DRS2020
BRISBANE, 11–14 AUG
SYNERGY

Phantom Volume: A spatial explanation for domestic clutter

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doi: https://doi.org/10.21606/drs.2020.255

Abstract: Philosophical assumptions influence empirical design. For example, physical shape is typically described in terms of 'positive form and 'negative space.' Here, a third type of shape is proposed, called "phantom volume," comprised of the geometrically-predictable forms delineated by movements of a product, its parts, accessories, the user's body, and the cone of vision. Phantom volumes are critical to product function, because things cannot be used if access is blocked. This observation suggests that domestic "clutter" may be defined as the *physical effect created when the phantom volume of one object is obstructed by the positive form of another* — proposing a mechanical origin for psychological frustrations. The concept is illustrated with 3D renderings of a domestic coffee maker, revealing unexpectedly large and irregular phantom volumes. The quantitative 3D methodology might offer future applications in planning, research, or student assignments.

Keywords: phantom volume; clutter; kitchen design; 3D visualization; hegemony of habit

1. Introduction

This paper is part of a broader investigation into the design of contemporary Western domestic kitchens, using the kitchen as a case study to examine the impact of philosophical frameworks on problem definitions in design. Here, the kitchen is examined as a physical site, in which product 'forms' include not just solid shapes, but also the volumes of space required for free movement of the product and user, described with the neologism "phantom volume." The concept is illustrated using the arbitrary example of a domestic coffee maker, for which a 3D visualization reveals unexpectedly large and irregular phantom volumes. This exploration follows a research strategy of 'narrow and deep' — studying a limited subject in order to permit a greater depth of detail.

2. The domestic Western kitchen

Typical Western kitchens are notable for an almost-universal adoption of a regular "type-form" (Heskett, 1980, 84), consisting of a waist-high counter set against one or more walls, and fitted above and below with boxy cabinets. This form is rationalized with references to qualities like personal virtue (Beecher & Stowe, 1869), and efficiency (Frederick, 1913), and codified into the 'kitchen work triangle' (Ranney, 1949; NKBA, 1996). Both kitchen design solutions and objectives appear to have formed a "hegemony of habit" that may not well suit contemporary kitchens, which often contain more than one worker, as well as multiple new appliances (Steggel & McFadden, 2015).

Kitchen renovation is a large industry; estimated by the National Kitchen and Bath Association to be worth US$157 billion in 2017 (NKBA 2019). It is therefore not surprising to find considerable research in the area, including recent explorations of computer applications (Dourish & Bell, 2011; Smart Kitchen Summit, 2019). Ironically, the dissemination of such research may be hindered by its potential commercial value. Investigations by the National Kitchen and Bath Association appear to be available only in expensive self-published books. A five-year study of kitchen design, completed in 1998 at the Rhode Island School of Design (RISD) saw exclusive rights to its Universal Kitchen sold to the Maytag Corporation (RISD, 2011), and apparently never seen again.

Kitchen innovation may also be hindered by conceptual "habitualization" (Shklovsky, 1917/1988). Six test kitchens at the Virginia Tech Centre for Real Life Design were recently built using only standard cabinetry, precluding exploration of the form (Virginia Tech, 2019). Enduring acceptance of the standard might be an example of "path dependence" not unlike that of the QWERTY keyboard (David, 1985), further reinforced by prescriptive building regulations (Queen's Printer, 2008) and manufacturing standardization (Sonderegger, 2006).

Non-standard conceptual proposals for the kitchen are common, including a 1956 "House of the Future" by Alison and Peter Smithson (Owens, 2001), the 1969 "Kitchen Satellite" of Luigi Colani (Archer, 2019), and the 2011 Philips bio-digesting "Microbial Home" (McGuirk, 2011). However, these appear to make little impact on everyday practice. There apparently still remains a need to "make strange" or "defamiliarize" the kitchen to inspire practical results (Bell, Blythe & Sengers, 2005). This might be seen in research that addresses the kitchen using frameworks taken from fields as varied as anthropology (Cieraad, 1999), design history (Sparke, 2009), human-computer interface (Bell, Blythe & Sengers, 2005), material history (Cromley, 1996), or world food waste (Gustavsson, Cederberg & Conesson, 2011). This paper seeks to contribute to the field with a novel quantitative exploration of the kitchen as a physical thing.

