

ARTICLE 2

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Performing hygiene: the influence of everyday practices on the health of home environments

Abstract

Recent research suggests that the greatest threat to children's health from home environments across much of the industrialised world may no longer be pathogenic microbes, but impoverished microbial communities and the chemicals used in everyday products, including those used for cleaning. This paper proposes that given this re-orientation of harm, concepts of hygiene should be updated accordingly. However, little research has been conducted which a) integrates knowledge from the diverse disciplinary fields concerned with indoor environments, such as microbiology, chemistry and design, and b) examines how individuals conceptualise and enact hygiene to create healthier indoor environments for their families, and to what extent their practices achieve this.

To gain insights into the factors that influence how hygiene is enacted in the home, and its consequent effects on the composition of the indoor environment, it is necessary to transgress traditional disciplinary approaches to investigating indoor environmental health and integrate knowledge from experts and lay people who inhabit these environments. To do this, this paper draws on recent scientific and design literature addressing key determinants of environmental health in homes, in combination with qualitative research into the ways that parents in Sydney, Australia define, perform and measure hygiene in the home environment.

The findings presented illustrate that common hygiene practices with potentially harmful outcomes often emerge from compromises between competing priorities within complexes of home practices. Factors that influence the dynamics that determine which activities are prioritised and how they are performed are highlighted. Some notable factors include: confusion and uncertainty associated with the sensory proxies used to determine cleanliness and risk of harm; increased sensitivity to the potential presence of microbes over other potentially harmful micro-species; and the health histories and experiences of parents and children.

Introduction

Recent research from diverse fields has demonstrated that indoor environments contain a number of significant health hazards. Air pollution in the home is now ranked the ninth largest Global Burden of Disease risk (Forouzanfar et al. 2015). Those most susceptible to its effects, including the very young, elderly and those with compromised health, are likely to have higher exposure than those who spend less time indoors (Kumar et al. 2016). The types of health hazards present in home environments are complex, varied and geographically contingent (Lyytimäki 2012). In much of the developing world key sources of pollution are indoor smoke from fires and cigarettes, while in developed countries pollutants primarily emanate from consumer products (Kumar et al. 2016). Products commonly used in home cleaning and bathing practices contain classes of chemicals, such as phthalates and some solvents, identified as harmful to human and environmental health (Clayton et al. 2011; Gosens et al. 2014). Of the 80,000 chemicals registered for use in consumer products, only a small percentage have been tested for their long-term effects (National Toxicology Program 2018). However, recent research has demonstrated that many of the chemicals used in common personal care and cleaning products have carcinogenic or endocrine disrupting effects (UNEP/WHO 2013; Weschler 2009; Zoeller et al. 2012). Children have been identified as particularly vulnerable to endocrine disrupting chemicals (EDC), which have been linked to health conditions including diabetes, obesity, some cancers, and impaired reproductive and neurological development (UNEP/WHO 2013).

In addition to chemical pollutants, another crucial contributor to poor indoor environmental health are certain types of microbial communities. On the one hand, homes can become sites in which pathogenic bacteria and viruses are transferred between people, and fungus can become established in damp areas causing allergic reactions. On the other, both a lack of microbial diversity in the home, and the absence of farm animals or dogs that carry particular microbes that 'train' human immune systems (termed 'old friends'), have been associated with the rise in childhood allergies (Rook, Lowry & Raison 2013) and Leukaemia (Greaves 2018). The design of domestic objects, homes and the use of anti-bacterial products have all been associated with declining microbial diversity in homes (Dunn et al. 2013; Flores et al. 2013; Rintala et al. 2008). For example, the use of chemically treated finishings such as anti-microbial paint, chemical cleaning products, and home designs that restrict airflow between the indoors and outdoors, can all contribute to a decrease in microbial diversity and can encourage more resistant microbial species to thrive and colonise (Adams et al. 2016; Martin et al. 2015; Meadow et al. 2014).

Despite clear evidence from chemistry and microbiology that the practices involved in particular modern lifestyles influence indoor environmental health, there remains a gap in the literature examining how different material, biological and cultural forces come together to create particular 'micro-ecologies' in the home. Moreover, no evidence could be found of research that examines how modern ways of defining and maintaining a hygienic home influences the composition of home micro-ecologies', which in turn influence health outcomes.

