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early writing

A cognitive archaeological perspective on literacy and numeracy.

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Abstract

This inquiry seeks to understand how the original form of writing in Mesopotamia—the small pictures and conventions of protocuneiform—became cuneiform, a script that could not be read without acquiring the neurological and behavioral reorganizations understood today as literacy. The process is described as involving small neurological and behavioral changes realized, accumulated, and distributed to new users through interactions with and concomitant incremental changes in the material form of writing. A related inquiry focuses on why and how numerical notations differ from other written signs. Crucially, numerical signs instantiate their meaning, a representational mode that contrasts with the signification used to represent non-numerical language and which makes numerical notations contiguous with their unwritten precursors, technologies like fingers, tallies, and counters. Instantiation is related to the perceptual system for quantity; this so-called number sense influences the function and form of numerical signs. Reading is then discussed as a cognitive activity that necessarily involves a material form, a plausible example of extended cognition. Because numerical notations share function and often form with precursor technologies, if the former participate in extended cognition, the latter likely do as well. In conjunction with the contiguity between numerical notations and their unwritten precursors, this complicates the idea that (all) writing is (just) language. Finally, potential follow-on research is suggested.

Keywords

early writing systems;
Mesopotamia;
literacy;
numeracy;
extended cognition

Introduction

Literacy is so fundamental to our experience in the 21st century that we often take it for granted. We see writing as a tool that encodes, preserves, and transmits knowledge across space and time, and which subjects ideas to analysis and revision (Olson, 1994). We forget that widespread literacy is mere centuries old, a consequence of the printing press and its ability to make writing more generally available. We ignore the fact that becoming literate means acquiring a set of specific neurological and behavioral reorganizations, the various ways our brains and behaviors change when we learn to read and write. And we think of written characters as symbols or graphemes, ignoring the fact that they are also material forms. As the material component of reading, writing is not just individual pieces of materials with writing on them or the particular characters they might contain. Rather, writing is sets of characters and conventions like the modern Latin alphabet and ancient cuneiform, the system of writing invented in Mesopotamia about 6000 years ago.

In the following analysis of how literacy emerged in Mesopotamia, the focus is the process whereby writing as a material form changed from protocuneiform, which consisted of small pictures and conventions, to cuneiform, a script that could only be read by acquiring the specific neurological and behavioral reorganizations understood today as implicit to literacy. In this discussion, there is a fundamental terminological issue, since *glottographic script*, which means writing that records language, does not readily distinguish between early forms meaningful through resemblance and convention and later forms whose morphological change implies the need to acquire specific neurological and behavioral reorganizations in order to read them. The first affords substantial differences in the choice of vocabulary and syntax and can be read with similar ease by people who speak different languages, while the second represents semantic and phonetic elements of a particular language in a way that restricts choice and is most easily read by someone who knows the language. However, the difference between early and later forms is not reducible to their phoneticity, the degree to which they specified vocabulary and syntax, noting that the later form had more ability in this regard because it incorporated techniques that were not initially available. More central is the morphological change in the material form of writing, something that is tractable to cognitive analysis and interpretation. Here the two states will be distinguished terminologically as *writing*, the early material form that approximated meaning through resemblance and convention, and *script*, the later material form that emerged through and accumulated incremental neurological and behavioral changes until it could no longer be read without them.

Seeing writing as a material form lets us examine how it changed over time. The case of Mesopotamian writing is analyzed here, noting that other cases of original writing (e.g., Egypt, China, Mesoamerica) have not yet been subjected to similar analyses. They are nonetheless mentioned briefly as appropriate to emphasize that the Mesopotamian case is not likely to be universal in all respects. However, the Mesopotamian case does exemplify a process in which writing by hand causes neurological and behavioral changes in the writers that influence the material form. In response, the material form changes incrementally in a way that serves to accumulate the neurological and behavioral changes, and it acts as a mechanism for distributing them to new users when they learn to read and write. Early Mesopotamian writing (Fig. 1) consisted of small pictures and conventions. Reading and understanding them was a matter of recognizing the objects or forms they depicted; these signs meant what they looked like, or things reasonably related to them (e.g., a picture of a head might mean "head" or "person"). Reading and writing these early characters would not have required acquiring the set of neurological and behavioral reorganizations required for later forms. In contrast, later forms no longer resembled or depicted; reading and writing them involved and depended upon a set of neurological and behavioral reorganizations acquired through training and practice.

Interpreting morphological change in the material form of writing as indicating neurological and behavioral change in writers requires insight into literacy from the perspective of contemporary neuroscience. In a literate brain, the portion of the fusiform gyrus known as the visual word form area (VWFA) recognizes written characters (Cohen & Dehaene, 2004; Dehaene & Cohen, 2011; McCandliss et al., 2003). It also interacts with Exner's area, the motor region that plans the movements specific to handwriting (Klein et al., 2016; Roux et al., 2009). This region and its functionality are thought to enable us not only to produce written characters, but recognize them as well (Dehaene, 2009; Konnikova, 2014). The fusiform gyrus also interacts with Broca's and Wernicke's areas, the brain centers for producing and comprehending speech (Nakamura et al., 2012; Perfetti & Tan, 2013; Tremblay & Dick, 2016). The interactions between these regions associate written characters with language, and the involvement of these regions is highly consistent across individuals, languages, cultures, and writing systems (Bolger et al., 2005; Carreiras et al., 2007; Frost, 2012).

Today, being able to read a script means acquiring these reorganizations, since a script cannot be read without them. These reorganizations are acquired when someone learns to read and write, and being able to read and write demonstrates that these reorganizations have been acquired. These reorganizations enable someone to interact with a specific material form, which is script, and interacting with the material form is how these reorganizations are acquired. For ancient writing, changes in the material form, including the decreased depictiveness often called "increasing abstractness" and the increased ambiguity that characterizes cursive, attest that these reorganizations occurred in ancient peoples.

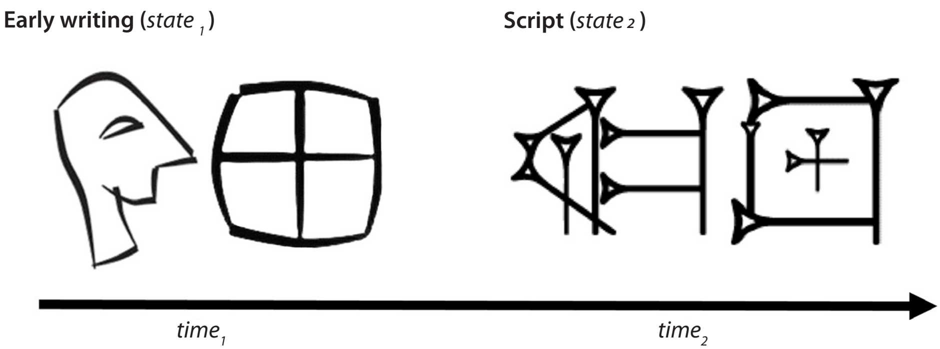


Figure 1.

Early Mesopotamian writing and later script.

(Left) Early writing (c. 3100 BCE) took the form of pictures and conventions. Shown are the picture used to represent head, person, or capital and the quartered circle used to represent sheep. (Right) The cuneiform script (c. 2000 BCE) was a descendent form. Shown are the signs SAĜ (head) and UDU (sheep).

Images adapted from Englund and Grégoire, 1991 (state$_1$) and the Pennsylvania Sumerian Dictionary (state$_2$).

A significant difference between the two states is that writing could be invented in ancient times, but scripts could not be. For a script to function, the necessary reorganizations in the brains and behaviors of the users would already need to be in place, which of course they were not and could not be until writing had first been invented and then interacted with long enough for brains and behaviors to change. And with no idea of what literacy was until it emerged, there was no teleology, no inventive purpose or goal, to guide its realization. Instead of invention, the material form of script emerged gradually from interactions with writing sustained over generations, a process in which the material form functioned to realize, accumulate, and distribute incremental neurological and behavioral change (Overmann, 2016a, 2021c). Notably, modern script inventions (e.g., the Vai script of Liberia; see Kelly et al., 2021) achieve literacy in generally the same way, but with a significantly compressed timeline that is plausibly related to knowing the purpose, use, effects, and outcomes of writing ahead of time.

Getting from *state*$_1$, pictures and conventions meaningful through resemblance, to *state*$_2$, script that could be read only with extensive training and practice, required change in brains, behaviors, and the material form of writing. Sustained, collaborative interaction with writing as a material form—communities writing across generations of time—incrementally changed the brains and behaviors of the writers. Changes in brains and behaviors, in turn, allowed for incremental adjustments of the material form. And as that material form changed, the neurological and behavioral reorganizations needed to use it became increasingly important, until at some point, writing—which by this time had become a script in the terminology adopted here—could no longer be read without them. Interactions with the material form that is writing influenced change in brains and behaviors, and change in brains and behaviors enabled writing to be manipulated into novel forms that potentialized more change in the system.

A Case Study in the Emergence of Literacy: Mesopotamia

Early writing in Mesopotamia consisted of small pictures that meant what they resembled, or things related to them, so a picture of a head could mean *head*, *person*, or *capital* (Fig. 1). There were also conventions; these meant what everyone agreed they meant, so the quartered circle meant *sheep*. Early signs (written characters) conveyed ranges of related meanings but gave no clues to pronunciation or type, which made them ambiguous regarding the words or morphemes intended. In fact, they were so inarticulate that scholars are still not sure which language was associated with the earliest writing. It was probably Sumerian, but there are also reasons to think that it could have been Akkadian (Englund, 1998b; Veldhuis, 2014). As can be seen in sign chronologies (Fig. 2), about six centuries after they had emerged, Mesopotamian characters had lost much of their resemblance to the things they once depicted. This change in form, which is also found in Egyptian and Chinese writing (Fig. 3), can be understood neuroscientifically, specifically, in how written characters become recognized.

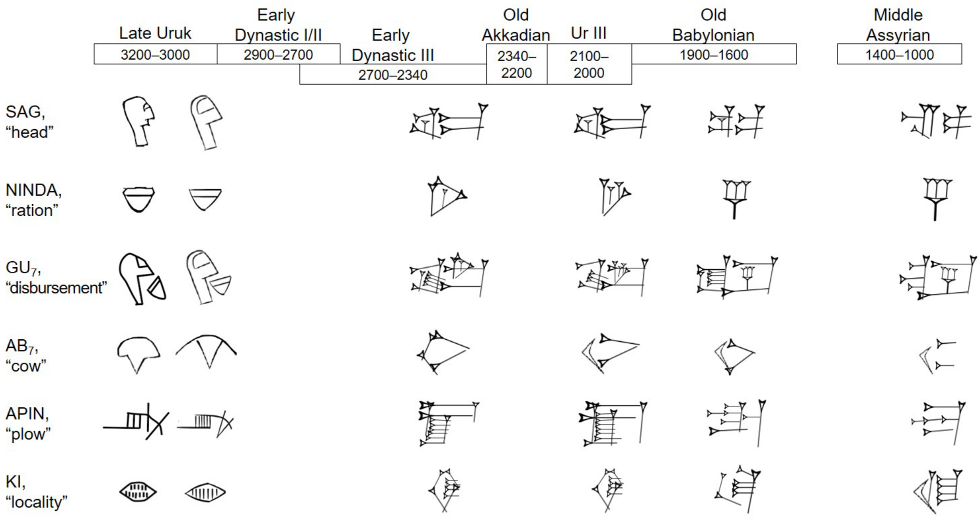


Figure 2.

Chronology of Mesopotamian signs.

Morphological changes imply neurological and behavioral reorganizations like topological recognition and automaticity.

The diagram does not include the 90 degree rotation that has been variously dated to the mid-third (Studevent-Hickman, 2007), late third (Powell, 1981), mid-second (Picchioni, 1980), and late second (Nissen et al., 1993) millennia.

Data from Nissen et al. (1993, Fig. 106, p. 124).

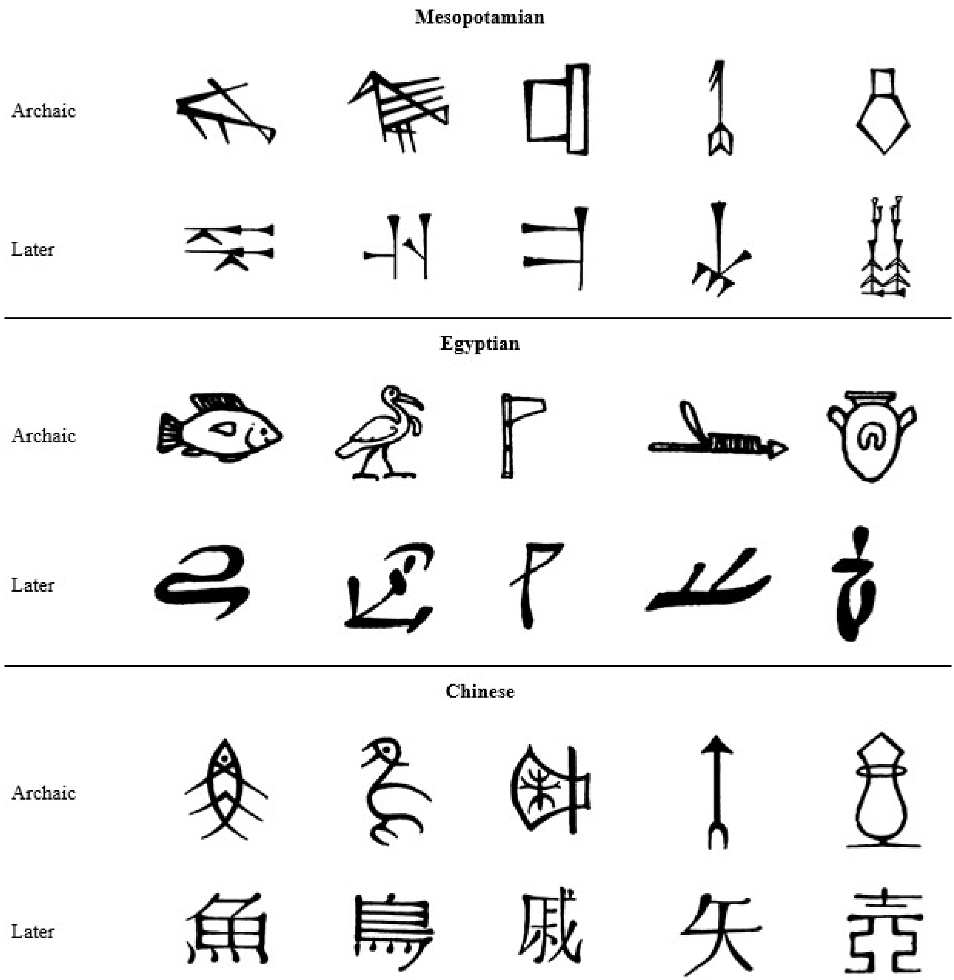


Figure 3.

Change in form in early writing.

Archaic forms are meaningful because they resemble objects (from left to right: fish, bird, axe, arrow, and vase).

Written forms that no longer resemble imply topological recognition; understanding these "increasingly abstract" forms requires training and practice. Notably, once they emerged, Egyptian forms with increased ambiguity (hieratic) and decreased resemblance (demotic) were used alongside hieroglyphs, which persisted throughout.

Image adapted from De Morgan (1905, Fig. 38, p. 243). (A version of this chart will appear in Overmann, 2022.)

