is largely vague and metaphorical. Therefore, in this paper, whilst deploying some similar analyses of emotions in respect of children's everyday learning, we do so *through and alongside* the languages of spatial literacy. Our analyses remain qualitative, but, we hope, offer a springboard for further collaborative studies.

On the other hand, we also seek to develop what have been rich but very patchy theorisations of *memory* in children's geographies. Principally, children's geographers have been concerned with questions as to the relative 'accessibility' of childhood memories in adulthood. Seminal papers have argued both for the possibility of retrieving childhood memories in adulthood, perhaps through 'indirect' methods like reverie or daydreaming (Philo 2003), and for the difficulty of doing so as some aspects of childhood experience may remain

fundamentally 'other' to adult experience (Jones 2003; Jones 2008). It is rarer, however, to find studies that directly reflect upon and analyse the more immediate and recent recollections of *children themselves*. Whilst children's geographers – like all social scientists – rely largely on the memories of their respondents when co-producing research data, children's geographers have rarely reflected upon those materials *as* memories.

A couple of exceptional studies have engaged with children's (recent) memories as legitimate objects of study. In a poignant and powerful piece, Verma (2012) examines how, in war-torn Uganda, homecoming children formulated multiple versions of the same stories of violence, depending on part on the social contexts within which they were telling these stories (also Blazek 2013). Verma's piece is powerful in emphasising how these 'other' stories might undermine standard narratives – often co-opted by NGOs working in such contexts – which may not be considered by otherwise well-intentioned interventions on children's behalf. Similarly, Marshall (2014) asks how – in a West Bank refugee camp – a focus on particular kinds of children's memories (individual traumas) might lead to narrow forms of intervention in post-violence situations.

Significantly, however, the analytical focus in the above articles is (in the contexts of their research, quite rightly), not upon memories-themselves, but on what accessing those memories might tell us about "particular forms of childhood political subjectivity" (Marshall 2014: 281). Indeed, they rarely reference 'memories' directly. Therefore, a key contribution of this article – prompted by the very combination of spatial literacy with more 'traditional', qualitative, children's geographies methods – is to more fully explicate these kinds of memories. Operating within the ostensibly more privileged (and secure) settings of newly-built communities in England, we focus on how children's recent memories of their communities are bundled into and produced through their commentaries on Google Earth tracks.

Finally, we note that, in our analyses, we deliberately draw together articulations of 'emotion' and 'memory'. Although cognisant of their differences, we are inspired conceptually by a range of writing that has demonstrated – going at least as far back as Heidegger's theories of being-in-the-world – that the temporality of human experience is often a recursive combination of embodiment, emotion, memory and world (see Jones and Garde-Hansen [2012] for a fuller discussion than is possible here). Thus, for instance, despite the differences in their arguments, both Philo and Jones offer accounts suffused with emotion, where memory and emotion *combine* to afford rich senses of place, belonging and attachment. As we will demonstrate, these entwined notions of emotion and memory resonate with children's experiences as they navigated Google Earth images during our research.

2.2 *Spatial literacy and children*

'Spatial literacy' is a recently emergent term, albeit one that is rarely defined explicitly. The absence of a standard definition, or even a common understanding, is a problem further confounded by the frequent use of many other terms and expressions associated with 'spatial' understanding (including thinking, cognition, knowledge, skills, abilities, strategies). As identified in a landmark report by the US National Research Council entitled 'Learning to Think Spatially' (National Research Council 2006), interchangeable uses of these terms have hampered research in this area. For our purposes, it is helpful first to think of the two words independently.

Thus, 'spatial' refers to all dimensions of space, including geo- or Earth-bound space, Euclidean space, geometric space, the 'table' space on which many psychology and cognitions experiments are conducted, our mental space, and the range of spatialities in which humans think and exist, and which, we assume, warrant no introduction to readers of a geography

journal (Freundschuh and Egenhofer 1997; Tversky 2003; Massey 2005). In terms of spatial understanding specifically, as both Montello et al. (1999) and Ishikawa (2013) have demonstrated, connectivity between spatial aptitude tests and geographical scales of spatial literacy is varied. Certainly in the context of spatial aptitude tests, gender is known to play an important role in performance (Self et al. 1992; Matthews 1992) but at geographic scale this is less marked, although differences in the aptitude for gaining route knowledge and survey knowledge remain (Montello et al. 1999). Thus, within the earlier geographical review literature (e.g. Self et al. 1992) the focus was on spatial ability, and the derivation of spatial thinking tests (paralleling work in the psychological domains). In the psychological sciences themselves, there has been emphasis on the development of spatial abilities in children between the ages of 3 and 6 (e.g. Frick and Newcombe 2012). Meanwhile, methodologically, the emphasis has been on controlled statistical experiments (e.g. Ishikawa and Montello 2006; Liben et al. 2010; Frick et al. 2014). There has also been some considerable debate in the literature concerning the ability of children slightly younger than those in this study to interpret aerial photography (e.g. Blaut 1997; Liben and Downs 1997), which may be scale-related.