This paper begins to address this gap by moving beyond discipline-specific investigations to integrate perspectives on indoor environmental health and examine the ways that home hygiene is actually enacted in practice, and how these practices might be contributing to suboptimal indoor home environments. This research was driven by a broadly 'transdisciplinary' approach, which for the purposes of this research, is characterised according to four criteria synthesised from definitions by (Brown, Harris & Russell 2010; Uiterkamp & Vlek 2007; Wickson, Carew & Russell 2006) – (1) problem oriented, (2) participatory/collaborative, (3) transgresses disciplinary boundaries and seeks to (4) integrate often disparate fields of knowledge. Based on this transdisciplinary orientation, the following section details how and why an approach focused on social practices was adopted to trace the relations between social and material elements within home environments that may be influencing the composition of home micro-ecologies.

Research Approach: tracing home hygiene practices

Theories of social practice, although heterogeneous, generally focus on the dynamic interplay between material things, meanings and beliefs, and embodied knowledge at different scales of social life (Shove 2004). A commonly cited definition of practice is provided by Reckwitz, who states that practice is:

"...a routinised type of behaviour which consists of several elements, interconnected to one another: forms of bodily activities, forms of mental activities, 'things' and their use, a background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge." (2002: 249)

An orientation to practices allows insights that integrate: first, the latent and explicit influences of hygiene in the design of domestic interiors and objects; second, the deliberate and the unquestioned ways of performing particular activities, such as dish washing and teeth brushing; and third, the more deliberate cognitive decisions and beliefs about what constitutes a healthy environment.

Although the dynamic enactment of all practices by all individuals in the home create material flows, some practices play a particularly significant role in configuring the flows of microbes and chemicals in the home. All routine activities conducted in the home, such as cooking, watching television, and getting ready for work, determine the flows of materials in, out and around the building. However, some practices, such as cleaning, have a more direct role in structuring the home micro-ecology, due to the common use of products containing anti-microbials and other EDCs, and the frequency and ubiquity with which they are used (Halden et al. 2017; Sherriff et al. 2005).

Conceptualising and practicing hygiene

The way that cleaning practices are conducted is closely linked to how hygiene is understood and measured. Hygiene is defined as the "conditions or practices conducive to maintaining health and preventing disease, especially through cleanliness" (OED 2016). However, since the mass popularisation of germ theory, hygiene has increasingly become synonymous with sterility, narrowing its scope to a focus on the extermination of 'germs' (Campkin & Cox 2012; Pink & Mackley 2015; Shove 2003; Smith 2007). Moreover, Shove (2002) and others (Campkin & Cox 2012; Smith 2007) have argued that cleanliness conventions have escalated and become standardised across the industrialised world in late modernity. These escalating, and increasingly complex standards of cleanliness, and the market's capitalisation of these trends, has meant that the networks of products that serve people's daily cleaning practices require ever-higher levels of energy, materials and chemicals to produce the desired functionality (Shove 2003).

To broaden ways of conceptualising and investigating home hygiene beyond a focus on germs to account for the complex actions and interactions of microbes and other significant micro-entities that influence health and disease outcomes, we use the term 'micro-species' (Wakefield-Rann et al forthcoming). 'Micro-species' include microbes (such as bacteria, archaea, viruses, protists, fungi and other microscopic animals and plants) and active organic and inorganic chemicals that exist at a micro-scale (invisible to the human eye) in homes. For the purposes of this research, the separation of living microbes, non-living chemicals when analysing a micro-ecology obscures important shared traits related to how they act, react and influence the environments they exist in. Unlike visible species, micro-species can only make their presence known through proxies that must be read by humans, such as odour, discolouration of surfaces and clothes, skin rashes and illness. The complex interactions between micro-species, guided by the actions and objects that populate daily life, shape the home 'micro-ecology' and whether or not it is a hygienic, healthy environment for human habitation.

Research sample and recruitment

This analysis draws on data collected from a qualitative study conducted in Sydney, Australia with 10 parents of children under five during 2017. The aim was to investigate the ways in which competition between complexes of practices structure the enactment of hygiene in the home. This necessitated a significant depth of engagement with each participant, adopting multiple research methods. Given the level of engagement and the purpose of the research, a sample size of 10 was deemed appropriate. In other studies where an exploration of complex phenomena or human engagements, rather the demonstration of statistical significance, is an objective, sample sizes of between 6-10 (Malterud, Siersma & Guassora 2016), over 6 (Morse 1994) or 5- 25 (Creswell 1998) have been recommended. We acknowledge that a larger sample size would have enabled an exploration of a greater range of practice complexes involved in the enactment of home hygiene.

Participants were recruited to the study through existing networks of parents in Sydney, including through email and social media. The only selection criteria were parents must have at least one child under five and live in Sydney. These criteria were selected primarily because children have been identified as the most vulnerable to risks posed by indoor environmental conditions. Although demographic diversity was sought within the sample, specific categories, such as income, gender and ethnicity were not selected for.