Characters are recognized topologically, through combinations of their structural features and spatial relations. Topological recognition is a function of the fusiform gyrus, a portion of the temporal lobe with an evolutionarily provided functionality for recognizing objects and faces (Coltheart, 2014; Dehaene & Cohen, 2007; McCandliss et al., 2003). As written objects became recognized topologically, the need for them to resemble was relaxed (Overmann, 2016a, 2021a). Once written objects were recognized topologically, their forms could deform and still be recognized. Character recognition and meaning became functions of (a) the characters themselves, even if deformed; (b) the context provided by adjacent characters; (c) and learned associations between the material form and language. This, in turn, freed the set of elements to converge on features and points of contrast that enabled them to be discriminated and individuated. Contrastive features were likely lines, orientations, and shapes that activated the visual system more strongly (Hodgson, 2007, 2012, 2019), a matter currently being explored at the University of Bologna, Italy.

Discrimination is telling the characters apart from one another, while individuation is identifying a character for what it is. As is true of writing today, discrimination and individuation involve recognizing characters through their features. The features of early writing were more obvious than was true of script (see Figs 1 and 2). Discriminating and individuating characters with subtle differences depends on familiarity. With familiarity, objects become easier to discriminate and individuate, so the clues that distinguish them can become more subtle. In turn, subtle clues mean that specific training and practice are needed to gain the familiarity that enables discrimination and individuation. This same effect is found today in facial recognition, especially in differences between same- and cross-race identifications (Brigham et al., 2007; Hayward et al., 2017). The difference in writing as a material form is that its features are subject to manipulation and change. The features differentiating early written characters were relatively obvious, while those differentiating characters of script had become more subtle. The characters of script still resembled the original forms of early writing. Nonetheless, the characters of script were becoming much closer to each other than the originals were. Topological recognition let characters deform, which freed them to differentiate in ways that enhanced the ability to tell them apart and identify them, while allowing the clues that did this to become more subtle.

The chronology of specific signs (Fig. 2) shows them starting as small pictures and conventions whose resemblance had a range of meanings. As writers practiced, they produced signs more efficiently and with greater standardization. Feature recognition of signs relaxed the need to preserve the original forms, so characters became less depictive. This let them converge on points of contrast, under the influence of things like movement automaticity and the biomechanics of production. Signs continued to simplify, suggesting that proficiency in using global cues may have reduced the need for local detail, explained below. Signs changed from forms whose meanings could be approximated with relative ease to forms that required acquiring specific neurological and behavioral reorganizations to recognize and produce. In essence, written characters became too much alike. It had been relatively easy to tell the earlier pictures and conventions apart, but as characters became less depictive and more alike, the differences between them were too subtle without familiarity. This intensified the need for training, which became more formal, and formal training, in turn, intensified systemic change. Overall, the set of characters lost variability, while the remaining variability converged on features that helped to tell characters apart and identify them.

In becoming simpler, characters lost some of their detail, suggesting an optimization or balance of local details and global cues (Overmann, 2021a). Local detail helps novices discriminate and individuate characters, but it also slows proficient readers, who make greater use of global cues, something novices find difficult to do. The more detail characters have, the longer it takes not just to write but also read them. The term "compression" expresses a similar idea, the reduction of information that minimizes the physical effort of producing characters (Kelly et al., 2021); this focuses on biomechanical aspects of production and principles like least effort (Zipf, 1949). Today, the tension between local detail and global cues is suggested by diacritics as used within African tonal languages (Bird, 1998, 1999). These have two written forms, one with diacritics for novices and one without for masters; a single form, in comparison, implies a compromise between proficiency levels. Simplification also suggests an effect associated with the adaptation of writing to new languages; further study is needed on this point. Interestingly, simplification is not characteristic of Chinese writing, where characters tend to become more complex over time, particularly in adding phonetic elements (Han et al., 2021). Notably, Chinese writing is also associated with distinct neurological activation patterns that suggest differences in phonological processing (Tan et al., 2005) and working memory (Cantlon & Brannon, 2007), matters that plausibly relate to the additional demands imposed by the greater visual complexity of the characters.

Writing by hand was critical to these developments. Today, we still learn to recognize written characters by interacting with the material form of writing. That is, we practice reading and writing until we become proficient, just like ancient writers did. And just like it did for them, handwriting changes our brains and behaviors, for example, improving our fine motor skills, hand–eye coordination, lexical retrieval, recognition and recall functions, and tolerance for ambiguity in written forms (James & Engelhardt, 2012; Longcamp et al., 2005; Mueller & Oppenheimer, 2014; Sülzenbrück et al., 2011). In the historical development of writing, handwriting afforded the practice and habituation that standardized how characters were formed and automated their production. Most importantly, handwriting allowed for the continual adjustment of the material form. This was essential to the system's ability to change, as the material form changed in ways that reflected, accumulated, and distributed incremental change in brains and behaviors.

About 15 centuries after writing began in Mesopotamia, a form of cursive developed, characterized by "abbreviated signs, crowded writing, and unclear sign boundaries" (Veldhuis, 2011, p. 72). Today, we think of cursive as a formal handwriting in which all the letters of a word are connected to each other; it contrasts with block print, where the letters are not connected (Bringhurst, 2004). Cursive can be written more quickly, so it tends to be sloppy and thus ambiguous in its form. Being able to recognize characters even when they are ambiguous is a training effect gained by handwriting practice (James & Engelhardt, 2012; Longcamp et al., 2005). Greater tolerance for ambiguity is simply the ability to recognize characters topologically, despite their increasing deformation. Because cursive can be written quickly, it is writing that is sloppy and ambiguous but fast. Being able to be produced more quickly means that writing keeps up better with the pace of thought, which makes it a tool that can interact with mental content, an important aspect of literacy.

Standardization is forming each character with particular strokes in a particular order. When writing first began, there was no such protocol. Over time, the strokes used in the characters and the order in which they were made became increasingly regular and standardized (Bramanti, 2015; Taylor, 2015); standardization, in turn, shows handwriting behavior becoming automatic. Automaticity frees up cognitive resources like attention and working memory (Logan, 1992). Simply, automated behaviors do not require the kind of sustained, dedicated attention that unfamiliar behaviors do. We experience this same thing when we learn to drive. At first, we must attend closely to operating the car and conditions on the road; as we gain proficiency, however, we pay less attention to these things, becoming alert only when conditions change (Charlton & Starkey, 2011). In writing, automaticity lets us focus on *what* we are writing, its content, rather than *how* we are writing, its production. This would have helped transform writing into a tool that could engage mental content directly (Tucha et al., 2008).

Phonographic script is writing that records pronunciation clues, which not all writing does. For example, the early pictures and conventions in Mesopotamian writing were associated with ranges of semantic meanings related to what they looked like, as distinct from expressing particular vocabulary. Mesopotamian writing reduced the ambiguity of its early pictures and conventions by incorporating techniques for specifying them, an important step toward phonographic script. Techniques for specification included *determinatives*, signs that determined or classified other signs, identifying the type of sign they were. Two such classifiers identified the signs they modified as the name of a god or a geographic place (Hayes, 1990, pp. 30–31). Determinatives are not believed to have been pronounced, and they could appear before or after the signs they classified (Edzard, 2003; Jagersma, 2010), effectively increasing the visual complexity of signs for non-numerical language.

Another technique for specification was *phonography*, the visual depiction of pronunciation clues. Sumerian had a lot of single-syllable words and morphemes. This meant that pictures of things like fish could also be used for their syllabic values (Woods, 2010, p. 43). Sumerian also had a lot of homonyms, words and morphemes that are pronounced the same but have different meanings (Hyman, 2006). Using a picture of a fish as a syllable leverages the rebus principle, the use of signs as homonyms, independent of their visual meanings. It is often illustrated by signs whose sequence of names are pronounced as "I can see you" in English. Understanding the meaning of a homonym depends on its context, and it also requires knowledge of the language being written. Otherwise, a sign for a fish used as a syllable appears in contexts where its visual meaning makes little sense. A later technique was the use of *phonograms*, signs with no meaning other than a phonetic value, typically a syllable.

In Mesopotamia, signs for numbers and then non-numerical language emerged in the late fourth millennium BCE (Krispijn, 2012; Nissen et al., 1993; Veldhuis, 2012). Handwriting at the repetition needed to administer a state-level bureaucracy initiated neurological and behavioral change, like the increased recognition of characters by their features and increased standardization and automaticity in their production (Overmann, 2016a, 2021a). By the third millennium BCE, writing had achieved enough specificity in representing language to identify it as Sumerian (Englund, 1998b; Veldhuis, 2014). The ability to represent phonetic values facilitated the adaptation of writing to other languages with different phoneme inventories, like Akkadian (Cooper, 1996, 2004; Krispijn, 2012). By 2000 BCE, a literacy analogous to how we understand the term with respect to ourselves as readers is signaled by several phenomena. Words and morphemes were no longer being split between lines of text (Cooper, 1996), an integrity of form that implies written objects were being recognized by their features. Cursive writing developed (Veldhuis, 2011), demonstrating tolerance for ambiguity and gaining speed of production. Writing was applied to many new purposes (Krispijn, 2012; Veldhuis, 2011), showing it had achieved significant expressive power. Training was highly formalized (Veldhuis, 2014), because script could no longer be read without acquiring neurological and behavioral reorganizations. And finally, the types and rate of change also decreased around this time.

These factors suggest a general "recipe" for developing a script from writing: It is a process in which the neurological and behavioral changes that writers acquire by interacting with writing, in turn, influence its material form; this then changes incrementally to accumulate and distribute those changes to new users. For characters to become recognized topologically, there had to be an initial repertoire of conventional signs. These had to be simple, and the material form malleable enough, to enable their production, repetition, recombination, and change. Signs had to be written by hand, enough hours per day and days over years, that brains became trained to recognize them and associate them with language. The behavior had to be repeated and sustained for generations, a production demand associated with state-level bureaucracies. Techniques for specifying words and morphemes, including pronunciation clues, had to be included. And signs could not be numerical, since numbers lack the qualities that motivate increased phoneticity. The next section discusses why numbers are so different.

Numbers

Numerical notations are often thought of as just another part of writing and script, and certainly, signs for numbers are involved in many of the processes just described. However, in actuality, there are many differences between signs for language and signs for numbers (Overmann, 2019), and these are important in order to understand how and why written signs for numbers behave the way they do, as well as their continuities with unwritten forms like tokens and quipus. Literacy is the ability to read and write, which means interacting with a material form that can represent the meanings and perhaps pronunciation clues to a particular language. In contrast, numeracy is reasoning with numbers, which can be written but do not have to be, since they can be represented with objects like the fingers, the notches on a tally, or the beads on an abacus. Literacy and numeracy are severable phenomena, as attested by the fact that there are several numerical notation systems that are not associated with any script, and a few scripts that lack any signs for numbers (Chrisomalis, 2010). For literacy to develop, signs for language must be handwritten, while for numeracy, numbers need not be written. Writing is arguably the first time that language takes material form, and antecedent forms like imagery and iconography on pottery are not engaged with the repetition frequency needed to realize neurological and behavioral reorganizations. In contrast, numerical notations follow and directly develop from material forms like fingers, tallies, and counters (Overmann, 2016b) and share function and often form. Writing for language potentially represents the entire lexicon and phoneme inventory, which requires many symbols. In comparison, numerical notations represent only a subset of the lexicon, and then without phonetic values, and this requires very few symbols. Most importantly, signs for language signify, or represent by depicting, indicating, or suggesting what they mean. In contrast, signs for numbers instantiate, or represent quantity by being an instance of it, though this is more apparent in early forms, as will be discussed.

Signs for numbers instantiate quantity because we perceive quantity, another evolutionarily ancient ability. Our ability to perceive quantity through the so-called number sense means that we can recognize one, two, and three without counting, an ability known as subitization (Penner-Wilger et al., 2007; Piazza et al., 2011; Railo et al., 2008) Without counting, quantities larger than about four are just "many"; here we can appreciate bigger and smaller in groups, assuming the difference is above a threshold of noticeability, an ability called magnitude appreciation (Brannon, 2006; Dehaene, 2011; Piazza, 2011). Besides the part of the brain that perceives quantity (intraparietal sulcus), numbers involve the parts that know and count on the fingers (angular gyrus), plan motor movements (cerebellum), and make decisions (prefrontal cortex; temporo-parietal junction) (Balsters et al., 2013; Brooks et al., 2014; Frank & Barner, 2012; Gracia-Bafalluy & Noël, 2008; Kringinger et al., 2011; Marinthe et al., 2001; Penner-Wilger et al., 2007; Roux et al., 2003; Vandervert, 2017). This neurological infrastructure means that our perception of quantity is integrated with, and thus directly informs, our interaction with the material forms used to represent numbers. The language functions are not highlighted here because numerical thinking does not significantly involve language (Amalric & Dehaene, 2016; Brannon, 2005; Varley et al., 2005).

As noted earlier, pictures represent by resembling, conventions through social agreement. Both convey ranges of likely meanings, rather than particular vocabulary choices, and both achieve specificity through strategies like determinatives and phonology, techniques that add new information to written signs, thereby increasing their visual complexity. In comparison, numerical signs instantiate quantity. Three fingers, three tally notches, three abacus beads, three cuneiform wedges, and three vertical strokes in the Roman numeral three all mean *three* by virtue of having three elements. Instantiation makes numerical signs unambiguous in their numerical meaning, so they do not need to be specified further with pronunciation clues. It also makes written forms of number contiguous with their unwritten precursors (e.g., fingers, tallies, tokens), something with no parallel in signs for language at any stage.

The same distinction between signification and instantiation was made by the Belgian surrealist René Magritte, who labeled his 1929 painting of a pipe, *La Trahison des Images*, with the phrase, "*Ceci n'est pas une pipe*" ["This is not a pipe"]. That is, the painting is an image of a pipe, which is signification. It is not itself a pipe, which would be instantiation. So, in the same way a picture of a pipe is not itself a pipe, a sign for *sheep* is not itself a sheep, even when it looks like one. In contrast, for numbers, four cuneiform wedges *are* four, six protocuneiform cones *are* six. A sign for a number *is* that number because it has that number of elements. Instantiation means that numerical meaning is unambiguous, across languages and even without language, which is why numerical signs do not need to be specified phonetically. This is true even when numerical signs include conventions like those distinguishing integers and fractions or expressing grouped or "bundled" quantities.

Instantiation involves repetition. However, because of the way the number sense works, we cannot appreciate quantities above *about three or four* without counting. This means we must count, and counting is laborious, unreliable, and assumes a system of counting already exists. The strategy used to mitigate this is known as bundling. Some specified amount of repetition is replaced and represented by a convention understood as a consolidated value. For example, in protocuneiform, in the general counting system known as sexagesimal system S (Nissen et al., 1993), one small cone meant *one*. Ten small cones were bundled and replaced by one small sphere that meant *ten*. Six small spheres were bundled and replaced by one large cone that meant *six tens*, which we would call sixty. The highest number of repetitions without replacement is known as the *unbundled maximum*. By consolidating and reducing repetition, bundling makes written numerical information more concise, relative to its unwritten precursors; concision, in turn, makes numerical information more accessible, but requires the user to learn the conventions (Overmann, 2019).