In turn, 'literacy' (when applied to 'spatial') suggests that one can 'read' or effectively interpret and extract meaning from, through and with any of those spatial skills listed above. A 'spatially literate' person would have the "habit of mind of thinking spatially, can practice spatial thinking in an informed way, and [could] adopt a critical stance to spatial thinking" (NRC 2006, p. 233). Therefore, we see 'spatial literacy' as a state of expertise, a culmination of the learning and practising of many individual and independent acts of spatial thinking. 'Spatial literacy' is, therefore, a continuously developing outcome of a (repeated) process involving spatial abilities, strategies, cognition and knowledge (Jarvis 2011).

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As noted above, within earlier geographical literatures (e.g. Self et al 1992) the focus was on spatial cognition and ability, yet the huge significance of spatial abilities and literacies has since been acknowledged because they

“[...] are so embedded in everyday life that they are rarely if ever given the attention ... that they richly deserve. So much is taken for granted about the way we live that it does not seem necessary for us to understand how and why we are able to find our way to school; why and how we learn about our neighbourhoods ...” (Golledge et al. 2008, 289).

In this light, Golledge et al. (2008) are amongst those (e.g. Gersmehl and Gersmehl 2007) who conceptualise a geospatial task-based framework, in their case based on the primitives of location, magnitude and space-time. Their paper provided a framework to support the considered development of spatial literacy for US third to sixth graders (Ages 8-12). They found that third-graders struggled with spatial primitives (after Nystuen 1968: direction/orientation, distance and connectiveness) especially as complexity increased and that there was a manifest lack of geospatial vocabulary at this age. There was an increase in performance in geospatial tasks with age between third and sixth grade, but still the poverty of vocabulary as regards spatial concepts was marked. Students found spatial relationships in the real world more easily than in abstract figures, but nevertheless the 'real world' used by Golledge et al. (op cit) were sketch maps and far from the rich imagery of Google Earth (as per the present paper).

There are two important research gaps here, which appear separate but, bearing in mind the extract from Golledge et al.'s (2008) work above, which are very much related. Both are as pertinent to the research we seek to propagate as those we identified in the previous section in terms of children's geographies. There is a *technological* gap with regard to the language and understandings exhibited in the use of virtual globes and viewing of GPS tracks by young

children. There has been work proposing the concept of 'minimal GIS' or virtual globes (e.g. Marsh et al. 2007; Schultz et al. 2008) for teaching, to emphasise the spatial concepts without getting bogged down in technical software detail, assessed by spatial or geographical thinking tests (e.g. Lee and Bednarz 2012). However, in this nascent area of research, there is little scholarship that takes a *qualitative* approach (e.g. Chen et al. 2013). Consequently, there is a broader *methodological and conceptual* gap in research on spatial literacy: much contemporary research with (or, more often, on) children is, as noted above, reliant upon controlled statistical tests. Those tests – predicated upon taxonomies and developmental indicators – are based in the very paradigm of which early childhood studies scholars were so critical (James et al. 1998), and, effectively, separate children's spatial literacy from their everyday experiences. However, as Golledge et al. (2008) explain, geospatial thinking is embedded in everyday life to the extent that it often goes un-noticed. Therefore, it is our contention that far more work is required that examines how children's spatial literacy is embedded *within* their everyday routines and mobilities – whether quantitative and/or, as we argue, qualitative.

3. Methodology

This article is based upon a major, four-year research project that examined children's (aged 9-16) everyday lives and mobilities in four, newly-constructed communities in southeastern Englandⁱ. The project evaluated the extent to which these communities – built under the erstwhile Labour Government's *Sustainable Communities* agenda (ODPM 2003) – constituted places that were any more 'child-friendly' than previous waves of urban design (for further context, see Kraftl (2014) and Horton et al. (2015)). The project adopted a mixed-methods approach, undergirded by an ethnographic sensibility. Briefly, our research included: up to six months participant observation in the four communities; between two and four themed

interviews (on children's everyday routines, mobilities, citizenship and sustainability) with each of the 175 young people from the four communities; 51 guided walks, where individuals or friendship groups of children led researchers around their communities; a 'GPS week', involving a rolling mobile telephone survey, which was integrated with the mobility interviews.