Respondents were primarily female (9/10), which may reflect availability and degree of engagement with domestic environmental health issues, as suggested by other research (Mackendrick 2014). Of these, 8/10 were engaged in paid employment and one was studying. Although ethnicity and income were not explicit selection criteria, only one participant identified cultural influences as a significant factor in their cleaning practices, and no participants were of a low 'socio-economic' status according to the Australian Bureau of Statistics definition (ABS 2011). Further examination of practice influences across demographic categories would be worth exploring in further research. The final sample of participants provides insights into the complex of practices performed by women from English speaking backgrounds, who work full or part time,

and are of a middle to high socio-economic status. Although not directly selected for, insights into the domestic practices of this group can be considered valuable given the expansion of the 'middle class' in both Australia and globally, as the normative lifestyle practices of these groups may form the basis of aspirational changes being made by upwardly mobile families (Koo 2016).

The methods used included a 'cleaning diary', semi-structured interviews and practice demonstrations in participants' homes. The cleaning diary required participants to record all domestic cleaning or hygiene related activities that they conducted over a period of 7 days, and when they were conducted. Participants were encouraged to note down when they cleaned and the stimulus that triggered them to clean. This method, adapted from Sofoulis' water diaries (2005), revealed when certain cleaning activities took place and what influenced this, in addition to highlighting the key forms of engagement between participants, products, other objects and perceived sources of environmental risk or 'uncleanliness' that take place throughout a day or week. Although there are clear limitations of self-reporting methods, the diaries provide a valuable indication of the frequency of particular tasks and other activities, how cleaning and hygiene are defined by participants, and how cleaning is entwined with other practices.

After completing the 'cleaning diaries' participants were invited to be involved in a semi-structured interview in their homes around a week later. Interviews were approximately 60 minutes and included partial practice re-enactments, which involved participants demonstrating how they used particular products and the ways that they approached cleaning different parts of the house. These methods were selected due to their capacity to access participants' practices from different angles, rather than relying exclusively on narrative descriptions of different activities. The diaries provided a sense of the temporal dimensions of particular practices and their alignment with other practices over the course of a week. They also provided an indication of the activities that participants actively defined as hygiene-related without external direction and prompting. The situated semi-structured interviews, although focused around the retelling of practice, enabled participants to demonstrate how they engage with particular materials and why. By situating the interviews in participants homes, there were also opportunities for them to be reminded of certain activities, product choices, irritations, quirks and other features of their homes that guide how they clean, while physically moving through space.

Discussion within the semi-structured interviews focused on how parents negotiate cleaning and other practice demands and how this influences the ways that they clean. Other focal areas included: their priority hygiene concerns, how they perform particular activities, products they did and did not like, their sensory engagements with their environment, how their home influences their practices, how their practices have changed over time and why and how cleaning and other hygiene-related practices are integrated and prioritised in their everyday lives. These methods uncovered the household dynamics and interactions between various practices that influence how hygiene is enacted in daily life. Interview data were professionally transcribed and thematically analysed in the NVIVO qualitative data analyses software program. The thematic codes centred on the focal areas listed above, and how competition within and between practices and practitioners influence how, when, and by whom the home is cleaned, and how different activities are prioritised.

The following section examines the findings from this research and how the interactions between practices that structure the flow of daily life shape how and when cleaning is performed, and the implications for home micro-ecologies.

Hygiene outcomes and competition within complexes of practices

The results from this research demonstrated that the way parents attempted to maintain a hygienic home environment emerged from compromises and competing interests within bundles and complexes of practices. The key findings discussed include how hygiene priorities shift after having children and the way time and resources are allocated to different practices under time pressure, how this dynamic influences the delegation and performance of tasks, and the implications for the composition of the home micro-ecology.

Within the social practice literature, co-existent practices are often described in terms of *bundles* of practices, which are loosely intertwined through co-location and co-existence, such as watching television and eating dinner (Shove, Pantzar & Watson 2012), and *complexes* of practice, which are more integrated and interdependent arrangements, such as washing one's hands and eating food. A focus on the dynamics of complexes of practices, rather than exclusively examining meanings or attitudes towards home hygiene, has generated insights into how competing priorities, such as family time, leisure time, work, and the aesthetic of the home, in addition to geographic and infrastructural elements, influence how hygiene is actually enacted.

The majority of parents interviewed reported that time pressures had a significant influence on how they prioritised tasks related to cleaning the house. For the 8/10 participants who were engaged in paid employment, the arrival of children simultaneously reduced the amount of time available for maintaining the house while introducing a range of new hygiene concerns.