3. Conventional form and space

Product design manipulates the forms of artifacts. As taught in design school, form-giving pays attention to the contours and arrangement of positive forms, and to the empty negative

spaces that surround them. In the words of influential Pratt Institute design educator Rowena Reed Kostellow (1900-1988):

> "A talented and intuitive designer may well arrive at sensitive positive volumes, but unless the important relationship of the negative volumes or concavities to the positive forms is explored, his [sic] visual solution is only half controlled" (quoted in Hannah, 2002, 112).

Negative space is not just an aesthetic issue, but is also critical to function. The importance of negative space was expressed by the legendary poet Lao Tzu (c. 6th century BC) in a passage quoted by Victor Papanek in Design for the Real World (1972, 23) — available today in multiple translations.

> "Thirty spokes share the wheel's hub;
>
> "It is the center hole that makes it useful.
>
> "Shape clay into a vessel;
>
> "It is the space within that makes it useful.
>
> "Cut doors and windows for a room;
>
> "It is the holes which make it useful.
>
> "Therefore profit comes from what is there;
>
> "Usefulness from what is not there" (Feng & English, 2011).

The importance of negative space in design is illustrated by a recent Australian project using 3D printing to create nesting boxes for endangered owls. Criteria for the boxes specify the shape and texture of the interior volume, and the exterior negative forms that must fit around selected tree trunks (Parker et al., 2020). Positive form is needed only to define the important negative spaces.

For the context of a kitchen, negative and positive space are illustrated in Figure 1, using the example of a domestic coffee maker. The hole inside the handle of the carafe is a negative space which allows the user to grasp it. The negative space inside the carafe holds coffee.

Figure 1 *Positive form and negative space in a domestic coffee maker, where the negative space inside the carafe handle permits manual grasping. 3D Illustrations are by Gerald DesRochers, 2017, © Sheridan College Institute of Technology and Advanced Learning*

4. Phantom volume

4.1 Phantom volume of a sample product

The domestic coffee maker also demonstrates the existence of the third type of shape: “phantom volume.” Figure 2 shows phantom volumes associated with the coffee maker. These are neither positive nor negative, but consist of the total space potentially occupied by the product as its parts are unfolded or lifted out. Any obstruction to this space will prevent use of the machine. Note that the shape of the phantom volume is geometrically precise, constrained by the size, location and motion of hard physical parts. In other words, the phantom volume is a predictable consequence of the design of the positive shapes.

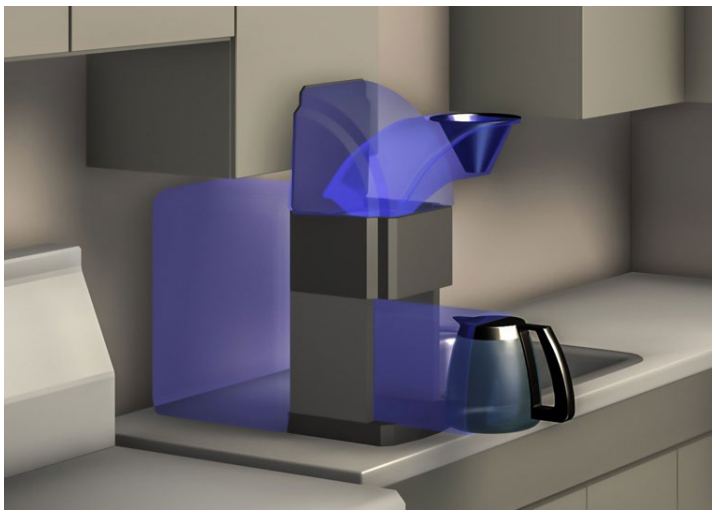

Figure 2 *Phantom volume of a domestic coffee maker, as defined by its movements in operation. The coffee maker must slide forward before the upper lid can be opened.*

As revealed by this exercise, the coffee maker’s phantom volume is large and irregular. It is also unexpected, as nothing in the appearance of the product on display in a store would warn the buyer to expect this shape at home. In addition, the phantom volume may not have been fully anticipated in the design process. For example, the flip-up lid over the water reservoir cannot be opened while the machine is tucked neatly under the upper cabinets. To open the lid, the machine must be pulled forward, whereupon the open lid blocks access to the cabinet doors. If fresh coffee grounds are stored there, as might seem convenient, then the doors and lid must be opened and shut alternately, several times, before a transfer of grounds can be made into the machine, and the package returned to storage.