Numerical notations instantiate, either by repeating, like three vertical strokes mean *three*, or by bundling, like the circle means *ten* in Minoan Linear A, identifiable through the unbundled maximum of nine vertical strokes. These distinctive properties mean that numbers can be identified in otherwise undeciphered scripts, like Minoan Linear A (Corazza et al., 2021; Packard, 1974). Repetition and bundling are not just unambiguously numerical, they are uniquely numerical. That is, because they instantiate quantity, they embody numerical states and relations that have no counterpart in signs for non-numerical language, and this lets them be identified as numbers. The difference in representational mode is found in the earliest writing. In Mesopotamia, signs for quantity instantiated number through repetition and bundling, while signs for commodity signified objects through resemblance or, in the case of the tablet shown in Fig. 4, convention. Bundling is more apparent in some number systems, like the one from Mesopotamia, than in others, like our familiar Western numerals. In cuneiform, instantiation through repetition was used to a specified extent, where a bundle was inserted and used. This point will be returned to later, because how a system of numerical notations develops in this regard is influenced by the number sense. For higher values, bundling and repetition are combined.

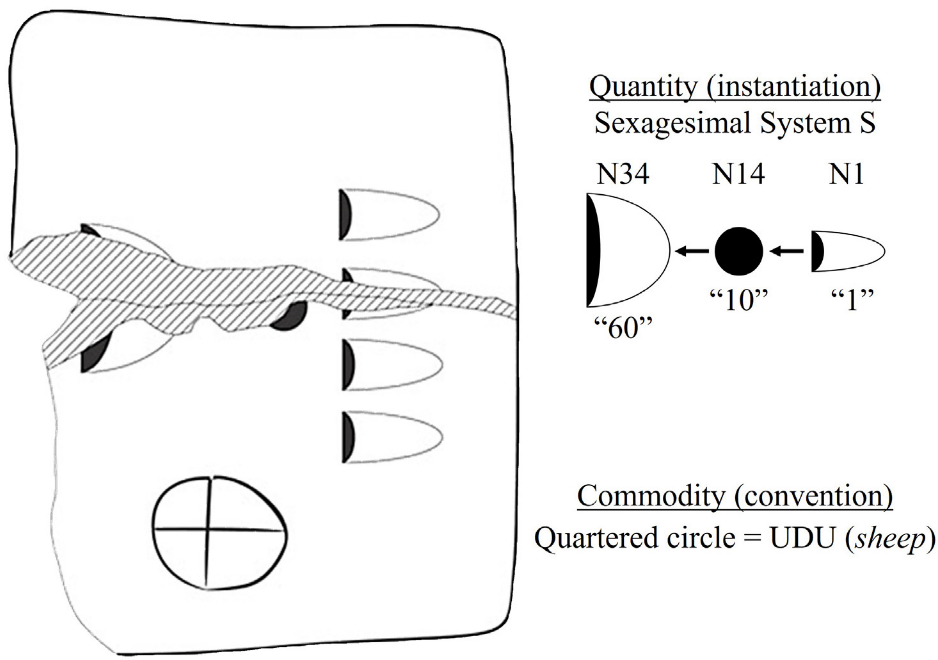


Figure 4.

Administrative tablet from Uruk (W 6881,b).

The obverse face shows the difference in representational mode as it appeared in early Mesopotamian writing (c. 3500–3350 BCE).

Signs for quantity represented by instantiating number using repetition and bundling. Signs for commodity represented through resemblance or, in this case, convention.

Extracted from the line drawing by Robert K. Englund (1994, pl. 17).

Our familiar Western numerals are ciphered forms that descended from the numerical notations of Mesopotamian cuneiform and Egyptian hieroglyphs, which were instantiated and bundled (Chrisomalis, 2004, 2010). The number sense influenced how these numerical notations developed. Of the unbundled groups shown in Fig. 5, the smallest quantities can be appreciated or understood as the quantities they are without counting because they are subitizable. More than *about three or four* becomes increasingly difficult to appreciate. Beyond the subitizing range, we appreciate differences in magnitude, like seeing there is less to the left and more to the right. As notations, groups with few elements are subitizable. This gives them an inherent identifiability that means they change little over time. Groups beyond the subitizing range are organized into subitizable subgroups. These also become difficult to appreciate, so over time, they are encoded as bundles, and they can simplify as conventional (ciphered) forms that avoid the need to count elements or element subgroups (Overmann, 2021c). For hieroglyphs, this visual simplification began with hieratic, a cursive form of hieroglyphs that emerged around 2600 BCE (Hoffmann, 2012; Lopriano, 1995; also see Fig. 6).

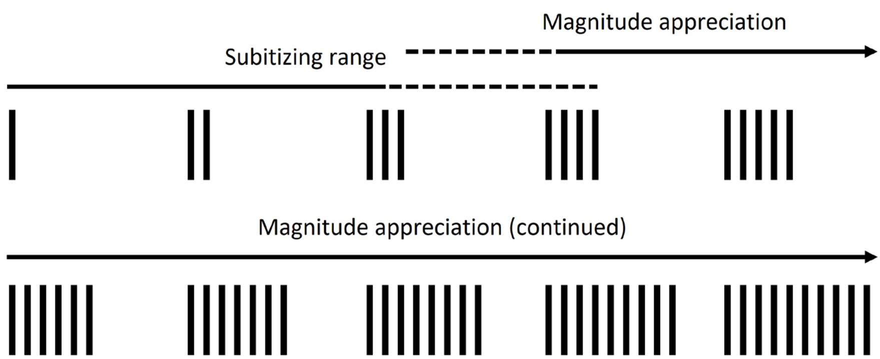


Figure 5.

The perceptual experience of quantity and notational marks.

Within the subitizing range, quantity can be appreciated without counting.

Above the subitizing range, quantity cannot be appreciated without counting, though groups can be appreciated as bigger or smaller when the difference is above a threshold of noticeability, as can be seen by comparing the outermost groups on the bottom row.

Consider change in the form of written numbers across five millennia and multiple languages (Overmann, 2021c; also see Figs 6 and 7). The forms of signs for subitizable numbers are conserved because their elements instantiate quantities that the number sense can appreciate. Numbers higher than about four are outside the subitizing range. Like subitizable numbers, they instantiate quantity. Unlike subitizable numbers, they are not appreciable by the number sense. To overcome this limitation, their elements are grouped into smaller, subitizable subgroups (Chrisomalis, 2010). Over time, and because of topological recognition, handwriting effects like automaticity, and so on, these simplify as forms that avoid counting elements or element subgroups; they become conventions whose semantic meanings are typically the numbers *one* through *ten*. This does two things. First, ciphered forms are more subject to the mechanisms that change written forms, so their forms change more than those of subitizable numbers do, but much less than the forms of characters for non-numerical language. Second, ciphered forms preserve their numerical relations, so they remain identifiable as numbers.

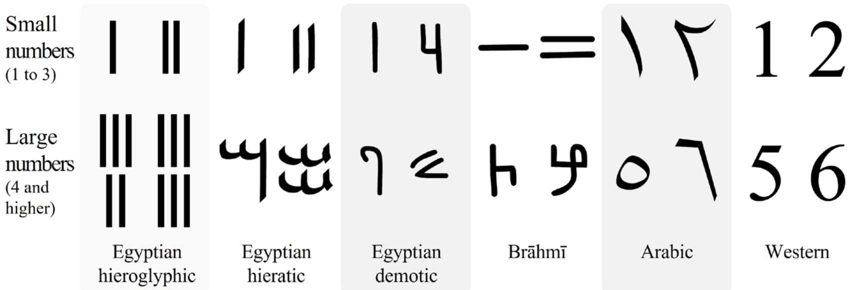


Figure 6.

Change in the form of written numerals over five millennia and multiple languages.

Numerical notations for the small (subitizable) numbers one and two instantiate quantity and essentially remain one and two linear strokes throughout. In comparison, numerical notations for the large (non-subitizable) numbers five and six change to a greater extent, though not as much as characters used for non-numerical language (compare with Figs 2 and 3). Cuneiform (not shown) and hieroglyph numbers instantiated quantity; hieratic was a cursive form of hieroglyphs whose instantiative elements are recognizable, and demotic and later scripts are ciphered forms that no longer instantiate. The complex links between Western numbers and their Mesopotamian and Egyptian ancestors are shown in Fig. 7.

The data were sourced from Chrisomalis (2010).

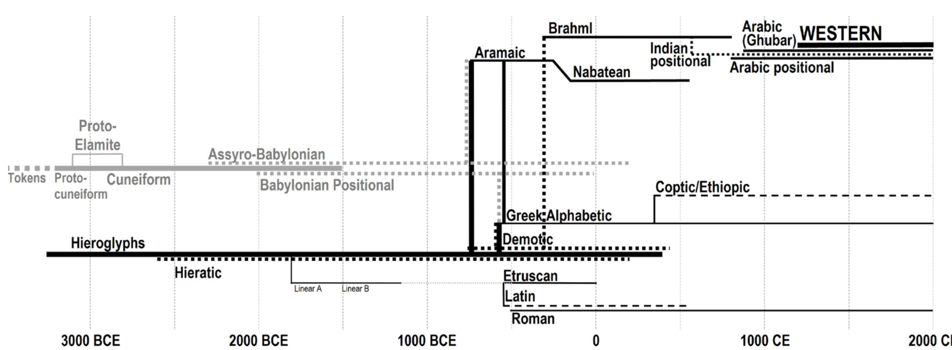


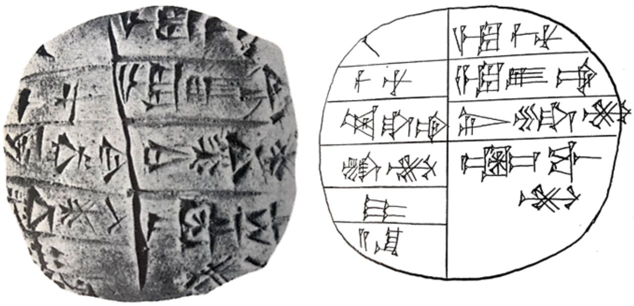
Figure 7.

The complex ancestry of Western numerals.

The diagram simplifies the links between Western numerals and protocuneiform and hieroglyph numbers, omitting, for example, potential interactions with Nabatean, Coptic, Ethiopic, Greek, and Roman numbers. Note that when the practice of using clay tokens as counters might have emerged in Mesopotamia is unknown; some authors have placed it as early as the tenth (Moore & Tangye, 2000) or ninth (Schmandt-Besserat, 1992) millennia; however, the use of small clay objects as counters is unverifiable prior to the emergence of numerical impressions found in assemblage with tokens in the mid-fourth millennium BCE (Amiet, 1966, 1972; Broman, 1958; Oppenheim, 1959; also see criticisms and discussion in Englund, 1998a; Friberg, 1994; Overmann, 2019; Zimansky, 1993). Data sourced from Chrisomalis (2004, 2010).

Instantiation has other consequences. One is that while numbers can be written with phonetic clues to their pronunciation in a specific language, they become much less usable as numbers when this happens. This is because phonetic values make signs visually complex, and visual complexity degrades or destroys the semantic concision that makes numerical relations and patterns apparent and accessible. This can be seen by comparing, for example, the numbers *one* and *two* written out phonetically in Arabic (واحد اثنان), Greek (ένα δύο), and Bosnian (*jedan dva*) with those represented by Chinese (一二), Western (1 2), and Roman numerals (I II). The lack of any need for clues to phonetic values can also be illustrated with Roman numerals, which most people use without knowing their names in Latin. The lack of phonetic values means that numerical notations work with any language. This is not true of non-numerical language, where reading a phonetic script, one that specifies particular words and morphemes in a particular language, requires both knowledge of the language and training and practice with the script.

Numerical signs are unambiguously meaningful and more usable as numbers without phonetic clues. As a result, phonetic forms of numbers emerge much later. For example, after writing emerged in Mesopotamia in the mid-fourth millennium BCE, the earliest phonetic transcriptions of the Sumerian numbers *two* through *ten* appeared centuries later, in the late third millennium (Edzard, 1980; Friberg, 1986; Pettinato, 1981a). As for large Sumerian numbers, their phonetic values were not recorded for over a thousand years (Damerow, 1988). Phonetically specified forms of numbers emerged not just later, but also only under specific conditions. Consider the conditions needed to produce the Ebla artifact TM.75.G.2198 (Fig. 8). Writing for non-numerical language had to be in place, as did the ability to depict phonetic values. Most importantly, there had to be a reason to add phonetic clues to numbers, since the visual complexity this adds degrades or destroys their semantic concision as numbers (Overmann, 2021c). The place where this artifact was found, the Semitic city of Ebla, suggests that it was made by Semitic-speaking scribes who wanted to learn the Sumerian vocabulary for numbers in addition to the Sumerian notations, much like we might today learn Latin vocabulary for numbers in addition to the Roman numerals. The artifact was also made just prior to adapting cuneiform to Akkadian, a Semitic language. Perhaps recording phonetic versions of numbers was an initial means and motivation for adapting cuneiform to Akkadian (Overmann, 2021c).



Sumerian	Meaning
[dili]	one
me-nu	two
iš$_x$-ša-am	three
li-mu	four
ia$_9$	five
â-šu	six
ù-me-nu	seven
ù-sa-am	eight
ì-li-mu	nine
u$_9$-wu-mu	ten

Figure 8.

Administrative tablet from Ebla (TM.75.G.2198, c. 2350–2250 BCE).

The obverse face contains the Sumerian numbers two through ten in phonetic form; one is not phonetically specified. Photograph by M. Necci and drawing published in Edzard (1980, Fig. 26a–b). Transliteration from Pettinato (1981, p. 212).

In the historical emergence of a number system, multiple material forms precede written notations (Overmann, 2019). Cross-culturally, the fingers appear to be the earliest device used for counting, presumably because of the neurological interaction between the parts of the brain that appreciate quantity and know the fingers (e.g., Roux et al., 2003). Finger-counting influences number systems toward properties like linearity and stable order (Gelman & Gallistel, 1978), as well as grouping by tens, fives, and twenties (Epps, 2006; Epps et al., 2012), though many other variations are possible (Overmann, 2021b). Since the hands cannot represent quantity for long, material forms that accumulate like the fingers do, but that can do so for longer and with greater capacity (e.g., tallies), may be incorporated. Devices accumulating to quantities higher than the hands encounter the perceptual limits on non-subitizable quantities, motivating the use of bundling. Written numerical notations garner the handwriting effects discussed earlier in conjunction with literacy, with the differences related to and influenced by instantiation as noted. In Mesopotamia, handwriting yielded the cuneiform numbers, which eventually added the convention of place value (Friberg, 2005; Robson, 2007).

As numbers elaborate, their representation becomes more concise (Overmann, 2019). For example, representing the number 75 takes the hands of eight people but a single tally with 75 notches, seven Mesopotamian tokens, three cuneiform signs, and two Western numerals. Concision increases the volume of data that can be brought together for simultaneous visual inspection, which increases the likelihood that relations and patterns will be noticed. Concision is achieved by minimizing the information that is explicitly represented, while increasing the implicit knowledge the user must supply, concepts like sign meaning and place value (Overmann, 2019). This means the need for training increases, just like it does for the system of writing generally.

For language, handwriting is critical to developing literacy because it is the mechanism that enables the material form of writing to change incrementally in response to neurological and behavioral change in the users. This is not true of numbers, since numbers do not need to be written. Nonetheless, handwriting has distinct neurological and functional effects on numbers. Neurologically, because written objects are recognized topologically, written numbers become objects recognized through their features. They are no longer collections of countable discrete objects, the way numbers represented with technologies like fingers, tallies, and counters are (Overmann, 2019). Functionally, written notations are concise to a degree that their precursors are not, and this enables the collection of relational data in previously unfeasible volumes. For example, multiplication tables are not feasible with fingers, tallies, or counters in the way they are with notations. The concision that notations added to the system for numbers allowed the collection of such numerical relations into tables, which scribes learned as part of their training. This would have caused the scribes to begin to think of numbers in terms of these relations. These new material forms and behaviors would eventually redefine numbers through their relations. Through handwriting and topological recognition, and through concision and relations, numbers would become objects in a relational system, and calculation would ultimately become a matter of manipulating learned relations, rather than physical counters, a transition that would continue for several millennia (Pullan, 1968; Reynolds, 1993; Stone, 1972; Woods, 2017).