After having children, greater emphasis was placed on removing potential germs from floors and benches, while activities such as tidying became less of a concern. One participant stated:

“There's probably lots I do now that I never would have been so fussed about. Just in terms of keeping, probably, surfaces way more clean, way more often. Probably, yeah, frequency is the biggest - would be the biggest thing, for sure. Then yeah probably floors. Just in terms of using Dettol and stuff. I would have never have thought - I just would have used a floor cleaner rather than an antibacterial thing like that.”

This heightened concern over the germs that children may be encountering, particularly on surfaces, meant that cleaning methods were sought that were less time and labour intensive but effectively addressed perceived hygiene risks. As a result, antibacterial surface sprays and wipes were reported as a popular option by all participants. These products enable the effective removal of food, toilet mishaps or any kind of grime without having to clean an entire surface or area. This is illustrated well by Participant 3:

“I've got these Dettol antiseptic wipes that I use to wipe the floor and her surface because I actually put the food straight on there, so she's feeding off that surface.”

The preference that children are in clean environment, but the undesirability of prioritising cleaning over other pursuits, such as family time or work, mean that parents often delegate a certain amount of cleaning to professional services and objects. Although all parents interviewed conducted some amount of cleaning, six out of ten employed a professional cleaner (one weekly, one fortnightly, three monthly and one as needed). A common reason provided was that the amount they perceived needed to be done for the house to be adequately clean, would detract too much from the time they spend with their family. Children also create more constant and new types of mess compared to adults, meaning that parents are often more engaged in frequent 'spot cleaning', and consequently delegate the less urgent, more substantive tasks to professional cleaners:

“The stuff we've let go since we had (child) - because we just don't have the time - is vacuuming, which we basically now have a cleaner that comes every four weeks and does it. We don't really do dusting. We don't clean in the inside of the oven. We don't clean the bathtub or the walls of the shower space. We let the cleaner do all that.... The stuff that we do, continue to do, is the vital kitchen related (jobs)... cleaning dishes... wiping surfaces, kitchen table, high chair.”

Tasks performed by cleaners are often more time and product intensive than the tasks parents reported to be conducting day to day. An implication of outsourcing more substantial cleaning tasks is that parents are often unaware of what products are being used to clean their houses. Only one of the six parents who hired a professional cleaner specified the products they wanted used. The others indicated that they were unaware:

“Do you know what? ...they come while I'm at work, so I'm not even here. I actually have no idea what they (cleaners) use or what they do... so I'll come home from work on the day the cleaners have been ... Before I give the boys a bath that night, I actually wash out the whole bath with water, because I can feel that it's got - you know how you can feel it's got residue on it? ...I'm like oh God, I don't want him soaking in something, I don't know what it is.”

Many of the materials and interactions that are influencing the micro-ecologies of homes are consequently often not the result of decisions directly made by parents about the particular micro-species they are concerned about. Rather, the desire to prioritise competing practices associated with family time, and more urgent tasks, in non-work hours meant that the products used in the home were often the choice of cleaning companies. Consequently, the emergent cleaning practices include products that are selected according to the attributes desired by cleaners, who are required to achieve a cost effective, yet satisfactory appearance of cleanliness for their client.

In addition to hiring professional cleaners, other cleaning tasks are delegated to objects that create a sense that the house is being adequately cleaned in between actual acts of cleaning. For example, Participant 6 uses a toilet 'disk' which releases product each time the toilet is flushed:

“These are the disk-y things that I put on the - I put on the - sits on the toilet bowl. ...Just because cleaning the bathroom seems like such a big deal. So, anything I can do to make it feel cleaner for longer is a Godsend.”

The delegation of certain cleaning tasks to professionals and objects has resulted in the adoption of cleaning practices that rely more heavily on chemical intensive products than methods which may take more time. Of all the parents that used professional cleaners, only Participant 2 directed their cleaner to use “more natural products”. Therefore, for the majority of participants, delegation of cleaning also meant that parents became less aware of the types of micro-species that were entering their homes and influencing their micro-ecologies.

Time pressure resulting from competition between practices also influenced how and where parents shopped for products used to maintain home hygiene. When asked what factors influence product choices, the ability to conveniently buy products where other shopping is taking place or online was a significant factor. When asked why certain products were selected Participant 1 noted: “Whatever's convenient at the time. So if we're over at (shopping centre) doing shopping that will be where we purchase things.”

These examples demonstrate that competition between practices within a given day result in different product choices at different points in time; even when parents are concerned about particular product attributes, purchasing decisions were not always made on that basis.