The need to pull the machine away from its resting position means that it occupies a double-sized footprint on the counter. The counter near the sink is a busy location, where dirty coffee mugs might be gathered to await washing. If these must be pushed aside to accommodate the moving coffee maker, the user is invited to feel bad about his or her poor housekeeping — an emotional pang that would not arise if the appliance had a smaller phantom volume. It is the appliance, not housekeeping, that defines the mugs as mess.

4.2 Phantom body volume

Phantom volume is also required to accommodate the moving human body. In the 1940s, photographic research measured volumetric body "space shapes" defined by activities like getting dressed, to be used in architectural planning (Callaghan & Palmer, 1944). Here, phantom body volumes are defined in terms of their relationship with product use, as shown in Figure 3. Any obstruction of the user's body space, such as with a bag of groceries set on the floor, will render the machine inoperable until the obstruction is moved.

Blockage can also occur if a second user tries to perform a different task in the same location, as the second user's body volume intersects with that of the first user. In an ideal kitchen, body volumes will not intersect. Such intersection is irritating as well as disruptive. The complaint "you're in my way" carries emotional content (Hall, 1966, 53). Again, the essential problem is not generated by any particular actions of the users, but arises in a straightforward manner out of physical qualities of the design.

Figure 3 *Phantom volume required for the user's body in relationship to the coffee maker. Note also counter space occupied by the can of fresh coffee, coffee filters, and compost bin.*

Body phantom volumes are not as predictable as that of the appliance, because they vary with small motions like arm position (Overhill, 2014). Unlike the geometrically constrained shape of the machine's phantom volume, phantom body volume is a zone of probability; an area in which the body might be located. This space is also elastic, in the sense that the human body can, if needed, be nudged aside, or even squished.

4.3 Phantom volume of the cone of vision

Another phantom volume arising out of the user's body includes the cone of vision between the user's eyes and the device. This must be kept open for the appliance to be used. In this example, the coffee maker's water-level indicator and power switches are located on opposite sides, so that the user must sway back and forth to see them alternately, thereby modestly increasing the phantom body volume.

Obstruction of the cone of vision is more significant in other kitchen locations, like storage shelving or the refrigerator, where small items may be concealed behind larger things.

As soon as something is hidden from view, for practical purposes it no longer exists. This describes small jars after they are tucked into deep refrigerator shelves, where only an unmarked lid can be seen, not the label. A previous inventory done of the refrigerator in this same kitchen revealed four open jars of the same brand of Dijon mustard. Presumably, three of these had been acquired under a misapprehension that someone else had used up the previous jar, explaining why a visual search had failed to locate it (Overhill, 2000).

Poor visual access may play a role in the legendary gender inequality of kitchen work. When statistics show that men fail to share housework with female housemates, the cause is generally assumed to be male selfishness (Wilson, K., 2006). However, spatial analysis might offer an alternative explanation. The closed type-form of kitchen cabinetry, originating in the 1920s, conceals its contents behind smoothly 'streamlined' cabinet doors (Hanks & Hoy, 2005). This approach does not significantly disadvantage a single user. The archetypical housewife can memorize the location of hidden items, making them accessible to 'recall memory.' But when a second worker shares the space, he or she may unexpectedly relocate utensils or supplies, leaving the first user uncertain of where — or even whether — to initiate a search for something that might have been lost or used up, like the mustard. When a second worker shares kitchen tasks, both people rely on 'recognition memory' to visually identify needed items. To be usable, things must be visible.

Thus, in a sharing scenario set in the context of closed cabinetry, it might actually be more efficient for one user to bar others from interfering. Theoretically, people who wash the dishes reduce work for others, but an ensuing search for misplaced things may be more time-consuming than doing the job yourself, as well as frustrating.

4.4 Phantom volume of retrievability

Visual access is related to physical access. The reach and gestures of the arm and hand parallel the muscle motions of the eye, and its field of vision (Wilson, F.R., 1998). Just as visibility relies on an unobstructed cone of vision, smooth handling relies on an unobstructed cone of reach. Reach is more demanding than vision, because things may be visible, yet hard to access, like a teapot on a high shelf, or a magazine underneath a vase of flowers. The goal of "retrievability" has been defined by Adam Savage of the television program Mythbusters (2003-2016), who described it in terms of his toolbox.

> The finished boxes housed everything I needed, but I repeatedly rebuilt the insides until finally no tool had to be moved out of the way to get to another. That's first-order retrievability (Savage, 2016).

Such "first-order retrievability" is evident in bookcases, where centuries of iterative co-evolution between the shapes of books and their shelves has optimized both visibility and handling (Petroski, 1999).