Non-numerical writing was also important to the development of complex mathematics, as it allowed calculations to be recorded, initially as narrative descriptions of the steps involved, much like a cookbook recipe (Devlin, 2003). This documentation helped to codify the calculations as algorithms, or series of specific steps to be performed in certain order. This in turn allowed calculations to become longer, more complex, and more accurate, since they no longer had to depend on human memory. This too would have helped numbers to be reconceptualized as objects, ones that could be manipulated by processes and operations. It would take several more millennia before these narrative descriptions would eventually become signs without phonetic clues, like the familiar plus and minus signs used today for operations like addition and subtraction (Schulte, 2015).

Cognition as Extended and Enacted

The insights into literacy and numeracy presented here were realized by analyzing them as systems composed of brains, bodies, and material forms. This model enables the examination of how these systems change over time and the inference of changes in brains and behaviors from changes in the material forms used in writing and numbers. The model itself is relevant to understanding the insights drawn from it, and it has potential utility in understanding how writing develops and the contiguity between written and unwritten forms of numbers. It also serves to complicate the view that (all) writing is (just) language.

What does it mean to say that cognition is a system? After all, cognition is generally conceived as activity in the brain, a construct in which activity in the brain is synonymous with the mind. However, this view of mind and brain is a recent historical development. By the early 19th century—a mere two hundred years ago—the idea that the brain might actually have something to do with cognition was starting to gain traction. Today, it is so uncontroversial to associate mind with brain that the two are often equated. Besides trying to figure out how a material organ like the brain is even capable of phenomena like sensation and consciousness (Block, 2002; Chalmers, 1995, 2017, 2020; Jackson, 1982), debate now centers on what else the mind might include, in addition to the brain. Several claims have become commonly accepted. Cognition is seen as embodied and embedded, influenced by being in a body and an environment (Lakoff & Johnson, 2008; Prinz, 2009; Smith, 1999; Wilson & Clark, 2009). Cognition is also understood as evolving, continuing to change in an evolutionary sense, including the last 10,000 years (Malafouris, 2013). Other claims, however, are minority positions found mainly in philosophical work, and almost never in the mainstream cognitive sciences. These see cognition as extended, as including materiality as an integral component (Clark, 2008; Clark & Chalmers, 1998), and as enacted, as consisting of the interactivity between brain, body, and world (Hutto, 2013; Hutto & Myin, 2013).

It is easy to link neural activity to environmental phenomena in causal terms, and this preserves the Cartesian distinction. For example, vision is a perceptual modality in which neural activity is causally linked to light waves and refractive properties. Simply, light entering the eye excites the neurons in the retina and brain. This chain of causes yields an effect, which we call vision. However, extension and enaction claim that material forms are more than just causally linked. Extension says that materiality is part of the mind, and enaction says that cognition is the interactivity between brain, body, and world. These claims are much more difficult to establish, for reasons that include the fact that we tend to think of things in the world as distinct phenomena that are only causally linked to cognition.

One issue is that not all researchers seem to understand what extension actually means. Some have claimed extension means that objects think, a position known as panpsychism (e.g., Johnson & Everett, 2021). This, of course, is not what extension claims, which is, rather, that objects are an essential component of our thinking. Another issue is that historical discussions of extended cognition were not entirely convincing. For example, an early thought experiment compared different forms of memory (Clark, 2008; Clark & Chalmers, 1998). Otto uses a notebook to help him remember things, and Inga does not. How Otto remembers by writing notes differs qualitatively from Inga's reliance on her brain's innate capacity for storage and recall. However, both systems arguably have the same functionality. Debate then centers on whether these forms of memory are truly equivalent, and the basis on which external aids like notes can be considered as a part of cognition, rather than just causally linked to it.

In the Cartesian model, Otto externalizes some of his mental content onto a notebook, which acts as a passive repository of that mental content. He consults it later, which allows him to recover the information it contains. The notebook appears to be causally linked to cognition, rather than a part of it. But now consider what happens when Otto reads his notes. A person is only reading while he interacts in a specific way with a specific material form, which of course is writing. Reading as a cognitive state does not, and indeed, cannot exist without that material component and its active engagement. Thus, the material form that is writing is critical to the cognitive state that is reading, and reading is the interactivity of brain functions, the material form that is writing, and the behaviors that interface the two. Reading is extended because it includes a material form, and it is enacted because it exists only when brain, body, and writing interact.

Once reading is accepted as a cognitive state that involves brain, body, and a material form, the question becomes what it is that assumes the cognitive state. If we think it is the *mind* that reads, then we must consider the mind as a *system*, of which the brain is a component, along with the material form of writing and the behaviors that actively engage it. Redrawing the boundaries of cognition to include material forms and behaviors does not mean the human brain is not critical to cognition, or special in an evolutionary sense. Nor does it mean the material or behavioral components function within the system in the same way the brain does. Certainly, for any individual person, brain and body are always part of the system, while material forms come and go in a way that reinforces the impression that the brain is where cognition occurs. For their part, material forms are malleable in their form and function, durable and persistent in their existence, and publicly accessible in ways that mental content, psychological states, and even behaviors are not. But once material and behavioral components are recognized as integral to cognitive states like reading, we have a valid model of cognition that includes more than the brain, and which possibly applies to more cognitive states than just reading.

The material component of reading—the sets of characters that comprise writing and scripts—includes numerical notations. Consider the earliest unambiguous numerical notations, impressions made in clay with counters made of clay some 6000 years ago in Mesopotamia. Because the impressions were made by counters, the two had the same form (shape and size) and function (instantiation through repetition and bundling). Now, if notations are recognized as part of the extended state that is reading, shared form and function imply that counters are likely part of an extended state as well. Granted, there are important differences between notations and counters, so the extended states they participate in likely differ. For example, counters are manipulable, while notations are fixed. This means that calculating with counters is a matter of physically moving them, while calculating with notations is much more knowledge-based. Such distinctions suggest there are likely to be qualitative differences in the extended states that notations and counters participate in, in terms of matters like the types and amounts of knowledge needed, the physical movements involved, and the focuses and durations of cognitive resources like attention and working memory. But these are the kind of details that can be established empirically, rather than questions that need to be settled.

Modeling cognition as extended and enacted lets us consider cognitive change at the level of groups and across spans of time that exceed what neuroscientific theories and methods can measure, but which are tractable to the theories and methods of cognitive archaeology, as was shown in the previous sections. The extended model lets us look at the historical dimension of literacy and numeracy, which were described as a process in which material forms accumulate cognitive effort, distribute it across space and time, and become increasingly adept at eliciting specific neurological and behavioral responses in their users. The extended model lets us examine how the material form of writing becomes capable of expressing particular languages fluently, and how and why numbers differ in this regard. It also complicates the view that (all) writing is (just) language. For numbers, writing is yet another device in a chronology of material forms that enable their realization and elaboration from the perceptual experience of quantity; the sequence of devices constitutes a manuovisual medium for representing and manipulating numerical information that can be expressed in language but does not reduce to it. Spatial perception is arguably similar in being instantiated by writing but expressible in language, the difference between "   " and "space." While these issues of categories and boundaries will not be settled here, they suggest that writing is a manuovisual medium capable of instantiating visual perceptions and expressing language.

Conclusion

The model of how literacy emerges as presented here is not concerned with writing's ability to store and distribute knowledge, nor the effects that the increased knowledge availability and the ability of writing to represent and organize knowledge have on a society's conceptual content, as these concepts and consequences are well-covered in other work (e.g., Goody, 1986; Goody & Watt, 1963; Olson, 1994; Olson & Cole, 2006). Nor is it concerned with social variability in degrees of literacy between individuals (Veldhuis, 2011). Instead, contemporary neuroscientific and pedagogical insights into the ways that brains and behaviors change through the embodied practice of writing are used to interpret change in the material form of an original writing system over time. The goal is explaining how a script might emerge from sustained, communal interaction with writing as a material form. It is nonetheless recognized that while the number of people actively engaged in writing and becoming literate in the manner described may have been relatively few, the concepts and conceptual changes realized through their engagement would likely have had a wider societal impact. This is because the availability of mechanisms like reading aloud and discussion provide opportunities for concepts and conceptual changes to be relayed far beyond the individuals who actually performed the reading and writing.

Mesopotamia was an appropriate initial case study because the material record presents a unique view of the emergence of writing from practices like seals (Shendge, 1983) and tokens and bullae (Schmandt-Besserat, 1992). While several aspects of how writing emerged in Mesopotamia appear to be common to other original writing systems, further study is warranted, as there are also noticeable differences. For example, in Egypt, writing appears to have increased in ambiguity before losing resemblance and detail. Hieroglyphs maintained their ideal forms throughout, likely the effect of an artistic mandate. Hieratic, a cursive form of hieroglyphs, emerged about six centuries later (Hoffmann, 2012; Lopriano, 1995) and was thereafter used alongside hieroglyphs. While cursive implies topological recognition, tolerance for ambiguity, and increased speed of production, hieratic continued to resemble hieroglyphs, with the latter serving as both visual anchor and ideal. Demotic, a cursive much less depictive of hieroglyphs, emerged about two thousand years later; its "more abstract" form suggests a relaxed social imperative for preserving form and an increased opportunity to develop contrastive elements. Systemic change would also have been influenced by use. In Mesopotamia, writing is seen as having emerged as a bureaucratic tool, while in Egypt, it served purposes like honoring and communicating with the gods, matters that continue to be studied. Use would have affected things like the number of writers and the amount of writing behavior, influencing the rate of systemic change.

Including more writing systems in the model may ultimately gain additional insight into the critical changes, temporal sequencing, and functional interdependencies inherent in the process, beyond the general outline realized from studying Mesopotamian writing presented here. The degree to which other original writing systems (e.g., China and Mesoamerica) are tractable to this kind of analysis will be determined by the availability of early material.

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brainstorm

Do/Be/Feel and Motivational Modelling:

Applying a new brainstorming process in the design of brandmarks

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Abstract

Brainstorming in design typically uses an informal scattered approach. In contrast to this we introduce a focused brainstorming process, adapted from an approach called *Motivational Modelling,* to guide the process of designing brands. We describe a case study of four real-world briefs, where 79 graphic designers created brandmarks over 12 weeks. The *Motivational Modelling* approach involves a structured, three-stage process. First, *Do/Be/Feel* goal generation sessions create word lists. Second, initial brand value diagrams are produced from a subset of the word lists to build brand understanding by entering the words into a custom designed software program. Finally, branded story diagrams are designed to match the brands. We found that the three-stage process was easily adopted by the graphic designers. Creating the diagrams kickstarted the overall branding strategy, which successfully prompted interesting brand values, and clarified project and organizational goals. Clients appreciated and implemented the final brainstorming and branding outcomes.

Keywords

brainstorming;
creativity;
design method(s);
design tools;
graphic design

Brainstorming methods are popular to encourage creativity in the ideation phase of the design process; however, designers typically use an informal ad hoc way to explain and to facilitate the brainstorming which we call a scattergun approach, that can be time-consuming and often difficult to document. Graphic designers want to document the brainstorming process to make the ideation process comprehensible for the client. We have not found any evidence in the literature that graphic designers have previously thought to learn from the systematic and repeatable software engineering methods to see what benefits they may offer the brainstorming process. In this paper we present a case study where we brought graphic design and software engineering methods together with the expectation that the brainstorming process and documentation in graphic design would be positively affected.

The approach we used is called *Motivational Modelling,* a focused and documented process for brainstorming and idea generation, with its key method being *Do/Be/Feel* goal generation (Lorca, Burrows, & Sterling, 2018). *Motivational Modelling* is a two-stage process, the method for which is described in an article by Lorca, Burrows, and Sterling (2018).

The first stage for *Motivational Modelling* is running a *Do/Be/Feel* goal generation session. *Do/Be/Feel* goal generation is a brainstorming method where key stakeholders of the project, such as key project members, produce four lists. The four lists are labeled as follows: "Do (what should the solution do?)," "Be (how should the solution be?)," "Feel (how should the stakeholders feel when interacting with the solution?)" and "Who (has a stake in the solution?)," The brainstorming aims to generate ideas for the stakeholders along with the functional, quality, and emotional goals/requirements of the system. *Do/Be/Feel* goal generation is an efficient, sophisticated, interactive, and adaptable process of capturing diverse ideas from a group of people. Typically, conducting a *Do/Be/Feel* session takes up to 30 minutes, though the duration can vary according to circumstances (such as topic and size of group).

The second stage for *Motivational Modelling* is converting the four lists from the *Do/Be/Feel* goal generation session into a diagram on a single page. Custom software has been developed to aid in this stage of the approach and is available through www.motivationalmodelling.com. After the four lists have been entered into the software, the designer drags (a subset of) the elements in the four lists into a hierarchy. The software then draws the hierarchy as a picture on a page, similar to what is seen in Figure 1. We aimed to explore the benefits of this focused approach to brainstorming, which was expected to add value to designing brands and the design process.

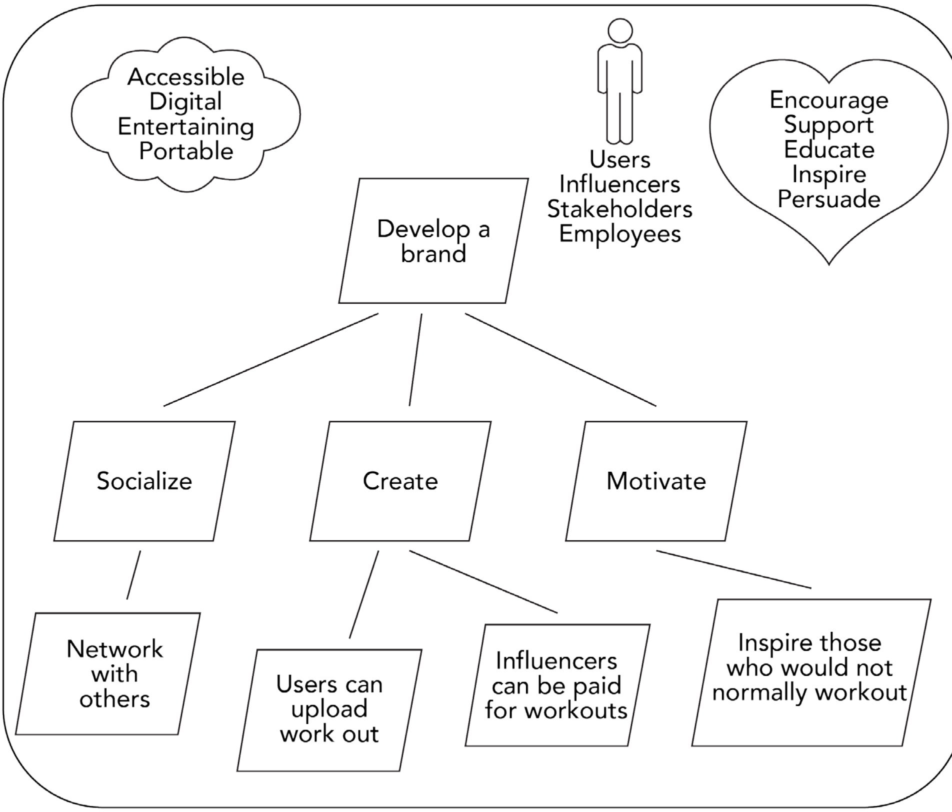

Figure 1.