Most pertinent to this paper was the GPS week, which in itself led to the generation of a very large dataset. The GPS week was fundamental to the project, since it was through this component that the key theme of 'mobility' was explored (for further detailed findings from the project on this theme, see Horton et al (2014)). It was also the key stage for collaboration between researchers specialising in childhood studies and experts on GIS and spatial literacy. Critically, in terms of the synthetic agenda we promote, we note that the GPS component was *integrated* into and formed a part of the qualitative approaches to understanding children's lives. 122 of the total sample of 175 young people took part in this research, in three of the four case study communities. Each young person was given a GlobalSat DG-100 GPS for a period of one week to record their daily movements, which logged data every 5 seconds. These GPS units were designed to clip-on in a relatively unobtrusive fashion. GPS data were downloaded at the end of the week. The project adhered to a strict ethical code of conduct, which was developed specifically for this project, and which was approved by the Research Ethics Committee of the lead institution. For instance, we could not 'track' the children in real time, we obtained separate parental and children's consent for this component of the project, and we took the (not straightforward) step of anonymising both the children's names and those of the communities themselves¹.

The raw GPS tracks were de-noised using software customised by the lead author. Unfortunately, the software accompanying the particular GPS used in this study did not report

¹It is for this latter reason that the names of the children's communities are not provided in this article; all children's names are pseudonyms, although the gender and age information is correct for each informant at the time they were interviewed

the number of satellites in range and bespoke algorithms were developed to clean the data, masking out erroneous points by omitting any sharp directional changes and impossibly rapid acceleration. Further, GPS tracks were cleaned between 7pm and 7am to minimise the effect of being indoors and, likely, without signal. The raw data were then imported to a GIS for further analysis. Of particular significance to this article, the GPS tracks for each child were converted to .kml files and uploaded into Google Earth for viewing by the children and researchers. Tracks for each day were represented in a different colour against the background aerial imagery of Google Earth.

At this stage (and usually the week after they had used the GPS), each of the 122 participants took part in a detailed, Google-Earth-elicited semi-structured interview to discuss their tracks. The interviews lasted approximately one hour each. The interviews focussed *both* upon children's everyday routines and mobilities, *and* questions designed to explore their spatial literacy, delivered through directed conversations about their interpretation of the Google Earth images. In light of the literatures explored in the previous section – and our qualitative approach – the questions were structured to explore children's expectations and any surprises they observed in their tracks; their ability to interpret the maps and individual features (e.g. houses, shops) without prompting; the use of Google Earth images as a medium to assist the children in explaining their routes; how these articulated memories and emotions associated with those routes and their daily lives; their ability to contrast their recorded tracks with routes they took in their communities; and, their critical evaluation of the accuracy of the tracks.

4. Analysis: embedding children's spatial literacy within their everyday mobilities

Our analysis is structured by the key themes listed at the end of the previous section, although it is framed to highlight the embedding of children's spatial literacy within their responses

about everyday mobilities and routines. We cross-reference our qualitative findings against *both* key indicators of spatial literacy identified in recent research *and* children's geographies research on everyday urban experiences, emotions and memories. As we do so, we also use our analyses from our specific dataset to articulate a range of potential lines of research for a synthetic research on children's geographies/spatial literacies.

4.1 Expectations and surprises

Whilst the majority of the children involved in the research confirmed that their tracks met their general expectations, around one-third were surprised at the distance they had travelled. One child summed up the potential reason for this: "Doesn't look like I've been far does it? Actually, yeah, it does doesn't it because it's a map?". This intuition connects neatly with the literature on scaling (e.g. Frick and Newcombe 2012), that is the ability of participants to estimate distances from a map to reality. Frick and Newcombe (2012) suggest that participants encoded relative rather than absolute distances and that this ability was fairly well-developed by the age of 6; here, a variety of relative encodings are manifested.

For some children, the explanation for this 'scaling effect' lay with the longer and more occasional journeys that they had forgotten about, the GPS tracks providing a useful memory prompt:

"I didn't expect the really big bits because I forgot about that we went there, yeah, so like the dark blue bit where we went to [local town] I'd completely forgot about and then I really forgot about going to the dentist as well" (Millie, Female, 10 years old).