Figure 4 *Book shelving in the Museum of Ferrante Imperato, Naples, 1599.Image from Ferrante Imperato (1599). Dell'historia natural di Ferrante Imperato, Napolitano, Libri XXVI. Public domain due to age.*

Figure 4 illustrates a Renaissance "cabinet of curiosities," where bookshelf evolution was not yet complete, and stored books were still piled flat in stacks. While visually accessible, books on the bottom of a stack would require awkward handling to retrieve; a problem later solved by filing the books vertically. If contemporary kitchen shelves lack an equally smooth relationship with their contents, it may be because kitchen goods have co-evolved to suit retail displays, rather than with their ultimate location in the home (Hine, 1995).

Imperato's cabinet of curiosities also illustrates the point that many household goods, even in the kitchen, are 'functional' not in the sense of performing a physical task, but in terms of display. Heritage china and expensive stand mixers convey symbolic values, for which purpose they must be seen. As in today's libraries and museums, Imperato's cabinet has solved this problem by displaying items in a single layer, making everything always visually accessible. This single-layer solution is not seen in contemporary kitchens.

4.5 Phantom volume for accessories

The example of the coffee maker shows that phantom volume is needed also for accessories. The background of Figure 3 shows counter space occupied by the coffee can and filters. These accessories arrive in the house at the same time as the coffee maker, and are necessary for its function, but its design makes no accommodation for them.

For appliances like washing machines, necessary accessories include operating manuals and warranties, which again seem not to be considered in design planning. Figure 5 shows ad hoc storage for the operating manual of a high-end domestic clothes dryer. The manual gives instructions for how to open and clean the lint filters; a complicated process for one of them in particular that is difficult to memorize since it needs to be done perhaps only

once every year or so, by any one of three regular users. Storage of the manuals could easily be integrated into the core machine, in the same way that photocopiers offer laminated instruction cards in a small pocket. (Electronic displays of critical instructions can also be provided, but are less effective because they vanish when the power fails.) Physical integration of the manuals into the core machine would simplify its phantom volume.

Figure 5 *Left: ad hoc storage of operating manuals*
Right: mysterious access hatch to filter compartment. Photos by author

4.6 Phantom volume of user travel

Kitchen phantom volumes also, of course, include space needed for movement of the user around the room. See Figure 6 for an illustration of coffee prepping, which requires emptying used coffee grounds into the compost container, rinsing the filter in the sink, and filling the machine with fresh coffee grounds and water. Overhead phantom volume is required for an upper cabinet door when it is opened to fetch a clean mug to measure water. Other users cannot access the sink or cabinet during this operation.

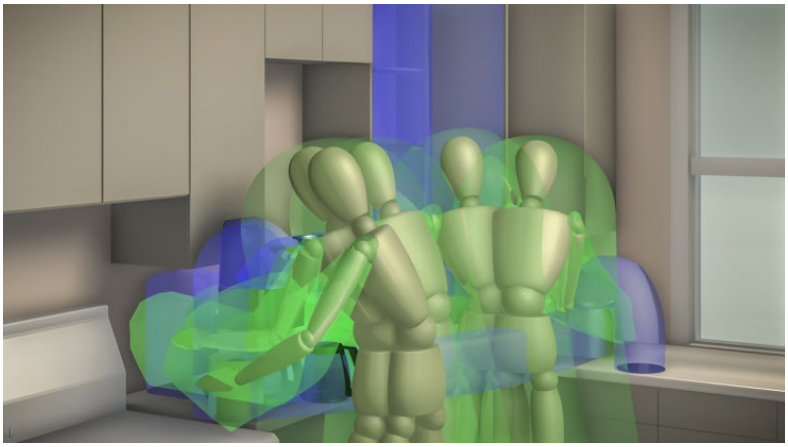

Figure 6 *Phantom volume of cleaning and loading the coffee machine, including retrieval of a clean mug from the cabinet.*

Once the coffee is ready, further phantom volume is required to pour it. See Figure 7 for a volumetric summary of pouring coffee and adding milk from a carton stored in the refrigerator. Note the over-swing of the thick refrigerator door, which can become problematic if a guest is standing nearby.

The large phantom volume required for milk pouring obviously increases the chance of collision with other kitchen users. Illustrations of kitchen work that indicate movement of the user with a dotted line, as in classic diagrams of the kitchen work triangle (Kohler, 2018), do a disservice to design planning, because they conceal the extent of body volumes. They describe only the vector of movement, not its spatial form.