In addition to competition between pressures on the individual, hygiene outcomes also emerge from the competing practices of individuals living together at any given time. The specific ways of cleaning, how it is valued and prioritised by different individuals and the combinations of personal care and cleaning products used in different rooms by different people, all influence the composition of the home micro-ecology. Although in some cases one person was responsible for the majority of house work and shopping, in most cases, these tasks were divided to varying degrees and expressed divergent hygiene, aesthetic and time related priorities, for example Participant 6 explained:

“(my partner) and I have a continual disagreement about personal care products... he likes things that really foam up, like a good body [lather]- and I'm just like, that's all not really good for you... but he wants (sports brand) stuff with beads in it or whatever.”

When asked about the use of antibacterial personal care products, she stated:

“That's another thing that (partner) and I disagree about...He's pro, and I'm anti...Because I just don't feel like it's a necessary step, and I feel like it's quite hard on your skin, especially for kids. I would rather that they just washed their hands.”

These examples demonstrate that the flow of micro-species through the home from different products is guided by a confluence of interests and the tensions between them.

The way practices are prioritised echo back to transform the meanings used to justify and make sense of how practices end up being performed. This effect was particularly apparent in relation to the exposure of children to ‘dirt’ or ‘grime’. In 8 cases, after expressing a concern about not having time to clean the house to an acceptable standard, participants subsequently stated that some exposure to dirt was okay, or even beneficial. For example, Participant 9 indicated that she felt less guilty about her existing practices when she learned that some exposure to germs was beneficial:

“I think - actually two things. Maybe just time-wise, I just didn't have time to get on top of him, to get him clean and hands washed. Secondly, I watched a doco on - it was about allergies, but it was about kids that are exposed to different types of bacteria really early on in their life are less likely to have an allergy later on in life... So, then I think I was more conscious of well, maybe that - yeah, not - everything doesn't have to be so clean... Well it gave justification for me not being very tidy. I don't know. I was like, see, I'm doing something good for him.”

Despite the persistence of germ-centric narratives and practices of hygiene risk in the home, the act of relinquishing some control over dirt/child interactions recounted in the case above did, however, seem to represent a partial erosion of the belief that such interactions are necessarily harmful, even if this belief was not always translated into practice.

Similarly, the ordering of practices influenced how parents attempted to limit the amount of chemicals that their children were exposed to. Participants expressed a desire to avoid products containing chemicals, particularly on children's skin, despite continuing to use chemicals around the house that the children interact with in other ways, such as surface sprays. For instance, Participant 6 stated:

“Yeah, I just think... as natural as you can get it, as possible, because I think that there's a real issue with plastics and chemicals... particularly with little boys, in boys it can influence reproductive systems. So, I've tried to reduce the amount of ingredients, chemical ingredients, that go on their skin.”

The inconsistency of practices associated with avoiding chemicals around children when cleaning can be understood as a manifestation of competing practice demands. Anti-bacterial chemical sprays and wipes generally offer the most convenient options for dealing with the perpetual mess generated by young children, particularly if one is already busy. These products are also imbued with sensory attributes designed to reassure the user that they are effectively cleaning, such as scent (lemon and pine), lather and shine, all of which are achieved through the addition of chemicals. The role of these sensory proxies will be the focus of the next section.

This section has demonstrated that the way hygiene is performed in the home is a result of competition and tension between competing practices, and the intertwining of and tension between practices enacted by different individuals in the home.

The ways that changing relations between practices is influencing the temporal rhythms of daily life has been noted by a number of social theorists (Blue 2013; Hui, Schatzki & Shove 2016; Schor 1998; Southerton 2006). The reasons for perceived decrease in available time, are not, they argue, the result of any single factor, but the “squeeze of practice-related injunctions of sequencing, coordination and personalized scheduling”(Shove, Pantzar & Watson 2012: 95). As Southerton notes, each practice is accompanied by a set of requirements that enables competent and meaningful engagement to be achieved (Southerton 2006: 440).

These requirements must be balanced with those of other practices, so that the sets of practices carried, and their respective demands in terms of duration and timing, determine the overall sense of time pressure.

In the findings presented above, participants demonstrated the need to accommodate and synchronise numerous practices that have significant time demands, such as work, food preparation, taking care of children, shopping and cleaning. The need to mediate between the practice requirements of each resulted in a mediation of the materials, meanings and bodily competencies used to achieve each with a tendency towards faster, labour saving methods, such as the use of surface sprays and wipes to conduct reactive cleaning when needed, rather than time-consuming, routinised, systematic cleaning of whole areas or rooms. The following section presents findings on the crucial elements, and perceived practice requirements, that determine the ordering and performance of practices that influence hygiene in the home.