For others, small twists in the tracks provided surprise recollections at a different scale, such as short walks to take the rubbish out at a friend's house. 'Pattern recognition' at this local level

was variable amongst children, with a small minority being surprised by the squiggly nature of the plots and less able to make sense of them. Gersmehl and Gersmehl(2007, 187) note that pattern recognition, defined as the ability to see patterns where these are “an arrangement of things that is not random – an imbalance, alignment, cluster, wave, string, ring, etc. that can be seen and described” is a basic spatial literacy skill present in young children and teachable at primary school, but which continues to develop until adulthood. Overall, however, the plots served as a useful prompt to young people concerning things they had forgotten.

More consistently, and despite their overall ‘agreement’ with their tracks, many children found the size of their community larger than expected. This may have been connected to the degree of movement exemplified by the ‘squiggles’ on the map in addition to the scaling effect when zooming in on the tracks on Google Earth. Previous work looking at children's spatial literacy and aerial photography has been with aerial photography at a fixed scale (e.g. Plester et al. 2002). However, for both adults and younger children Möhring et al. (2014) found a linear increase in response times and errors as scales were varied systematically between a larger referent space on a touch screen. This would suggest that the ability to zoom in and out in Google Earth would assist with the scaling problem, although further controlled testing is necessary to isolate this issue. Whilst they found their communities to be larger than they expected, several participants were, simultaneously, surprised by the volume of short tracks:

“Because now, because when I'm going on my little trips, it doesn't feel so long and so much time but when I look at this map it's like, oh my God, where have I been?”

(Timmy, Male, 11 years old)

“I just thought it would be a good idea, just to, and to see what I do during the week as well because I, sometimes I lose what I'm doing during the week. It's pretty strange,

the amount of places I go in one week, especially Saturday and Sunday, which it doesn't seem like I'm doing that much" (Billy, Male, 13 years old)

Here, the embedding of spatial literacy within everyday routines and mobilities began to emerge. Children's perceptions of the size of their communities – and the lengths of their tracks – were recursively produced by, and productive of, their memories and feelings about where they had been. Indeed, in Billy's case, reflection upon his tracks led to the observation that it was 'pretty strange' to see where he had been. For other young people, the Google Earth maps showed less variety of travel than they had expected, but reflecting on the reasons for this, young people noted that there were particular family circumstances in the week of the research project that had constrained travel.

From the perspective of mobilities research, these initial findings are striking. Several studies (notably, O'Brien et al. 2000) conclude that children's self-reported independent mobilities have declined since the 1970s, noting at least some measure of disappointment in terms of *adult* perceptions of appropriate levels of mobility. However, the above analysis relates children's *own* expectations to the GPS tracks they produced – again, these appear surprising, if not disappointing to children – but for different reasons; principally, because they had expected their tracks to look longer and therefore their mobilities more extended than they appeared on the maps. Further research in the vein we promote in this article is required to ascertain *why* they expected their tracks to be longer, whether their perceptions of 'greater' mobilities tally with those of adults, and what this might mean for their everyday mobility practices (Horton et al. 2014).

From a spatial literacy perspective, the most striking element of these initial findings was children's ability to scale from absolute to relative distances despite a lack of visible scale bar on the Google Earth projection. This has echoes in the work of Plester et al. (2002) in which

children slightly younger than those in this study were able to make a map of a location they knew well from an aerial photograph; here, the scale was variable, avoiding the fixed large/small scale debates of Blaut (1997) and Liben and Downs (1997).

4.2 Interpreting the maps and individual features of the community

Although not a central part of our questioning about children's mobilities, the research team noted moments during the interviews where the children – often unprompted – attempted to interpret the maps and identify individual features. Generally, interpreting the maps to find their own houses and those of their friends proved easy. As Kevin (Male, 10 years old) pointed out: “[w]ell my house is actually here under that big red blodge”. Thus, like the majority of our respondents, Kevin correctly made the connection between track intensity, repeated visits and home, because the underlying feature (his house) was masked by multiple, criss-crossing tracks on Google Earth. Other children used colour and texture recognition on Google Earth to find their home, which Gersmehl and Gersmehl (2007) note is a form of regionalisation: “[w]ell that's the big giant field and that's, I think that's, I think that's my house I think” (Claire, Female, 10 years old), whilst a few participants found the identification of their home easier with the tracks turned off.