An example motivational model for the fitness app.

This paper describes a case study where we trialed *Motivational Modelling* with graphic designers who were creating brandmarks. Seventy-nine novice graphic designers, out of a group of 150 designers, chose to trial the method on real-world industry branding briefs in a university context. We were interested to see if and how the method influenced brainstorming in branding, as well as the overall benefits and limitations of the new process. We discovered that the process led to novel diagrams displaying brand values and a branded story derived from the *Do/Be/Feel* goal generation sessions. Each designer formed their own unique *Do/Be/Feel* branded story diagram to match the intent of their branding project. We found that the goal generation sessions had a positive effect on the quality of brand values and the brandmark design. For our case study, applying and adopting methods developed by software engineering added efficiency and focus, enhanced creativity, showing potential for influencing the strategic direction of how graphic designers can design brands.

Background

Graphic design is described as the process of conceiving, planning, and organizing textual and visual elements for the purpose of communication (Frascara, 2004). The field of graphic design traditionally favors intuition as a method of creative idea generation. Graphic designers traditionally have balanced freedom of creative expression with the boundaries of client expectations; the more famous a graphic designer, the more freedom they can enjoy (Cross, 2004). Privileging intuition as a creative idea generation method limits the field's interest in exploring systematic methods such as "guided brainstorming" and stakeholder involvement for coming up with new and creative ideas to answer design briefs (Coyne, 1997).

The classic brainstorming method was originally conceptualized in the 1930s by advertising executive Alex Osborn, who coined the word "brainstorming" in his book *Applied Imagination*. In the book, Osborn detailed procedures for group brainstorming where groups of, ideally, 12 people share ideas on a focused problem (Osborn, 1953). Osborn's four rules for brainstorming, widely used today, are: 1) aim for quantity of ideas, 2) defer judgment of ideas, 3) welcome wild ideas, and 4) combine ideas to improve ideas (Osborn, 1953). Osborn's assumption is supported through recent studies that suggest that striving for a quantity of ideas leads to more quality ideas (Paulus, Kohn, & Arditti, 2011).

Various creative brainstorming techniques have been used in fields other than design, such as engineering and management (Dorst & Cross, 2001; Holt, 1996; Rossiter & Lilien, 1994; Shih, Venolia & Olson, 2011). However, De Bono (1977) argued that the traditional scattergun brainstorming technique, which focuses on as many wild ideas as possibly, was devised for advertising, which seeks novelty (De Bono, 1977). De Bono claimed that novelty is not the focus of idea generation in other fields, so he devised alternative lateral thinking techniques such as his "six thinking hats," a concept that is outlined in his books on serious creativity (De Bono, 1995; 2015).

Brainstorming has been referred to as a scattergun approach to creative idea generation (De Bono, 1977; 2015). It is a method that is widely used in design to discourage designers from becoming fixated on an early workable idea without exploring a wide range of options (Vasconcelos & Crilly, 2016). Researchers have developed varieties of brainstorming such as brainsketching and braindrawing (Van Der Lugt, 2002). A structured form of brainstorming called "bootlegging" has also been introduced, which proved successful for participants who had limited experience with brainstorming. This method was more open-minded than conventional brainstorming (Holmquist, 2008). There has also been a call to integrate stakeholders in the design process with the rise in popularity of user-centered design and co-design methods—hence the need for systematic and easy-to-use methods that are not based on intuition (Sanders & Stappers, 2008).

Brainstorming in groups has been found to be more productive than individual idea generation (Perttula, Krause & Sipilä, 2001). One argument for employing groups rather than individuals is to produce a variety and volume of ideas, but research from social psychology is unanimous that the pooled performance of individuals outweighs the performance of a group (Perttula, Krause & Sipilä, 2001). This finding is supported in another study that brainstorming in isolation generated more ideas and motivated more original ideas compared to interactive group brainstorming (Putman & Paulus, 2009). One theory is that working collaboratively in groups causes designers to use mediocre techniques for idea generation (Perttula, Krause & Sipilä, 2001). It is possible that because only one person speaks at a time in a group setting, participants are reluctant to contribute ideas to avoid hostile evaluation from others, and people don't contribute ideas because they think their ideas are not required (Perttula, Krause & Sipilä, 2001). Other research shows that individuals who share ideas momentarily with others produce more ideas than those who work individually, but idea exchange does not increase the variety of ideas produced (Perttula, Krause & Sipilä, 2001).

Interestingly, research has shown that people tend to produce similar ideas within the group early in a brainstorming session and more individual ideas towards the end of a session (Perttula, Krause & Sipilä, 2006). In experiments where groups use a "brainwriting" technique in which ideas are exchanged by written notes instead of verbal expressions, greater idea productivity is achieved compared with groups who did not share ideas in this way (Perttula, Krause & Sipilä, 2006). Other research claims that people from a range of backgrounds provoke the whole group to evaluate ideas, heterogeneous teams being repeatedly found to outperform homogenous ones in complex problem-solving tasks (Stempfle & Badke-Schaub, 2002). Stempfle and Badke-Schaub (2002) argued that the group can eventually accept discarded ideas when ideas are challenged through the creation of a "shared mental model."

Playing games and being part of small groups have been shown to improve the quality and quantity of brainstormed creative outputs, creating a space for people to experiment with new ideas and freely express themselves (Lam et al., 2018; Vegt et al., 2019). In a study that investigated creative design thinking with design students, the findings suggested that it is important to balance the pressure from teachers as extrinsic motivators with the students' intrinsic motivation in the process of acquiring creative design thinking for creative solutions (Friis, 2019). Inclusive design significantly opens up new approaches for teaching design students in providing necessary evidence through the learning framework (Rieger & Rolfe, 2021). Some authors argue that playful and creative interaction in a group of participants releases important knowledge in each individual, enabling them to combine their opinions productively and solve problems (Clemensen, Larsen, Kyng & Kirkevold, 2007). Being part of a multidisciplinary small group has been shown to unlock ideas by giving participants confidence to speak out (Perry-Smith & Shalley, 2003). Using a variety of methods for idea generation has been shown to result in better quality design outcomes (Lee & Joo, 2017).

While brainstorming methods are continually being developed to understand the influence of working in groups or individually, as well as revealing different ways of structuring the process, they remain time-consuming, and it is difficult to document the breadth of ideas gained in the process. Graphic designers typically use a loose scattergun brainstorming approach and then use intuition to leap to a chosen concept. Designers could consider adopting the systematic qualities of software engineering methods to understand what benefits they offer the brainstorming process for design.

The Case Study Method

The case study presented in this paper sought to understand how an approach used in software engineering called *Motivational Modelling* could benefit the graphic design ideation process of brandmark designs.

The Case Context and Participants

The authors of this paper have used *Motivational Modelling* in a variety of contexts prior to this study, which led us to believe that it may be useful in the graphic design of brandmarks. We had already proved the approach worked well in industrial design and digital design settings (Lorca, Burrows, & Sterling, 2018). This time, we were interested to see how novice graphic designers with little experience in industry standard brainstorming methods would respond to using *Motivational Modelling* and if and how it would influence the design process of brandmarks.

Four real-world branding briefs were undertaken in a branding design studio within a university context in 2019, where novice graphic designers worked with industry clients who required new brandmark designs. We met with each of the four clients for an initial briefing where the same set of ten questions was posed to each client to help the designers learn about the client context. The four client briefs to create new brands given to the designers were:

1. **Trainr: A fitness app**;
2. **VPremium: The concept of "future of cinema" for a cinema and movie business**;
3. **Profectus: An educational consultant**; and
4. **SEIL: A social enterprise impact lab**.

The designers worked for 12 weeks with their clients to explore suitable brandmark concepts. The designers all followed the same overall process for what to produce for their clients. We ran an information session to explain how to use *Motivational Modelling* where we outlined our structured three-step process, aiming to create project goal maps for our clients and their project briefs. This session was led by one of the authors of this paper who is an experienced software engineer and creator of the appraoch, and 150 novice graphic designers attended. At the session, we first explained how the *Do/Be/Feel* goal generation session works. Out of the 150 designers working on the four briefs, 79 chose to trial *Motivational Modelling* for their client brief. None of the 79 who chose to trial the technique had used it before, so this was their first experience.

The ages of the designers ranged between 18 and 30, and most had prior freelance design experience. Experienced branding designers assisted with art direction during the branding design process. The authors of this paper supported the designers as they learned how to use *Motivation Modelling* for the first time. An experienced software engineer briefed the designers in how to use the software (www.motivationalmodelling.com) and assisted with the use of the computer program to convert *Do/Be/Feel* goal lists into brand value diagrams.

Data and Analysis

We ran an anonymous reflection survey at the end of the 12-week branding process to understand what the designers found useful in the design process using the *Motivational Modelling* approach. We asked the designers what they liked and disliked about the software for creating brand value diagrams and what improvements they would make. We have drawn our reflections from the designers' final brand values, brandmark designs, branding reports: reflection surveys; the client briefs; and the diagrams produced through *Motivational Modelling.*

Thematic analysis was used, which meant that all these components were placed chronologically under activity headings into a large case report. The analysis was organized in themes answering the broad research question: *"What are the benefits of Motivational Modelling to idea generation, in the graphic design of brandmarks?"*

Motivational Modelling: A Software Engineering Process

Motivational Modelling is a process used to develop a big-picture view of a system, problem, product, or service that can be agreed on by a diverse set of stakeholders. *Motivational Modelling* has been developed from research into methodologies for agent-oriented software engineering (Sterling & Taveter, 2009). A key component in the development of the method was to augment requirements engineering methods for agent-oriented systems by putting more emphasis on the elicitation of goals and roles. As the modelling methods were applied to nontraditional domains such as health and wellbeing, they evolved to explicitly include emotional goals (Lopez-Lorca, Miller, Pedell, Mendoza, Keirnan, & Sterling, 2014).

Motivational models present a hierarchical diagram of the goals of a system (or design solution) at a high level of abstraction. The modeling notation uses four main elements: roles that represent the stakeholders; functional goals, which express what the system must achieve; quality (or non-functional) goals, which express goals such as performance, security and scalability; and emotional goals, which express positive feelings intended for people to have when interacting with the system.

An example of a motivational model has been given in Figure 1. It was one of the models produced by one designer in this case study and was drawn using custom software developed to facilitate *Motivational Modelling*. The model describes a fitness app that was one of the client briefs. The functional goals are in the parallelograms. The desired qualities are in the cloud—namely that the fitness app be viewed as accessible, digital, entertaining, and portable. It was aspired that people interacting with the app would feel encouraged, supported, educated, inspired, and persuaded, which are the words listed inside the heart. The qualities listed in the cloud and heart are clearly relevant when thinking about brand values. The researcher expected that the process of eliciting them would be helpful for branding students. The example given to the designers in the briefing meeting was of a company developing an app to support people over 45 in their fitness goals.

The Three Stages of Our New Brainstorming Process

The branding design process was structured in three stages.

Stage 1: *Do/Be/Feel* goal generation sessions

In the first stage, called *Do/Be/Feel* goal generation, word lists were created. We ran a group whiteboard session where the 79 designers working on each of the four briefs grouped together to brainstorm words in relation to the client brief. We placed the headings *Do, Be, Feel,* and *Who* at the top of four columns on the whiteboard using different color markers. The designers worked quickly to brainstorm words (or sketches, or a combination of both) for the goals of their client brief under each heading. They could complete each heading before moving to the next heading or, alternatively, move from heading to heading as ideas came to them. Sometimes the words offered naturally fit with one of the headings, and sometimes the facilitator (one of this paper's authors) suggested an appropriate word/term. For example if a person suggested champion for the 'Feel' heading the facilitator would suggest this belongs for the 'Do' heading and words suggested like encouraging and supportive belong for the 'Feel' heading.

The designers were asked to mark with a star the most important goal word under each category heading (Lorca, Burrows, & Sterling, 2018). After completing this session, the designers took photos of the whiteboard and proceeded to run a further *Do/Be/Feel* goal generation session with their clients, or on their own, to further the brainstorming process. The clients were open to the exploration of new names for their business if required, which were proposed from the list of words created in the *Do/Be/Feel* session.

Stage 2: Brand value diagrams

In the second stage, brand value diagrams were produced from a subset of the word lists from the *Do/Be/Feel* session to build a deeper understanding of the required brand direction. The initial *Do/Be/Feel* words were mapped in categories and subcategories under a hierarchical system in the form of a diagram. The designers used software to create a brand value diagram. The designers entered the words they had brainstormed in the *Do/Be/Feel* session and the software program automatically created the diagram (see Figure 1). The aim was for the brand value diagrams to identify appropriate brand value words to be used in strategy reports for the clients. The designers used their brand value diagrams to decide on eight brand value words to capture the essence of their project.

In this stage, the designers also conducted a visual audit of the client's competitors' brandmarks, analyzing them on a position map and preparing three in-depth case studies. The designers created a mood board with their own or found visual imagery to symbolize the brand values and brand direction. We met with the clients to gather feedback before proceeding. The designers then created at least 50 diverse brand-mark sketches by their own hand, inspired by the words from the *Do/Be/Feel* session.

Stage 3: *Branded story diagrams*

In this third stage, branded story diagrams were created to match the final brandmark design. After the branding process was completed, the designers revised their computer-generated brand value diagrams into branded story diagrams (Figures 2, 3, 4, and 5 are all examples of branded story diagrams). After consultation with the clients, the designers chose and refined one final brandmark and prepared a brandmark creative rationale. Branding extension design was applied to a range of applications such as letterheads, business cards, websites, mobile phone displays, packaging, posters, vehicles, and signage, as well as a set of explanatory guidelines. The designers then created a visual language for their brand involving choice of colors, typefaces, patterns, illustrations, and photography style. This style was applied to the branded story diagram to create a seamless branding story for our clients.

Experiences Using *Motivational Modelling*

In the following sections, we outline our experiences of building brands using the *Motivational Modelling* brainstorming process on four real-world briefs requiring new brandmarks.

Fitness App

Designing a brand for a fitness app involved understanding how to support everyday people through their fitness, health, and wellbeing journey. The existing brand had undergone numerous changes, which caused confusion and resulted in poor brand affinity. Therefore, the client wanted to develop consistency across their visual communications. They wanted their brand to speak to a younger demographic, helping the members of this new audience to feel more confident, happier, and empowered to take on their day. The fitness app concept involved an online "marketplace" that allows fitness, health, and wellness influencers to create video-based online training programs, where unlimited access to these programs is then provided to consumers via a monthly subscription. The aims were to tap into the reasons people have or have not taken better care of their health, and to create a brandmark and suite of applications that would break down the barriers to fitness and promote action towards better health. The brief was to design a branding strategy focusing on the people, not the exercise, and help them to feel great.

In our briefing, the client wanted the customers to do what felt fun and intuitively right. After the brainstorming in the *Do/Be/Feel* session one designer of this brand settled on a new name for the fitness app: Trainr. In response to the question "*What should the fitness app Do?*" the brainstorming suggested that it should: motivate, encourage, educate, support, persuade, and provoke. For the question, *"What should the fitness app Be?*" the words suggested were: accessible, habitual, digital, portable, enjoyable, addictive, intuitive, and affordable. The words proposed as answers to the question, "*How should the fitness app Feel?*" were: powerful, rewarding, unintimidating, provoking, and nudging (see the top left area in Figure 2). The brand value diagrams (at the top right in Figure 2) show the summary of the final brand values: connectivity, fitness, enjoyment, play, cutting edge, and motivation.