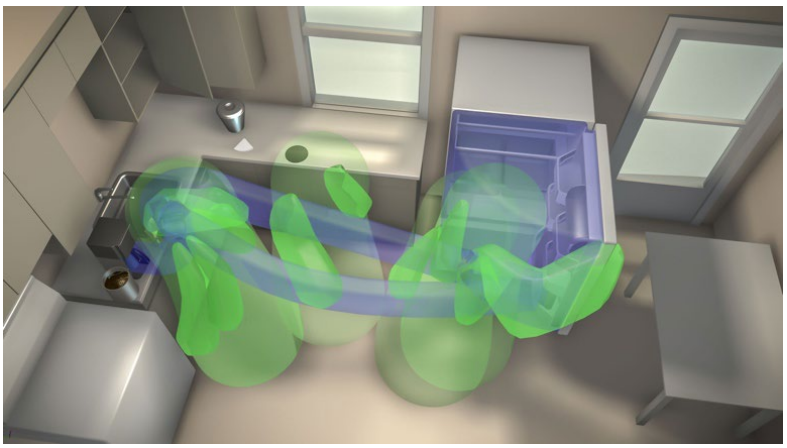

Figure 7 Phantom volume of pouring coffee and adding milk.

4.7 Tacit recognition of phantom volume

Tacit acceptance of the importance of phantom volume may be seen in some contemporary designs. For example, refrigerators with freezers in a bottom drawer minimize phantom volume because the forward movement of a drawer is more intuitively predictable than the over-swing of the thick door. In addition, because the open freezer drawer is wide and shallow, it provides better visual access to its contents than does deep shelving inside the boxy refrigerator form.

Newer four-wheeled suitcases also improve phantom volume when compared to two-wheeled ones. Because they can roll upright, they minimizing the floor area occupied when compared to a tipped-over triangle. Such reduced phantom volumes makes a considerable difference to the density of passengers queued in train-station ticket lines or airplane aisles.

Phantom volumes are also tacitly recognized in elder care, where accidental falls are “the leading cause of injury deaths” (Stevens, 2002/2003, 7). Causes of falls include “clutter, storage problems, and tripping hazards such as furniture or throw rugs,” exacerbated by the physical ailments of aging. Heuristic or rule-of-thumb remedies include tidying to remove obstacles, and physical exercise to increase strength and stability (Pynoos et al., 2004, 57). Here, the theory of phantom volume might offer more precise insight, by quantifying

the influence of shuffling on tripping. Shuffling, which is to say not fully lifting the feet, lowers the phantom volume of walking closer to the floor, where it begins to intersect with formerly-insignificant small physical obstacles.

4.8 Emergence

Phantom volume is an emergent characteristic. It resides in neither the product nor the user alone, but rather in the relationship between them.

Problem-solving under the tenets of Modernism urged that problems be studied in pieces; carving "where the natural joints are, and not trying to break any part" (Plato, c. 380 BC). This approach has been very productive in understanding the parts that compose wholes, such as the chemistry that underlies biology. It is less useful for understanding the emergent characteristics of assembled parts. In phantom volume, it is not the static parts that are of interest, but rather the relationships or 'joints' between them and users. Intersections between things and users is not revealed by a study of either in isolation.

In this understanding, fault can be found in design's tendency to focus on subsets of a subject rather than the whole – such as by studying the power consumption of a washing machine in isolation from the messy gestalt of laundry (Strengers, 2014, 28).

4.9 Missing phantom volumes

The concept of phantom volume might also describe situations where a physical object ought to be present and isn't. For example, a phantom volume could be established to define as the shape of "potential grabbing" that would be reachable by an unsteady elderly person. That volume would then form part of the performance specification for a physical solution for the unsteadiness, like a handrail or grab-bar.

5. Clutter

5.1 Existing definitions

"Clutter" is defined by the Oxford English Dictionary as a "collection of things lying about in an untidy state" (2019). Similar definitions can be found in psychological studies of home life, where one source describes clutter as "an overabundance of possessions that collectively create chaotic and disorderly living spaces" (Roster, Ferrari & Jurkat, 2016, 32). Thus, while the clutter itself is a physical phenomenon, its definition often seems to focus on personal failings of the clutterer, who first accumulates a needless abundance, and then fails to impose order on it. The resulting chaotic environment generates stress, driving a cascade of other dysfunctional behaviours (Vartanian, Kernan & Wansink, 2016).