Sensory proxies are biased towards microbes

The elements that comprise a practice determine the amount of time, energy, thought and skill required to perform it. These relative demands of practices influence how they interact with other practices and how they are prioritised. We discussed in the preceding section how parents often felt that they did not have time to clean their home to a standard they deemed acceptable, resulting in the delegation of particular tasks to others and the use of products they perceived to be more effective and efficient at eliminating microbes. This section presents findings that suggest the way hygiene and 'cleaning well' have been defined in practice, necessitate a degree of engagement and rigour that is not achievable without a significant time and labour commitment. This is illustrated by Participant 9, who relates that:

“I just found that ... even with one kid, never mind two,...everything was always filthy. I think it's the adjustment to having a child in the house and being tired. So I got a cleaner once a fortnight, and we've kept it since.”

This section draws on our data to examine the standards and sensory proxies that have come to represent hygiene and 'cleaning well', and the implications this has for how and when cleaning is performed. In particular, it highlights a significant over-sensitivity embedded within cleaning practices to the potential risks posed by microbes.

The sensory qualities of micro-species play a significant role in how their capacity to cause harm is assessed. A unique characteristic of micro-species (compared to macro-species like humans and pets) is that they cannot be detected directly through the senses, rather, individuals must rely on sensory proxies, such as scents or visual clues, to determine their presence. However, the proxies that are relied upon are not always accurate indicators of micro-species presence, or the type of threat they may pose. The reading or misreading of sensory proxies used to ascertain micro-species presence and risk has a significant influence on the types of demands that accompany a practice such as cleaning. If a house is constantly presenting signals for germs, such as discoloured white tiles, dirty marks on the floor or lingering bathroom odour, the time and energy that parents perceive they must dedicate to cleaning becomes considerable and influences how cleaning is performed and prioritised in dynamic, daily negotiations between practices.

In all cases, our research revealed that participants were sensitive to more sensory proxies for microbes than for chemicals. This finding supports existing research which indicates that the minds and senses, particularly of people in western industrialised cultures, have been trained to perceive microbes through multiple sensory inputs, such as foul odour, sticky surfaces or visible dirt or discolouration (Smith 2007), while other micro-species lack the proxies that would enable them to be detected. This is an example of what Murphy (2006) terms a 'regime of perceptibility' in which the skills required to perceive harmful chemicals have not been as culturally or physically well entrained as those required to perceive 'germs'. This regime was expressed not only through narratives, but in product designs that make certain forms of dirt more detectable, and the way bodies have been trained to recognise and react to the presence of particular materials and substances.

The design of the home, interior furnishings and building materials all influenced how participants determined how and when parts of the home needed to be cleaned. All participants were particularly sensitised to the presence of visible dirt on the floor and its implications for their children's health. The non-porous, light-reflecting qualities of floorboards reassure participants that dirt would not be 'hidden', as it would in carpet. However, the increased dirt-revealing capacities of floorboards mean that participants perceived they require much more cleaning, much more frequently. The following quote illustrates how floorboards reveal dirt in particular ways that other surfaces, such as carpet, may obscure:

"Because its all floor boards in this house... I get up in the morning and the sun comes beaming through this window here and it will show every single cat hair .. I always think I thought that floor was clean. It's actually just covered in cat fur [laughs]. So that's when I think okay I've got to clean the floors today. So even though without the sun shining on it's actually - it looks okay, it's really not. It really just needs cleaning." Participant 8

The revelation of 'dirt' on surfaces influences the flow and prioritisation of practices by commanding immediate attention. The way that dirt and other substances materialise on surfaces also guide product choices. For example, three participants noted that they do not like to use of soap because of the 'scum' it creates on shower tiles and glass:

"I like body washes because they don't put much scum on your glass. Soap is just awful for scum." Participant 8

The aesthetic qualities of surfaces were also identified as key deterrents for parents attempting to use less chemical intensive products for cleaning, such as vinegar and bicarbonate soda. The expected 'sparkle' and 'shine' of surfaces that is expected to represent cleanliness, is often not achievable without chemical-intensive products:

"So I have tried some other things and I've tried some natural methods. I've tried vinegar and water and... Facilitator: It didn't work out? Interviewee: That didn't quite do it. It didn't get that sparkle." Participant 1

These examples corroborate historical accounts of domestic objects that show how the design of cleaning appliances has not only been guided by the increased need for convenience and efficiency, but the imperative to make pathogen carrying dirt more visible (Smith 2007). In their history of the aesthetics of the modern home Lupton and Miller (1996) describe the process by which hygiene became the driving aesthetic in bathroom design from the 1890s in England, white porcelain fixtures made from vitreous china and enamelled iron were liberated from their moisture and germ-gathering dark wooden enclosures, and made flush with the floor and walls, thus rendering dust and grime immediately visible. Similarly, when vacuum cleaners became standard household appliances in the post-war period in places such as Europe, the United States and Australia, the dirt that was previously on the floors was aggregated and made visible and an isolated mass, making floor dirt more perceptible, and reinforcing the need to regularly clean (Lupton & Miller 1996).