In the final branded story diagram (all parts of Figure 2), the designer was to redesign the initial lists of words to match the brand colors, type, and look and feel elements. The curved edges of the red bars in the brand values list match the curves in the final brandmark, and the red circles in the buzzwords match the circle that represents a head in

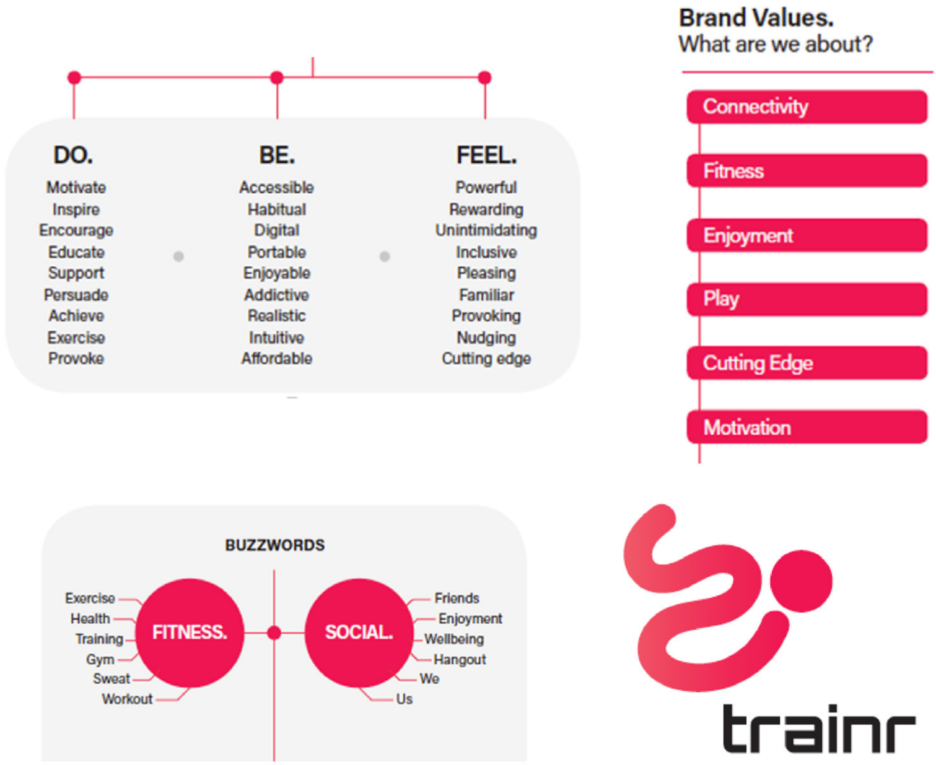

Figure 2.

An example of a branded story diagram for the fitness app [designed by Max Johnson]

the trainer brand. The designer was inspired by the process to create a set of "buzzwords" for the project, which were divided into two themes. Under the theme of "fitness," words such as *exercise*, *gym*, *sweat*, and *workout* were identified; under the theme of "social," the words prompted were *us*, *we*, *friends*, *hangout*, and *wellbeing*.

The future of cinema

The aim of the future of cinema brief was to design a physical space and experience combining cinema and entertainment, where the brand was to represent a space that felt like an escape where people could share experiences with loved ones. The idea was to offer shareable food and beverages such as rustic pizzas, burgers, and nachos, accompanied by craft beers and local wines. We were briefed to consider a space that would combine the feel of warmth of a mountain lodge with an

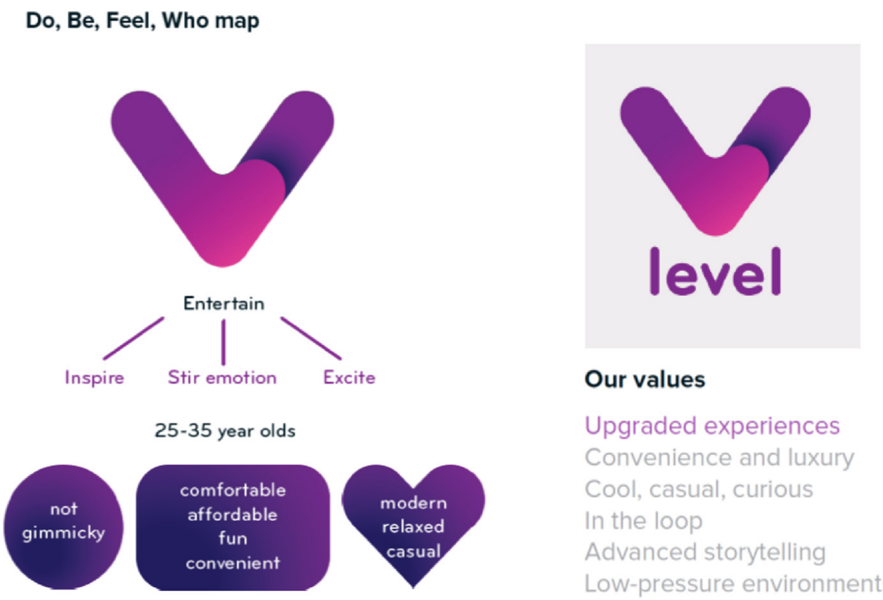

Figure 3.

The future of cinema's branded story diagram, designed with the V from VPremium [designed by Trinity Ross]

urban atmosphere using materials such as timber, exposed brick, and steel beams. In addition, the space could include a cinema, mini bowling lanes, pool tables, and an outdoor al fresco dining area. Ideally, the space would suit families and kids in the daytime and 25–35-year-olds after dark, with a nostalgic leisure-time feel where people could socialize and connect.

For the question, "*What should the future of cinema Do?*", the resulting words were: comfortable, affordable, fun, and convenient. In answer to the question, "*What should the future of cinema Be?*", the phrase suggested was "not gimmicky" (at the bottom left in the circle, in Figure 3). The summary words for the question, "*How should the future of cinema Feel?*" were: modern, relaxed, and casual, represented in the heart icon (Figure 3, bottom middle). The brand value words for the new cinema entertainment concept were: upgraded experiences, convenience and luxury, cool, casual and curious, in the loop, advanced storytelling, and low-pressure environments (Figure 3, bottom right). The completed branded story diagram (Figure 3) shows a simplified diagram with three shapes: a circle, rounded rectangle, and a heart. This designer pinpointed three words to summarize the process and reflect the project brief: "inspire, stir emotion, and excite." This summary is reflected in the final brandmark (Figure 3, top left).

Profectus Education

Designing a brand for Profectus Education first involved understanding the client. Profectus is an education, consulting, and coaching service that aims to positively influence teaching and learning in education settings. The company is known for the following characteristics: "practical, contemporary thinking and informed." Key words the client used to best describe the business were: quality, change, and value-driven and the main audiences for Profectus consist of academic leaders, teachers, and school principals. The brand would be mainly seen online, but would also be visible on signage, emails, letters, and certificates. The client wanted people to feel "positive, have their needs met, and confident" when they interact with Profectus. In response to the question "*What should Profectus Education Do?*" the answers generated were: educate, train, review, and evaluate. When the question "*What should Profectus Education Be?*" was posed, the responses were: innovative, professional, valuable, and courageous. For the question "*How should Profectus Education Feel?*", the words were: confidence, knowledgeable, effective, and growth (see Figure 4).

The final branded story diagram shows the 3 main directions: educate, evaluate, and develop (toward the top of Figure 4). The feeling of the brand is noted next to the green cloud, using these words: qualified, informed, professional, valuable, courageous, and innovative. This branded story diagram of the goals has been reused as an exemplar motivational model for new clients wanting to develop their business aims and goals.

Social Enterprise Impact Lab (SEIL)

The Social Enterprise Impact Lab (SEIL) is a collaborative research project. The aim of the project is to examine the effectiveness of different approaches that social enterprises use to evaluate and report their social impacts, and to determine what works and why. The business is known for its transformational research, which the client described as rigorous and purpose-driven. SEIL has created a unique online data dashboard that social enterprises can use to monitor and communicate their impact. When we asked the client how they wanted people to feel when interacting with SEIL, the client told us that they wanted their customers to feel confident, knowledgeable and empowered when interacting with their ground-breaking collaborative research initiative.

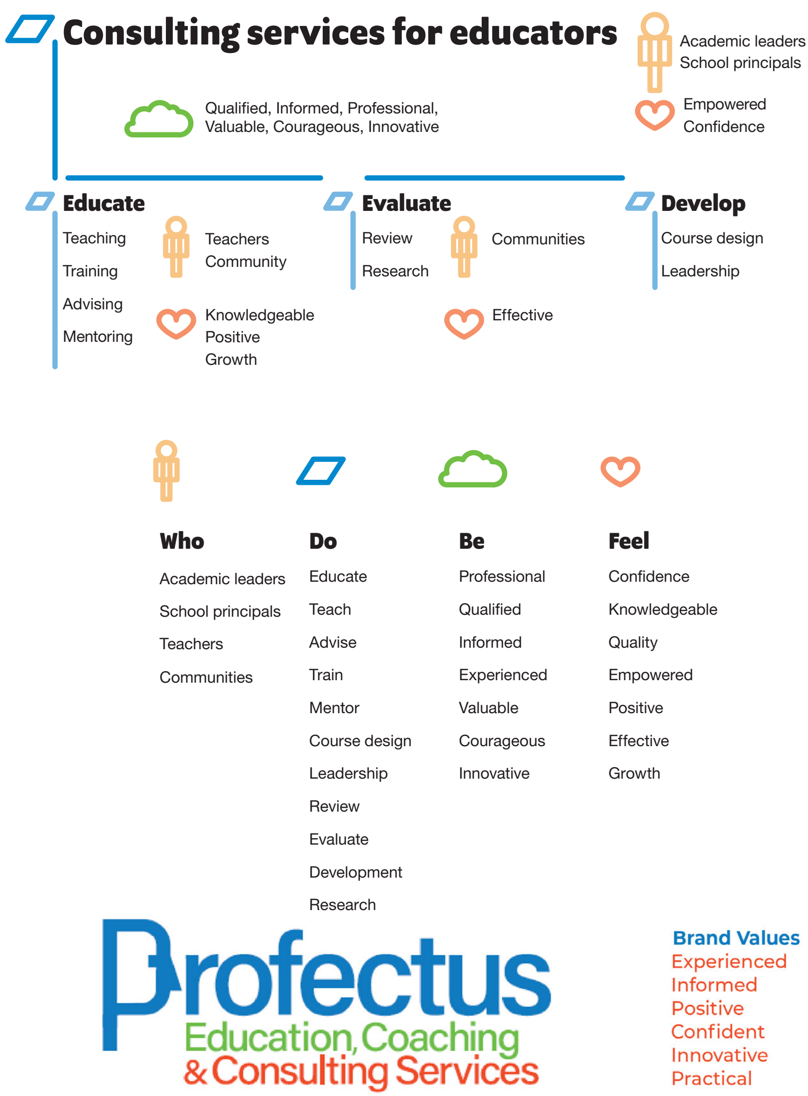

Figure 4.

Profectus branded story diagram, including brandmark bottom left and brand values bottom right. This diagram is a draft and not a final polished artifact.

[designed by Lewis Barnes]

In response to the question "*What should SEIL Do?*", the answers that came up were: educate, evaluate, motivate. When asked "*What should SEIL Be?*", the final collated words were: affordable, approachable, and innovative. Finally, for the question "*How should SEIL Feel?*", the associated words were: distinctive, positive, and advanced (seen at the top left in Figure 5). The brand value diagram (top right in Figure 5) shows the summary of final brand values, with the main value highlighted in a green box; it reads "Catalyst to enable the success of social enterprises." The final brandmark inspired by this brainstorming process is shown at the bottom of Figure 5.

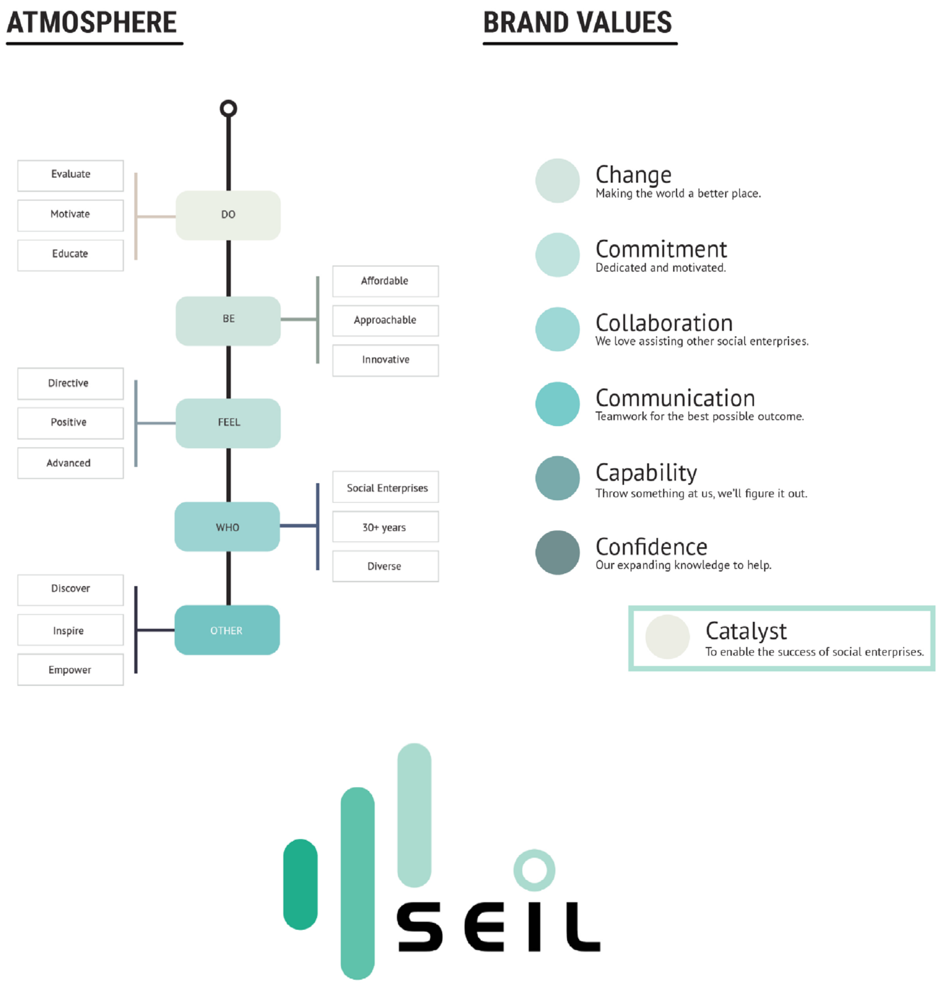

Figure 5. SEIL: branded story diagram [designed by Shaun Thoo]

In the final branded story diagram (all parts of Figure 5), the designer was inspired to redesign all the elements using a green color palette and a simple tree diagram. The curved corners have been used throughout the diagrams, and the circles next to the brand values match the circle above the name of the company in the final brandmark (Figure 5).

Benefits of *Motivational Modelling*

In the following section, we discuss the benefits of using *Motivational Modelling* as a new brainstorming process for idea generation in the graphic design of four brandmarks.

Providing Efficiency and Clarity

Motivational Modelling provides a three-step process to assist designers in the early stages of a design project. Overall, the designers liked the simplicity of the *Motivational Modelling* software for step two. When using the software, the first task is to input words in a list in the tool, and then the software program generates a diagram with the words placed in either heart, cloud, or parallelogram shapes. These shapes are also positioned in levels to visually reveal a hierarchy of concepts in form of a tree. When inputting the *Do/Be/Feel goal* words in columns in the tool, one designer commented that it was "Easy to add to the list … easy to create a hierarchy." Mostly, the designers were delighted by how fast the tool created a snapshot of the project ideas in a tree diagram. Example comments in the open text box in the feedback form were: "Very straight forward and easy to use; easy to apply goals"; "Easy to follow the steps"; "Simple and serves its intended purpose." One designer liked the fact that "it was online."