In contrast, one participant was able to correct the interviewer's assumption that tracks were amassing on their home using both their 'pattern recognition' and regionalisation, or classification, abilities. As Simon (Male, 10 years old) observed: “[n]o, that's not my house, that looks a bit like the school”. Indeed, density of built forms was used in other cases to identify built forms on the map:

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“Yeah, and then this concentrated area around here, this was, that's the ATC Centre, so that's where I do Cadets and then that night they had us out marching up and down [street name].” (Stuart, Male, 13 years old)

Like Stuart, a number of children pointed out many, diverse, features in their communities, and, critically, they too *embedded* these in their everyday routines – whether attending Cadets (like Stuart) or engaging in less formal play. For instance, Henry (Male, 14 years old) told us: “[t]his is the train track all the way down there and I usually go and play around there.” Additionally, and significantly, many children displayed ‘rotational ability’ as they transferred and configured their memories of their everyday, embodied movements to aerial view recognition; that is, they could “mentally represent a viewpoint different from one’s own” (Frick et al. 2014, 1). As Kevin (Male, 10 years old) was able to point out, for example, “The takeaway's just up there” while Wayne (Male, 14 years old) noted “I can recognise the park because we can just see the shed”.

During the interviews, several young people also demonstrated more advanced forms of spatial literacy. For instance, they were able to point out areas of the communities that were now constructed, but not shown as such on the Google Earth maps, including *inter alia* their own homes. Other children (around a third) corrected aspects of either the background maps or their tracks, as we discuss further below. Around a quarter of the children, unprompted, began to take control, navigating around the map in particular ways – zooming in or out and panning. Moreover, several children actively disputed their tracks, noting that they were missing, incomplete or not in the right place as far as they were concerned.

In general, however, the types of errors reported by children related to the GPS signal being out of range and the need to ‘clean’ the data (see section 3).As Oliver et al. (2010) describe, the use of GPS technology is not without its problems in regard to issues such as

battery life and signal. Significantly, though, these 'problems' were an opportunity for further discussion. In some cases, researchers had to explain the presence of the 'spikes' to young people: "[w]hy's there a big spike? I didn't go there then [unprompted]" (Harry, Male, 10 years old). In other cases – for example tracks going across houses – children correctly interpreted errors in the data, leading to moments of satire and humour during the interviews (compare Hadfield-Hill and Horton 2014, on emotional moments in research with children):

“[A]pparently I've walked across some houses” (Charles, Male, 11 years old)

“Well that bit, no, I don't think that's an actual line because that's cutting through the middle of a house, crossing the road and then going through another house into their back garden, [laughs] see there, because there's no pathway going through there so I think that might just be a, say” (Chris, Male, 5 years old)

Abby Why hasn't it gone all the way round [the reservoir]? I didn't swim [laughs].

Interviewer You sure? Didn't get a boat?

Abby I did not swim. No, I didn't go in.

Interviewer What happens is sometimes if, if, because this, there's more trees round this bit of the reservoir.

Abby Oh yeah, there was loads of trees and we went down a bit.

(Abby, Female, 10 years old)

These examples show young people were adopting what NRC (2006, 4) terms 'a critical stance to spatial thinking'. Albeit through irony and laughter, GPS traces were being weighed

up in a logical fashion for the likelihood that they were incorrect, based on known knowledge of local routes or their memories of where they had actually been that day. This suggests – once again – that children's levels of spatial literacy (or environmental cognition) are often higher, at an earlier age than adults (including our research team) would expect. Matthews (1992) observed something similar two decades ago, yet it is interesting to see this replicated in the context of newer mapping and visualisation technologies. At the same time, it indicates the interweaving of emotions (especially laughter) and memories as children interpreted their maps – a point that we pick up in more detail later.

Critically, these observations and corrections have two implications, which might be extended in future spatial literacy research *with* children. First, they point to the discursive and co-constructed nature of spatial knowledge that is made possible through allowing children's 'voice' to be heard. Reflecting on our own approach, this implies that a yet-more child-led use of the interactive interview might have been possible and might be possible in future (cf Ergler et al. 2016) – perhaps in combination with standardised and/or statistical tests. Second, they demonstrated – qualitatively – spatial thinking related to Golledge et al.'s (2008) space-time primitive, together with a critical appreciation of images that is part of more advanced spatial literacy (NRC 2006, 4). In other words – in part *because* of the embeddedness of their observations and commentaries within their everyday routines – children were able to demonstrate the kinds of advanced spatial literacy skills, in context, that might be presented through other methods for 'testing' spatial knowledge.