Along with implicit criticism of the clutterer, definitions of clutter often imply remedies. One examination of possessions in British homes defined clutter as "the underside of storage" because storage is the "veritable panacea" to remedy the anxiety and shame induced by a

disordered house (Cwerner & Metcalfe, 2003, 229 & 233).

A more-positive perspective can be found in the "joy" promised by popular writer Marie Kondo in her prescriptions for household tidying (2014). In other contexts, clutter can even be seen as positive, in the sense that a home cluttered with heritage knickknacks and linen may commemorate family lineage (Makovicky, 2007, 291). Clutter or mess can also be a valid sorting strategy for items that hold "an ambiguous status in the home," like the contents of the junk drawer (Swan, Taylor & Harper, 2008). It might even be an invitation for creativity, in the bricolage of a garden shed (Dourish & Bell, 2011, 174).

Moving away from qualitative judgement, quantitative measurements of clutter can be found in discussions of clinical hoarding disorder (Mayo Clinic, 2019). Numerical tools like the ICD Clutter Hoarding Scale® (ICD, 2018), or the Clutter Image Rating Scale (YSL, 2019), measure levels of physical mess as an aid to medical or psychological diagnosis.

Measurement of clutter is also found in the field of graphic interface design, where an accumulation of "excess items" is known to cause "a degradation of performance at some task." Rather than blaming users for their confusion, graphic designers understand the problem as preventable, and to that end measure characteristics like set size or visual complexity (Rosenholz, Li, & Nagano, 2005). However, if graphic approaches offer insightful observations about clutter, these seem to be only metaphorically applicable to three-dimensional domestic environments, probably because, unlike graphic representations, artifacts usually cannot be reduced in size or detail (Buckland, 1991, 358).

5.2 Clutter as a conflict of physical and phantom volumes

Here, a new quantitative definition aimed at three-dimensional environments proposes that clutter is *the physical effect created when the phantom space of one object is obstructed by positive form of another.* In technical terms, the blocked object might be described as the "patient" of a active physical "agent" doing the blocking (Schlosser, 2019). When access is blocked, a planned task must be preceded by preliminary work to move aside, put away, get out, or otherwise relocate items in order to liberate the needed phantom volume. This straightforward definition describes a physical effect based on geometric spatial relationships, leaving aside symbolic and social issues to be examined with other tools.

While the problem of domestic clutter is not big, it is real. Many contemporary Western households are plagued by mounting accumulations of possessions (Arnold et al., 2012). At the same time, many homes and apartments are shrinking in size. More careful consideration of phantom volumes might ameliorate at least some spatial woes.

The 3D methodology used here to identify the shape of the phantom volumes is time-consuming. However, it might find future application in spatial planning, in research, or to facilitate increased precision in ergonomic analysis or scenario building. It might also suggest student assignments intended to heighten awareness of spatial interactions. Users of this approach might ultimately assemble a library of gestural 3D phantom volumes, to complement existing catalogues of physical forms.

6. Conclusion

The vocabulary term “phantom volume” focuses critical attention onto non-tangible volumetric forms established by the motions of a product in use. Phantom volumes are generated by movements of the product and its parts, by the space needed for accessories, and by the spaces occupied by the user’s moving body and its cone of vision. Cone of vision is particularly important in the kitchen, where storage may conceal items from view, particularly when multiple workers organize the contents in different ways.

The definition of phantom volume identifies an apparently-overlooked aspect of product form. It shifts attention away from static physicality onto the temporary spatial volumes delineated by products and users in movement. While phantom volumes are invisible when not in action, they are essential to proper product function. Any physical obstruction to them prevents proper use of a product, and generates an impact here defined as “clutter.”

A sample analysis of one kitchen appliance suggests that products may carry unexpectedly large and obstructive phantom volumes, which might be improved by better advance planning. The spatial definition avoids moralistic attribution of clutter to user laziness or disorganization, and instead points to design oversight in failing to optimize the spatial geometries of use. The 3D visualization technique used in this study might find future application in planning, research, or student assignments

Acknowledgements: The author would like to thank the Sheridan College Institute of technology and Advanced Learning, Oakville, Canada, for the internal SRCA grant that provided generous seed money for concept development. Thanks also to Gerald DesRochers for his skilful development of the illustrations. And thank you to the anonymous reviewers of the DRS Committee for their astute recommendations of improvements to the written essay.

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