Setting up a branding strategy and identifying the key criteria for a branding program is an important skill that is often lacking in novice graphic designers. Clarifying project goals is a necessary step for designers and clients before embarking on the creative design stages of a branding project. This is where projects often fail—when goals are not agreed upon at the outset of the project (Lundmark, 2018). Finding tools to help designers navigate this stage, where the need is often to translate business language and ideas into designer words and concepts to steer the project forward, is crucial. One designer explained that they liked "the idea behind it, the way the information you input automatically generates a visual and the way it makes you think about your brand."

Another designer claimed *Motivational Modelling* was useful to clarify the branding project goals:

— "I had not heard before about *Motivational Modelling* which might look simple at first, but I found it helpful for creating the brand since it allowed me to clearly identify the goals and values of the Fitness app."

There was also interest in using *Motivational Modelling* in future design projects:

— "'Do/Be/Feel' was a fantastic method in helping me come up with brand values and helping me discover what needs to be covered and what I may need to avoid. I will be using this any chance I can get."

The value of the *Do/Be/Feel* goal generation approach was highlighted by one designer for its ability to work out the essence of a brand message:

— "One industry skill I learnt was the 'Do/Be/Feel' mapping tool for determining important concepts for a brand. Using this, I was able to figure out what the most important things were to convey through the branding."

Using *Motivational Modelling* for organizing core brand values was seen as an useful skill to take into industry:

— "Constructing brand values, which I found to be a handy tool in analyzing & organizing the core values for evaluation. This will be a good industry tool."

The *Do/Be/Feel* goal generation session were valued for their ability to kick-start the overall branding strategy:

— "Before naming a brand, one needs to come up with strategy or theory - using the '*Do/Be/Feel*' method helped kickstart the process."

Structuring Brainstorming

This was the first time that the 79 designers had used a structured brainstorming process. At the first client presentation, the designers reported that the clients enjoyed reading the details of the *Do/Be/Feel* brand value diagrams. The diagrams helped explain design elements by brokering design language with business language. In our study, the designers found the structured process using brand value diagrams helped to make the branding process accessible for their clients. The *Do/Be/Feel* brand value diagrams were a useful method for translating a list of words into a visual map of ideas and concepts, as one designer reflected in the feedback survey: "It visualizes your brand's image making it easier to work towards a brand."

The designers expressed the view that using the tool was beneficial to the branding process, as the concept map of ideas that it created inspired the designers to think creatively about how to proceed to the concept design phase of the branding process. One designer liked the "Detail and clear project steps," which indicated how to proceed to the next step of the branding process. We imagined the designers might not like the structured process of organizing and mapping a branding project; however, the feedback indicated that designers liked how the process was "very structured." One designer was excited to learn a new skill, exclaiming, "the concept of it I think is really brilliant."

A structured process to brainstorming was appreciated by another designer who commented how freeing it can be: "The importance of brainstorming and collecting the best options is that it provides a large number of choices to choose from." Another designer realized "how much effort and brainstorming is involved in incorporating specific ideas into a brandmark and how each decision made needs to be well thought out and rationalized."

Our experiences contrast with Jones, Stanton, and Harrison's (2001) research, which aimed to improve traditional brainstorming with the "PIT" method. Their method assisted groups with producing ideas after initial ideas had "run dry," where a trained person records the ideas, freeing others' ideas (Jones, Stanton & Harrison, 2001). Their research found that overuse of structured methods may inhibit the quantity of ideas produced, warning that "over-structuring" may cause participants to feel like they are working on a chore. In contrast, we found that structured activities were easy to use and enjoyable.

Brainstorming Into Brand Concepts

As the designers were encouraged to freely sketch their branding ideas alongside generating the word lists in the *Do/Be/Feel* goal generation session, they found it efficient to avoid fixation on initial ideas and instead, move quickly through various ideas. One designer found that "by creating a large number of quickly drawn/sketched logos, you focus less on the perfection of the sketch, and rather focus on the different aspects of the design." In addition, another designer reflected that "sketching many ideas and concepts down on paper is essential to help formulate a well-rounded design approach that directly correlates to the values of the business." When it came to translating the *Do/Be/Feel* list of words into brandmarks, one designer explained:

Sketching is such an important part of the brand making process. You can visually see your ideas come to life for your logo. It is also a great way to show clients what you visually took away from their ideas, and it can make them see what they like and dislike.

In this way the word lists were not only capturing the results of the brainstorming, but also became a communication tool between designers and clients.

Overall, the designers found *Motivational Modelling* a new and useful brainstorming process while generating ideas through sketching. The *Motivational Modelling* process didn't inhibit their creativity; in fact, it helped the creative brainstorming process and expanded the creative process overall. One designer commented, "I learned that it is best to generate as many ideas as you can think of in the brainstorming and sketching stage to ensure that you will have the most suitable brandmark to further refine." Another designer found that *Motivational Modelling* opened up the possibilities in the brandmark design idea generation stages: "Through the process of sketching during brainstorming, it enabled me to see countless design directions and how it can help the brand accordingly making sure you develop the right ideas in order to create the most effective brand mark." This process could be further supported by accessing the ideas of the group which is beneficial for designers. One designer commented, "My '*Do/Be/Feel*' map was completed in front of the class with everybody adding their own suggestions. This was helpful for me to better understand what direction to take the branding identity in." Our case study suggests that a group brainstorming session is useful for generating many ideas, and for hearing from others in a group discussion about the direction a brand might take.

Conclusion

We brought graphic design and software engineering methods together with the anticipation that it would positively affect the brainstorming process in graphic design. The process we used is called *Motivational Modelling* with its key method being *Do/Be/Feel goal generation* in the brainstorming creative ideation stage of branding projects.

Based on our results we suggest that *Motivational Modelling* is a useful technique for structuring brainstorming during the ideation process. We avoided the negative result of brainstorming, where a scattergun approach can result in a plethora of random and broad ideas, which leaves designers confused as to where to start in sorting the relevant from the irrelevant ideas. Grouping words and ideas along the way under the themes of *Do/Be/Feel* was productive. We found that the logical approach of *Motivational Modelling*, where brainstorming ideas are sorted into categories and prioritized as they come, was counterintuitive to designers' natural, intuitive brainstorming methods. It is worth noting that all the 79 motivational models created by the graphic designers resulted in an acceptable standard according to the experienced software engineer.

We recommend using a structured form of brainstorming ideas as an efficient method for coming up with a project focus. The designers commented that they enjoyed trialing a specific technique that they could use again during industry branding projects. Our experience suggests that *Motivational Modelling* would be useful to formally include in branding education or in industry branding projects.

In addition to our recommendations, we believe that this case study adds to current thinking on brainstorming methods. We were open to see how *Motivational Modelling* would be used by the designers and to explore its influence on the process and final branding design outcomes. The structured three-stage process was easy for the graphic designers to use. The *Do/Be/Feel* sessions also helped to focus the brainstorming process. Creating the brand value diagram kickstarted the overall branding strategy and was useful in both prompting interesting brand values and clarifying project goals. The final brandmarks and branded story diagrams were well-received by our clients. Our experiences suggest that *Motivational Modelling* provides a promising new approach for graphic designers and designers in other fields looking for a brainstorming process that can translate business goals efficiently and capture the design rationale into a design language with logic and focus. Overall, the *Do/Be/Feel* goal generation method to brainstorming was a structured process that we used to produce results in the design of brandmarks. The novice designers who participated in our research project ultimately responded that they found the *Motivational Modelling* approach and the *Do/Be/Feel* goal generation sessions easy to participate in, and enjoyable in the design of brandmarks.

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symbols

Interaction of Symbols:

Multiple symbols interact to provoke meaning, the foundation for better icon design

Mike Zender

Abstract.

Numerous studies support the thesis that icons frequently fail to communicate because designers have not appreciated that icons combine multiple symbols which interact to evoke meaning. Because symbols interact, a designer must know which symbols to combine and how to draw each symbol so that icons communicate clearly. This article brings together numerous research studies that explored new methods for designing icons based on the interaction of symbols.

Keywords:

theory;
icons;
symbols;
pictograms;
design methods.

Introduction

Otto Neurath, the inventor of the international symbol language *Isotype*, got the idea for *Isotype* from a 19th-century picture game. “Three of these pictures represented a hammer, a bell, and a hammer and bell combined. I never forgot the particular impression I got from the possibility to combine symbols as one may combine letters...” (Eve & Burke, 2010, p. 89). Neurath eventually combined symbols numerically to represent quantities, but his observation might also apply to combining symbols to convey ideas. Combining symbols to evoke new meaning might sound simultaneously trivial and profound, and it is both. The act of reading combines symbols to bring ideas to mind in ways whose impacts linguists are still exploring. The profundity is magnified by the role symbols, pictures, and icons have come to play in everyday life across the world. Today icons are useful, ubiquitous, and misunderstood. They are useful because they condense information to the scale of a smartphone, which is also an example of icons’ ubiquity. Icons are misunderstood for a variety of reasons.

Figure 1.

Symbols which inspired Otto Neurath

Icons are not well-understood

Icons are misunderstood in the sense of lack of agreement about how they work or what they are. To begin, what we are calling icons here are given different names in different disciplines. For software professionals they are symbols, in healthcare they are called pictograms, in safety they are safety signs. Another reason for misunderstanding is that icons have been studied by different disciplines with differing agendas. Interface experts, for example, want to know "why some symbols are easier to use than others" (McDougall, Curry, & de Bruijn, 1999, p. 487). This is understandable given that icons are used in an interface to identify and use software features. Interface researchers have concluded that the critical factors of an icon are its visual complexity, concreteness, familiarity, and semantic distance, that is, how much an icon looks like what it means. For example, an icon of a file folder to represent "file" has a close semantic distance, while an icon of a trash-can to suggest "delete" has a greater semantic distance. In Medicine, icons are called "pictograms." Pictograms are valued by healthcare professionals to the extent that they attract attention, convey information, and help patients remember to do what has been prescribed (retention and adherence). "Pictograms can serve as communication tools to enhance visual attention, comprehension, recall, and adherence of instructions provided" (Barros et al., 2014, p. 14). As a result, healthcare pictographic research focuses on measuring comprehension, retention, and adherence to verbal or written instructions. Safety and Transportation professionals are also concerned with the comprehension of what they call "safety signs" but in the context of rapid recognition by all people. This leads Safety professionals to explore concerns related to safety-sign comprehension by those of various ages and physical limitations. One study found that older adults took longer to process iconic information (Liu & Ho, 2012). All this research might lead you to conclude that icons, or pictograms, or symbol-signs, or whatever you call them, must first attend to visual complexity, or perhaps that retention and adherence are most important, or that overcoming physical limitations such as those brought on by aging is the primary concern. You can see why icons might be misunderstood. Ironically, very few of the many studies in these disciplines have had icon designers as co-PI's in their research, and most made no attempt to consider the design quality of the icons used for their research studies. It's as if these studies assumed icons to be naturally occurring objects whose study can ignore the fact that human designers with varying levels of skill and knowledge created them..

A. B. 21. "binary file" 34. "center align"

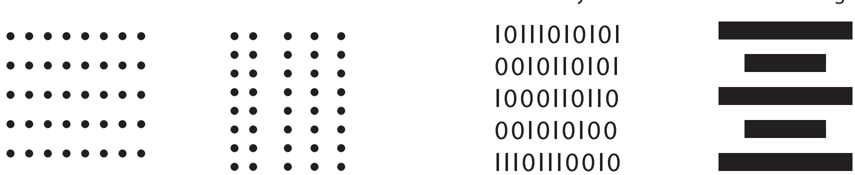


Figure 2.

Misunderstanding previous research

Small objects are perceptually grouped into larger wholes, as explained by the Gestalt principle of spatial proximity. Eight individual dots in the top row of A. are, due to spatial proximity, seen as a horizontal row, meaning A. is perceived as five rows rather than 40 dots.

In B., five vertical columns made of eight dots each are organized into two rectangular blocks due to spatial organization.
In a study measuring icon characteristics where "complexity" was considered a key factor, participants rated icons' complexity based on the number of lines they contained.

Icon 21. "binary file" received a complexity score of 3.88 on a 5 point scale (5 = most complex). Icon 34 was rated 1.90. Yet when Gestalt principles are considered, each icon is perceived as five lines.
Author's drawing after McDougall, 1999.

In addition to the diversity of ideas about what icons are and what makes them work, they are widely misunderstood, meaning poorly comprehended. One needs to look no farther than one's automobile dashboard to be confused by an icon such as the tire inflation pressure light, which 40% of people cannot identify (Woodyard, 2010). ISO and ANSI call for 67% or 85% (respectively) correct comprehension for safety symbols. This means that the "tire-inflation" icon fails badly. It also shows that standards agencies do not agree on the threshold of correct comprehension. Our work found that icon comprehension test design and how responses are scored significantly impact reported levels of correct comprehension (Zender, Han, Fernàndez, 2011). Multiple choice and matching tests yield a much higher percentage of correct responses than open-ended fill-in-the-blank tests. How the icon's context is described in a test also significantly impacts correct comprehension. No wonder icons are often unsuccessful: we have real difficulty defining and measuring success!

Figure 3.

Tire pressure warning icon.

Tire inflation icon found on automobile dashboards as a warning light indicating "Low Tire Pressure." Forty percent of people do not know what this is or what it means.

Our analysis based on informal research suggests that a primary contributor to the lack of recognition is that the tire symbol is not drawn from a conventional point of view and therefore is not recognized as a tire.

Icons may be common and useful, but icon designers have a plethora of confusing input about what an icon is called, how it functions, and how to measure its success. This led the author and colleagues to study icons for the past 20 years to understand what makes icons work. To simplify, we call icons what other disciplines variously call icons, symbols, pictograms, symbol-signs, and signs. Our definition of an icon is a picture intended to evoke a concept (the referent). Our core findings are that **most icons have multiple symbols and that these symbols interact to provoke meaning in peoples' minds**.

Multiple Symbols Interact

How people make meaning is outside the scope of Communication Design, so we must look to the disciplines of Psychology and Visual Perception for answers. To learn how people construct meaning, Psychologists studied how infants develop meaning-making skills. Eleanor J. Gibson's 1992 review of 25 years of studies confirmed that at 6 months, infants begin to identify "visually distinct features of objects" (Gibson, 1992, p. 222). Eleanor J. Gibson said, "perceiving is itself a mechanism of learning" (ibid, p. 234) and went on to find that the capacity to categorize visual objects is the foundation for the categorization of knowledge. As children grow, they learn that a small box with blobs of brown inside is a box of candy. Dewey and many others after him have said that as people observe relationships between objects, they infer meanings in an inductive process (Dewey, 1910, pp. 79, 116). Primary school children infer from a candy box with a bundle of flowers and a heart symbol that love is in the air, or at least Valentine's Day is at hand. Clusters of objects seen together can evoke a precise meaning that could not be predicted easily from seeing each object separately. As people mature, they accumulate additional associated meanings. A box of chocolate might even lead one to think of the movie Forrest Gump and his famous quip "life is like a box of chocolate you never know what you're gonna get" and from that make a link to the Vietnam War, the 1960's, Tom Hanks, and Hollywood and on and on.