4.3 Describing routes and routines: embedding spatial literacy in (memories of) everyday lives

In the previous two sections, our focus has been upon how qualitative indicators of spatial literacy are entangled with/in children's everyday mobilities. This section examines in more depth the recursive relationship between children's spatial literacy – particularly in for-

the-moment articulations of spatial skills evident in interviews – and the details of children's routes and routines. In particular – and moving *beyond* an emphasis on 'mobilities' – it explores how the GPS/Google Earth activities enabled children to outline lucid, detailed *memories* about their everyday lives, often heavily infused with emotion. In these ways, this section both extends and specifies our more general call to (re)connect spatial literacy and children's geographies, and develops recent work on children's memories and emotional geographies (and especially belonging and place attachment – e.g. Bartos 2013).

Fundamentally, the Google Earth images helped several children remember where they had been during GPS week, leading to observations in which spatial literacy was entwined with discussion of where friends or family lived, and daily or weekly routine. Characteristic of the type of memories triggered are Billy and Nazia's responses to their tracks:

“Yeah, I remember that because I went, I went up here, obviously I went here to get my mate Georgio and we went up to there and we decided to go up to the shops, we saw my grandad who give me a couple of quid and then we decided to go to Morrison's but then we didn't, so then we kept on walking back and forwards to try and pick up my mate to go and take him” (Billy, Male, 13 years old)

“We were picking, playing from, with my brother and we went there, played, played a couple of tag games and we came back home because of the, because it was going much more darker” (Nazia, Female, 12 years old)

Clearly, from a methodological point of view, the tracks worked as a stimulus for further discussion with young people (Oliver et al. 2014). This links with literatures on visuo-spatial working memory as a specific memory type with differentiated sub-types (Cornoldi and

Vecchi 2003, 73), although in this case memory is triggered by an image recursively linked back to 'real', remembered experiences as opposed to more classic testing in which simultaneous or sequential images are shown first and their retrieval investigated through a practical task. Thus, Google Earth (and Virtual Globes more generally) could usefully be used in tandem with other stimuli in future work, given that self-report does not give a fully accurate picture of journey ordering (Oliver et al. 2014).

Nevertheless, the advantage of the Google Earth activities was that children provided very detailed accounts of the routes they had taken, within discussions that entwined daily/weekly routines, events that happened during GPS week, inter-personal relationships, and detailed descriptions of places. Significantly, it was possible to discern moments at which children's memories of place were being actively (re)constituted in the for-the-moment situation of the interviews. For instance, in Hayden's interview, the frequent 'oh yeahs' and pauses highlight quite straightforwardly how spatial memories and literacies were entangled:

“Let me think, oh yeah, yeah, that's my friend's house, so I come here, that's the roundabout, I come over the roundabout and then go, turn right and then go into [street name]and then ... Erm, oh yeah, course that's the farmers field and then that's the, they're the, all the trees and stuff and then go over to there and then that's, that's my road”
(Hayden, Male, 10 years old)

Recursively, in terms of spatial literacy, this was a type of 'referential searching', a gradual orientation to both the map and Hayden's embodied, spatial memories (finding the house in relation to the surrounding fields), and was typical of that practised by young people during the interviews. At a general level, this finding is broadly in agreement with Gersmehl and Gersmehl's (2007) term 'association', in which a pair of features that have a tendency to

occur in similar places arises. Here, however, we do not have the highly generalised and physical associations of Gersmehl and Gersmehl (op cit.); rather, we have highly personal associations gathered by the children as part of their everyday experience. This practice had strong links to children's way-finding experience using familiar landmarks. Several young people orientated themselves on the Google Earth outputs via other known places (Liam [Male, 10 years old]: “[i]f Elliot lives there, Brogan lives there”), or did this specifically in relation to events during the GPS week (Liam: “[t]o Lexis's, then Lexis weren't in”).

Thus, the Google Earth activities acted as a cipher and frame through which the embodied geographies of children's everyday routines could be articulated. In distinction to much previous work on children's embodied geographies, however (e.g. Horschelmann and Colls 2009), these activities explicitly enabled detailed reflections upon the *memories* of those embodied experiences – in fact, these resembled spur-of-the-moment, unanticipated ‘reveries’, the kinds of which Philo (2003) calls for in his discussion of how childhood memories may erupt in/to adulthood. On the one hand, such reflections led to rich recollections of the games children played – and of having *fun* – but which were thoroughly place-aware (Bartos 2013):

“Erm, that's the little field, I kept on going round it and round and round. I just like going round places over and over again, so I can pick up speed on my bike, so I want to go round and round and round and pick up speed then” (Taffy, Female, 14 years old)