The intertwining of hygiene, design and aesthetics over the 20th century complicates the meanings and materials and skills that encompass cleaning practices. Although microbes are made more perceptible by many modern furnishings and objects, cleaning may not always be explicitly intended to remove them. Participants frequently cleaned to influence the appearance of a space or surface. As Participant 6 put it:

"It's the Zen of a clean surface, like looking across clean surfaces, he (husband) appreciates that."

However, because of the legacy of hygiene in 20th and 21st century design definitions of a presentable attractive home are inextricably bound to definitions of hygiene that require surfaces to reveal dirt and people to remove it.

This section has demonstrated that the evolution of cleaning practices alongside definitions of hygiene that require dirt to be revealed and removed has resulted in cleaning practices that demand a significant time and labour investment. The inability of parents to meet these perceived needs given the other practices making demands on their time has made faster more efficient cleaning options more attractive. A key way that this greater efficiency is achieved is through targeted applications of chemical intensive products, such as anti-bacterial sprays and wipes. This crucial role of sensory proxies in perpetuating this issue suggests that design will have an important role to play in future transdisciplinary research into how the sensory attributes of objects can be re-oriented to create new indicators for hygiene.

The following section examines instances where parents have become sensitised to non-microbial environmental risks in the home, and how this has influenced how their cleaning practices are performed and negotiated.

Health history and experiences sensitise parents to new-micro-species

Despite the dominance of microbes in the perceptual landscape of the home, factors were identified that sensitised parents to other micro-species. Disruption to practice elements that introduce new variables to consider often caused confusion and uncertainty in cleaning practices. The two most notable disruptive elements that emerged were reactions in children's bodies, particularly their skin, and the health experiences of mothers. These two experience types in particular enabled the perceptual dominance of microbes to partially recede, and chemicals and other allergens to become more apparent.

The reactivity of children's skin, especially due to eczema, was the most pronounced factor that sensitised parents to new micro-species in the home that affect children's health. The rashes that appear on children's skin as a result of eczema and other allergies made many parents begin to read the labels of cleaning and personal care products for the first time. In relation to learning about chemicals in products one participant noted:

"I'd never thought about it before... then I think it all started because my son had eczema and I think then the first thing was to consider what washing powder you're using because it can be irritating to the skin. Then that was what started the whole journey into reading more about these types of things."

In addition to making chemicals more perceptible to parents, eczema and skin rashes also made parents realise that the use of certain types of products, such as soap, may not be necessary at all. Participant 9 mentioned that she only ever washes her children with water, and did not raise any concerns about the hygiene implications of this:

"Yeah, we don't use any soap at all on either of them... The little one doesn't touch soap at all...so even if he's washing his hands, I do it with water, because he's quite sensitive to stuff."

Commented [RW1]: Maybe remove

The other significant factor that sensitised parents to new micro-species was the health experiences of mothers. Participant 2 has undergone a long process of diagnosing "ongoing low energy and digestive problems". A lack of solutions led her to begin to examine the ingredients of products and prompted her to start removing certain chemicals from her family's diet and home practices. Participant 2 increased awareness of chemicals in products resulted in a heightened sensitivity and aversion to the proxies for chemicals, such as strong product scents:

"With the laundry powder, I can't stand the strong commercial (products)- like I can smell when the neighbours are doing their washing. I just can't - I hate that smell. Like a friend just gave me some pants that didn't fit her and I just can't stand the smell of them because I've quite a strong sense of smell I think and I can't stand the really strong - like I like things that have the natural, pleasant smell, not if it's really super strong."

Other participants health experiences influenced their sensitivity to chemicals in other, more conditional, ways that resulted in a practice change for a limited period time. For example, Participant 1 explained that she became aware of more chemicals in products and began to avoid them when she begun to undergo In Vitro Fertilisation (IVF):

“I mean the reason why I was sort of a little bit more conscious of it is because I had to do IVF with both the boys. So I guess I was trying to sort of think okay I'm not going to jeopardise anything... So I think at the time I made sure that I wasn't using any nail polishes unless they were chemical free... I avoided any sort of hair products and even getting my hair dyed and things like that for a while.”