“It's a game, one, one person's it and we've got to hide, there's loads of people, there's like and we said that that was the, that was the place where you had to go and that's the safe area and you have to, you have to get there and, before the other person gets you, so basically we was doing a massive game of Manhunt” (Simon, Male, 10- years old)

On the other hand, children's engagement with the Google Earth images enabled incredibly detailed memories of and feelings about the everyday sociabilities through which their mobilities were produced (Mikkelsen and Christensen's 2009). For instance, Kevin recalled:

"I called for my friend Olis and then we walked down here, we played at the park, we went all the way back down to call for James, see if he wanted to come up but for some reason he just never comes out, I don't know why. So we walked all the way back, after we realised he wasn't in, so we walked back. Olis got a call from his mum saying we need to go home, so I walked, I was walking down, I walked down home and then I saw my mum go past and she was picking up Charlotte, so I asked her if she could drive me home" (Kevin, Male, 10 years old)

Tying these two observations (about play and sociability) together, children pointed out shortcuts that they had used during the GPS week. However, these shortcuts were not simply ephemeral, spur-of-the-moment choices (compare Mitchell and Elwood 2012). Rather, they were embedded *both* in children's own more enduring spatial knowledges *and* in knowledge about their communities passed on by parents and grandparents. Therefore, shortcuts featured strongly in children's narratives, as important kinds of place-based knowledges, shared and remembered between different generations of the same family – but, equally, part of the process of meaning-making in new communities that had only existed for ten years:

"Well some, my nan knows like lots of shortcuts, she's got to walk a long way to her house and she knows some shortcuts, places and that. [...] And my dad knows shortcuts and he knows how to cut through streets and that to get to places. [...] And sometimes I use shortcuts to get to school and the shops

because when, shortcuts to the shop we just, I'm, I go round the edge of the, there's a little hole in the fence" (Claire, Female, 10 years old)

In this section, we have argued that the GPS week, and associated Google Earth activities, not only enabled children to articulate qualitative indicators of their spatial literacy, but to co-produce – with the researcher and the visualisation – detailed, embodied *memories* about their routes, routines, play and sociabilities in their communities (Pyry 2016). The latter is significant in that, as Oliver et al. (2014) explain, small detours and local meanderings are frequently not reflected within travel diaries or more traditional interview methods. They do show on GPS tracks, but without the co-production of memories through the interactive interview process, the detailed richness of children's experience is not discernable. Therefore, this approach has huge potential in terms of investigating the *embeddedness* of spatial literacy with/in children's everyday lives and a wider agenda that integrates children's geographies with spatial literacy scholarship.

5. Conclusions

Our fundamental aim in this article has been to argue for – and to begin to evidence – greater attention to how spatial literacy and children's everyday lives, mobilities, emotions and memories are embedded in one another. Given longstanding cynicism amongst children's geographers and other childhood studies scholars about psychological research techniques, we have sought to promote a (re)turn to a synthetic research agenda combining scholarship on children's geographies with a range of approaches that we have for shorthand termed 'spatial literacy'. In so doing, we have argued for an agenda that also (but not exclusively), attends to the recursive articulation of a range of *qualitative* indicators of spatial literacy, *with* children's everyday mobilities, routines, emotions and memories. Most pertinent to the diverse literatures

on spatial literacy, we demonstrated that children not only displayed analytical skills (for instance, in relation to scaling effects and pattern recognition) but that many also exercised higher-level, critical analysis, especially in relation to errors on Google Earth outputs. Therefore, we (re)connected with one of the founding principles of children's geographies, whose rootedness in studies of children's environmental cognition is, today, either taken for granted or, in much work, simply ignored. Additionally, we have sought to analyse how new conceptual languages around spatial literacy, and newer technologies (like GPS and Google Earth), might, recursively, afford a more enriched understanding of those issues – like mobility and emotion – that children's geographers now more routinely study, as well as more recently-emergent topics, such as memory.

In this article, we drew upon a large dataset to articulate some potential priorities for scholarship wherein children's everyday geographies and spatial literacy are viewed as *embedded* with one another. Throughout the article, we outlined a number of *specific* considerations for future research (not necessarily in priority order). Firstly, we highlighted the potential to use GIS, GPS, virtual globes and other digital technologies in research *with* children about their everyday lives and spatial literacy. In particular, we would advocate that spatial literacy, children's geographies and childhood studies scholars engage in *critical* but *creative* consideration of a range of emergent technologies (including 'wearables' that can capture video or sense changes in skin temperature) in bolstering the work presented in this paper (also Ross et al., 2009; Kullman, 2012). We call on spatial literacy scholars to draw more systematically upon the various methods that children's geographers and childhood studies scholars have developed for research *with* children – whether qualitative or quantitative – and have evidenced some of the benefits of doing so in terms of understanding how spatial literacies are embedded in mobilities, memories and emotions about particular places. Secondly, we argue that a synthetic approach might enable a toolkit for further extending 'beyond' voice in