The participant acknowledged the potential for particular chemicals to cause harm through her limited use of certain personal care products and did not go to the hairdresser, however she abandoned most of these practices once the children were born and the perceived risk was gone. When asked if these chemicals and products were only avoided during pregnancy, she said:

“Yeah, yeah probably... Also going back to work and things like that”

Participant 1's experience meant that her practices were altered for the duration of the period she believed particular products might cause her harm. However, the demands of other practices, such as working and looking after two children, meant that she reverted back to using products in practices that enabled her to achieve a state of personal and home hygiene efficiently and to her usual high standard. Conversely, the chronic nature of Participant 2's health condition resulted in a permanent alteration to her practices to avoid chemicals.

This section has highlighted that cleaning practices are guided by sensory proxies that determine the type and amount of time, energy and resources that must be dedicated to achieve a cleanliness standard deemed adequate. The co-evolution of cleaning practices, culturally prevalent definitions of hygiene, and domestic objects, furnishings and products, have made 'germs' and 'dirt' more perceptible than other micro-species. However, research also revealed that particular health experiences of children and parents sensitised participants to the potential risks posed by non-microbial micro-species by making them perceptible in new ways. The manifestation of new micro-species in the minds or bodies of participants and their children altered the normal performance cleaning practices and how different hygiene outcomes were prioritised. Participant 1's reversion back to her old practises once the risk posed by chemicals in products was perceived to be less acute demonstrates the persistence of the notion of cleanliness centred on the elimination of microbes.

Developing a new research agenda

To improve the environmental health of homes, the conceptualisations of hygiene embedded in current normative practices must become more nuanced and encompassing of a broader range of hygiene risks beyond microbes. Practices that implicitly define good home hygiene and 'cleaning well' as the extermination of dirt and germs require a significant amount of time, vigilance and labour. This paper has highlighted that in the context of homes characterised by significant competition between practices for time, parents often feel they do not have the capacity to meet normative expectations of a clean home. This combination of time pressure and high-demand cleaning practices results in the delegation of cleaning tasks to professionals and products that are perceived to clean fast and effectively. These products, such as anti-bacterial wipes and surface sprays, generally contain a range of chemicals to make them smell fresh, create a 'sparkly' surface, and sterilise with anti-bacterial agents. Scientific research suggests that none of these product attributes are more effective than soap and water in creating an environment free of potential pathogens (Aiello, Larson & Levy 2007). They are creating a *sense* of cleanliness, while contributing significantly to the amount and diversity of chemicals in the home's micro-ecology.

To begin to investigate how cleaning practices could be reformed to address the actual risks posed by micro-species in the home, we propose that a new transdisciplinary research agenda must be developed. Based on the findings presented in this paper, an approach to investigating indoor environmental health that includes, but does not *prioritise*, scientific understandings of the problem and potential solutions, are evidently required. The dominant research discourses on indoor environmental health issues often presented in scientific journals frame the issue based on disciplinary orientation – such as particulate matter in indoor air (Meadow et al. 2014), chemicals in consumer products (Loretz et al. 2008), or the micro-biology of the built environment (Adams et al. 2016). A single discipline's exclusion of all variables within the indoor 'ecosystems' and how they interact with one another, leads to narrow definitions of the problem, and obfuscates solutions that do not fit disciplinary framings. Scientists examining the microbiome of the built environment have begun to call for a new research program that accounts more for chemical use practices (National Academies of Sciences & Medicine 2017). However, the integration of relevant scientific knowledge is only half the picture. Unless social scientists and 'users' are engaged to analyse how and why particular practices are leading to the development of particular micro-ecologies, the design of effective interventions will be obscured. Finally, in addition to social and physical scientists, this paper has demonstrated the crucial role that the design of the built environment and objects play in the reproduction of dominant domestic cleaning practices. Architects and designers will consequently play a crucial role in any attempt to reorient material engagements to sensitise people to risk, and encourage practices that more accurately reflect the actual needs required for hygienic human habitation.

For a transdisciplinary research agenda addressing sub-optimal home environments to be effective and genuinely transdisciplinary, the boundaries that separate and stratify the disciplines detailed above must be transgressed. This will involve not only the dissolution of expected methodological approaches, but critical reflection on the politics of knowledge which has prioritised scientific ways of knowing, over 'softer' more qualitative forms of enquiry or lay experiences, in indoor environmental health research to date (Brown, Harris & Russell 2010). Such a research agenda has the potential to match knowledge about health risk with knowledge about the material culture, meanings and habituated actions which constitute current home hygiene practices, to gain a more sophisticated understanding of how this issue can be addressed, and by whom.

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