witnessing children's embodied and emotional engagements with place. Therefore, such an approach might inform and be influenced by a nascent 'new wave' of childhood studies that has sought to combine biological and psychological with social analyses of children's lives (Kraftl, 2013a). Thirdly, and relatedly, a (re)turn to spatial literacy and cognition should not mean a lack of critical perspective about the socially-constituted deployment of such (knowledge) technologies. Rather, we would advocate careful consideration of the creative possibilities of such techniques on a path that weaves between an impulse to 'test' children and critical perspectives on the moral and political challenges of psychological knowledges (Gagen, 2015; Ergler et al. 2016). Fourthly, a key contribution of this article has been to extend beyond the familiar analytical frame of children's mobility, to consider children's *own* memories (rather than those of adults reflecting on their childhoods). We would argue both that memory should form an important part of the synthetic research agenda we advocate, as well such an agenda might enable scholars to extend beyond the little work that exists in subdisciplinary children's geographies on memory (Philo, 2003; Jones, 2003). In particular, a focus on more recent memories provides a way to stitch together the immediate, embodied, emotional interactions of children with/in urban environments (whose immediacy has been a locus for critique by some geographers) with the spatial knowledges gleaned repetitively over a longer-term basis, and which are *sedimented* through relationships with friends and family. In other words, these more recent memories offer further insights into syncretic processes of meaning-making and place-building – especially in newer communities such as those we studied.

In light of the above – and prompted by, but extending well beyond, the findings presented in this paper – we also suggest three *broader* considerations areas for further research, which articulate and extend contemporary scholarship in other areas of human geography too. Firstly, whilst children's geographers and those interested in geography

education have increasingly collaborated, albeit under the banner of 'geographies of education' (Holloway et al. 2010), there is significant potential to do so more specifically around issues of spatial literacy. Such work might not only address a key gap in research on geographies of education – a general lack of attention to practices of learning-itself (Kraftl, 2013b); it might also offer the possibility for worthwhile collaborations between a range of scholars using diverse methodologies. Cutting-edge research about the learning of spatial literacy can, and should, be combined with appropriate critical reflection on the socio-spatial contexts in which such learning takes place. Secondly, this article has demonstrated that the *qualitative* unpicking of everyday personal geographies, as distinct from the statistical testing of spatial literacy models under controlled conditions, may have distinct advantages. It is our hope, however, that children's geographers and spatial literacy researchers might develop integrative, quantitative-qualitative models from which scholars in each field might benefit, and which might further our understandings of spatial literacy. Specifically, the use of Google Earth/GPS tracks, integrated with/in everyday experiences, memories and emotions, might extend recent work on individual variations in the development of perspective amongst children (Frick et al. 2014) and adults (Gersmehl and Gersmehl 2007), more general analyses of the evolution of visuo-spatial working memory capacity (Conte et al. 1995; Cornoldi and Vecchi 2003) and questions of scale.

Finally, and more broadly, self-defined children's geographers might (re)engage in more diverse ways with contemporary research in various branches of spatial cognition and, for instance, cognitive developmental psychology. Journals like *Children, Youth and Environments* contain many of the latter kinds of study, yet interaction and citation between that scholarship and (especially UK-based) children's geographies is relatively and problematically rare. This is not to say that children's geographers should seek to 'return' to an approach that pre-dates the – still-valid – critiques of feminist geographers and the new

social studies of childhood (nor are more recent studies by psychologists so uncritical). Indeed, we must build upon these critiques and their subsequent approaches to studying childhood to more fully consider the possibilities for developing methodologies through newer, digital technologies like Google Earth. Any new research agenda that encompasses both children's geographies and spatial literacy must consider ongoing questions about the adult-led nature of research in both fields, and the resolution of emergent ethical issues – not least in terms of the 'ownership' and archiving of data (Ergler et al. 2016). Therefore, as part of a nascent turn to critical engagement with neuroscience, attachment theory and other cutting-edge psychological research (Kraftl, 2013a), we would suggest that critical, but engaged, collaborations between children's geographers and spatial literacy scholars could offer many fruitful opportunities for future research.

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ⁱ Further details about the project will be provided after the review process is complete.