Figure 4.

Combining symbols.

A 20th-century game called "Rory's Story Cubes" uses 9 dice, each die with a different icon on each face of the die. The dice are rolled, and a player invents a story from each face-up icon.
This game illustrates our capacity to evoke meaning from the interaction of symbols.

Most past icons combine several symbols.

You might expect that inference to meaning from objects in the physical world transfers to symbols, and according to eminent scientist Paul Kolers, it does. He wrote in 1969 that people naturally infer things implicit in a particular combination of symbols (Kolers, 1969, p. 356). As our physical environment is filled with objects seen in relation to each other, so too, the artificial world of symbols most often brings together multiple symbols to provoke a specific meaning intended by the icon designer. We confirmed this in our 2006 research study of the AIGA/DOT symbol system, the system that launched the ubiquitous Helvetica Man icon seen on men's restroom doors the world over. We found that 40 of the 60 icons, 66%, use more than one symbol in the icon (Zender, 2006, p. 30; Zender & Mejia, 2013). The "Baggage Locker" icon, which combines a symbol of *a bag*, puts that bag-in-a-*box*, with the symbol of a *key*, is one example. The "Barber Shop" icon is another (see *Figure 5*). In people's minds, these symbols do not remain isolated; they interact to evoke meaning. We found the interaction of multiple symbols in icon systems across disciplines: U. S. Highway signs for Recreational and Cultural Interest Areas – 71% are multi-symbol; SEGD Recreational icons – 83%; DOT/ANSI/ISO Safety Symbols – 83%; Hablamos Juntos Medical icons – 94%. People make meaning from icons and do this most often by looking at icons that contain multiple symbols.

Complex concepts need multiple symbols for expression.

One reason most icons contain multiple symbols could be that most concepts transcend a single object. A case in point is "Helvetica Man." What does a man symbol in isolation mean? The answer is that it means "a man," which is true, but what about the man? Is he in danger or safety, dead or alive, doing or resting? Context is key to interpretation and will be discussed more below, but at this point, it is enough to suggest that it is hard for a single symbol to say much more than it is itself. A *man* symbol symbolizes a man. "Helvetica Man" in the context of a door into a room successfully suggests a room for men, and a men's room in the United States is a "Men's Toilet." A *luggage* symbol with an *arrow* in the context of an airport successfully suggests "Baggage Area this way." But a *luggage* symbol alone does not incline one to think "Baggage Locker" any more than a *man* symbol alone inclines one to think "Barber Shop." Complex concepts like "In-Patient," actions like "Fishing," states of being like "Waiting," all require a combination of symbols for their successful communication. There's a lot to be said about

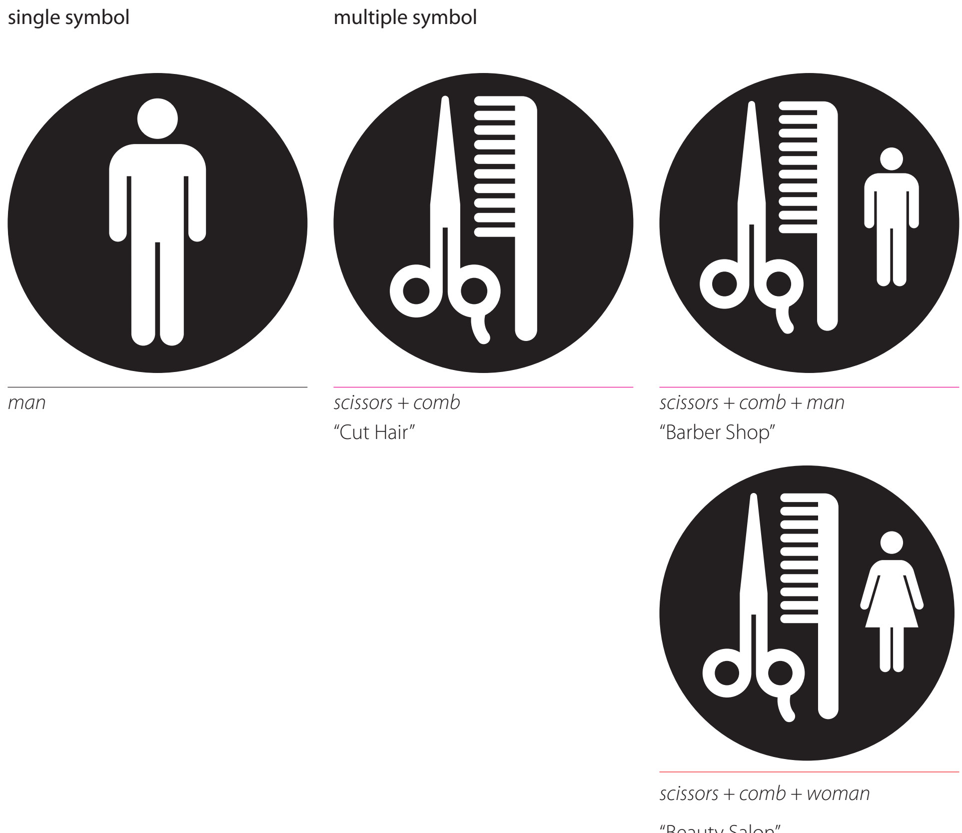


Figure 5.

Multiple-symbol icon.

This illustrates a multi-symbol icon. This icon represents "Barber Shop" by combining three symbols: scissors + comb + man, in a circle containing-shape.

The containing shape affirms to the reader that these symbols should be read together. The icons under the "Barber Shop" icon show the breakdown of single-symbol and multiple-symbol icons in the AIGA/DOT icon system.

cultural determinatives and the ways cultural and physical contexts impact meaning-making, and more will be said later, but for now, the focus is that much of our communication requires multiple symbols.

If designers have been combining symbols from the time of hieroglyphic writing to the present day, what novelty is this paper proposing? Simply this: that while knowledge has advanced, icon designers have failed to develop new icon design methods founded on the interaction of symbols.

Adding symbols improves comprehension.

To understand how multi-symbol icons work, we conducted numerous research studies. In one, we changed symbols in some multi-symbol icons (Zender & Mejia, 2013). In 2006 the University of Cincinnati was part of a five-school consortium commissioned to design icons for medical facilities for the *Hablamos Juntos* project. Several of the icons expressed complex concepts such as the referents "Waiting Area" and "Medical Library" (the intended meaning of an icon is called its "Referent" – referents are in quote marks throughout this paper). At first thought, a waiting area and a medical library may seem difficult to confuse, but that was not the case. The draft "Medical Library" icon combined a *person/man* symbol (from the waist up), holding a *book*, and a *medical cross (*see Figure 6*)*. This combination scored poorly when tested with various cultures and language groups – only 22% correct comprehension. When raw answers were analyzed, the dominant incorrect answer was "Waiting Room." Apparently, in a medical context, many people sit and read something in a waiting room. The incorrect answers caused us to look at the library's definition, which says nothing about reading but a lot about collections of books. So for "Medical Library," we added a symbol of *books* on a *shelf* and transferred the medical cross symbol to the *books* (see Figure 7). Correct comprehension jumped from 22% to 67% (see Figure 8). We also added a line under the man to clarify that he was sitting at a *desk* or *table* to prevent association with a more comfortable *chair* in a waiting area. To check our findings, we created an icon with the *man* symbol sitting in a *lounge chair* but leaving the *bookshelf* and *cross* symbols alone. As expected, comprehension for "Medical Library" was lower – from 67% down to 50% correct – as the number of incorrect answers associated with "Waiting Room" increased. It wasn't just adding symbols that clarified meaning but adding the right symbols.

Figure 6.

"Medical Library" and "In-Patient" icons from Hablamos Juntos Healthcare icons.

"Medical Library"

"In-patient"

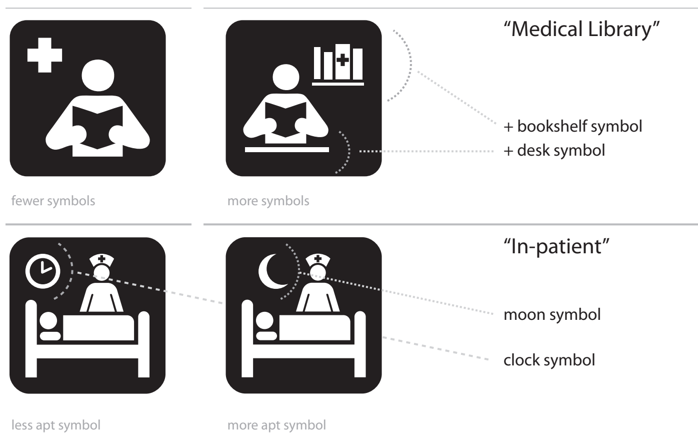


Figure 7.

Revised"Medical Library" and "In-Patient" icons .

These icons have added symbols in "Medical Library," and with a different symbol - moon instead of a clock - for "In-patient."

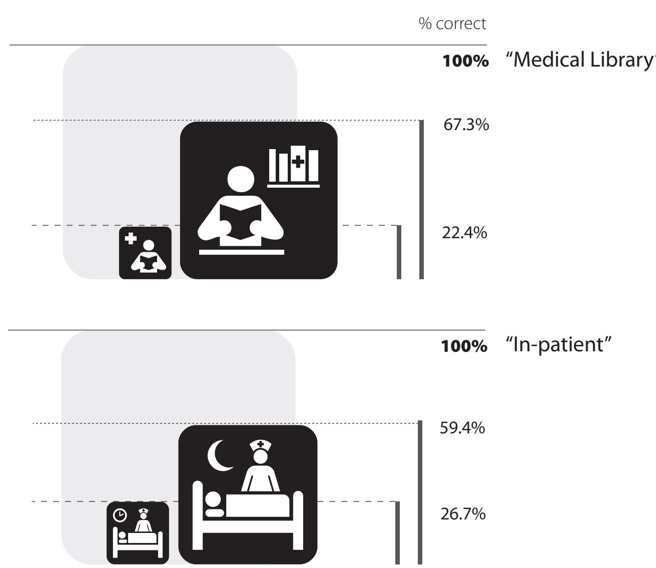


Figure 8.

Comprehension scores for "Medical Library" and "In-Patient" original and revised icons.

Comprehension comparison of "Medical Library" and "In-Patient" icons. The simpler "Medical Library," which followed ISO guidelines by re-purposing the existing icon for "Library," was less well comprehended than the icon with more symbols.

Both "In-Patient" icons used the same number of symbols, but the icon with better comprehension used a symbol that better fit the referent definition

Combining symbols that fit the referent definition improves comprehension.

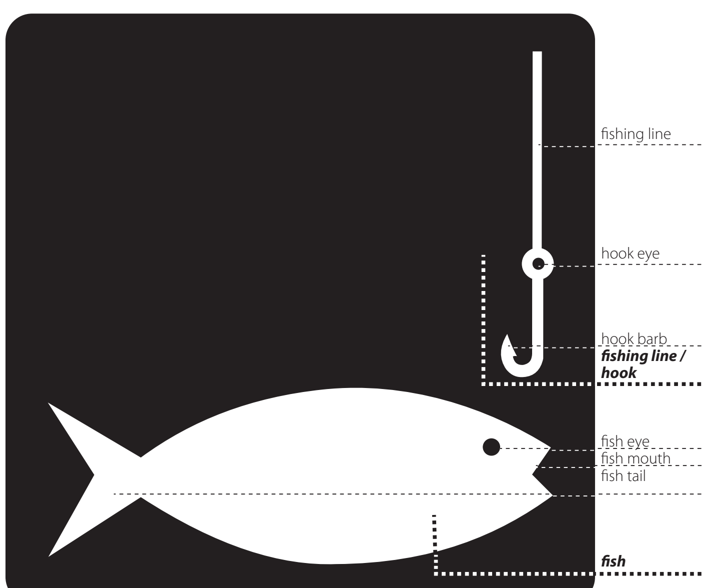
Of course, adding any symbols increases complexity, and this flies in the face of a longstanding preference for icon simplicity in design. So we also looked at whether changing symbols to ones that more accurately fit the definition of the referent would measurably improve comprehension. We again turned to a problematic icon in the Hablamos Juntos Medical Icons, "In-patient." An in-patient is broadly defined as a person who stays in the healthcare facility overnight. The original poorly-comprehended "In-patient" icon combined symbols of a *nurse*, a person-in-a-bed = a *patient*, and a *clock*. This was poorly comprehended at 26%. We changed the *clock* symbol to a *quarter-moon* symbol to better fit the definition "over-night-stay" and comprehension increased to 59% (see Figure 8). Changing to a symbol that better fit the defined meaning increased comprehension.

What is a symbol versus a feature?

It may have occurred to the reader that a symbol can contain multiple physical objects. The *person*-in-a-*bed* is two objects but functions as one symbol: a *patient*. What gives? One answer might be found in the mechanics of Visual Perception. Research shows that we recognize objects by remembering the key features shared among objects forming a mental category. For example, after seeing many chairs, a visual activation pattern of "four legs, a seat, and a back" is stored and remembered as the mental category *chair*. When a new object is seen, its features are compared with all the existing activation patterns, clusters of visual features associated with each other, until a match is found or not. This process is summarized nicely by Steven Kosslyn in his book, *The Case for Mental Imagery* (Kosslyn, Thompson, & Ganis, 2006). A quick trip back to Psychology shows that our mental categories are connected to the objects of visual perception. Barbara Tversky wrote that "One of the most fundamental aspects of human thought is the ability to perceive similarities and differences in objects and organisms and thereby to group or classify them" (Tversky & Hemenway, 1984, p. 170). She and her colleagues identified three levels of mental category that range from broadly defined and highly abstract Superordinate level to the more narrowly defined Basic and Subordinate levels. Examples given included the Superordinate level "furniture:" large movable objects in a physical space; Basic level "chair:" a seat four legs and a back; and Subordinate level "office chair:" a seat four or more legs with wheels and a back. Tversky and others found that Basic level objects were the most recognizable and the most abstract level that is easily identified. Given these findings from Visual

Perception and Psychology, we can better define a symbol as a basic level object that is defined visually and categorically as a mental pattern combining several individual features.

Returning to the original question, visually-based categories might help define whether *person*-in-a-*bed* is one symbol or many. A chair has three essential features: *four legs*, a *seat*, and a *back*. Not *three legs*; that would be a *stool*. Not *five legs*; that would be an *office chair*. Whether an object like a *seat* is part of a *chair* or *seat* symbol on its own depends on the context. If the whole chair is shown, the *seat* is a part of the whole. If just a *seat* is shown, the *seat* becomes the symbol. Another example can help clarify. An *eye*-on-a-*fish* is a necessary feature of a *fish* symbol, yet an *eye* symbol can also be understandable on its own. For an eye symbol to stand on its own, it would likely require additional features like lashes and an eyebrow to make it recognizable. Just a circle will do to symbolize an eye as part of a fish, but a circle by itself will not symbolize *an eye*. The context determines whether an object is a symbol or a feature of a larger symbol. Determining what should be included when drawing symbols that people will recognize as symbols is discussed below, but first, a little more on context.



"Fishing"

adapted from the *Manual on Uniform Traffic Control Devices for Streets and Highways*, 2003 edition, U. S. Highway signs from the collection in *Official Signs and Icons 2 by Ultimate Symbol*

Figure 9.

Distinguishing a feature from a symbol.

Fishing" icon. Note that the eye is one feature of the fish symbol, compared to an eye symbol that can stand alone.

Context informs meaning-making

Before going further, a brief digression into the principles governing meaning-making is needed. In the physical world, we interpret objects and actions in contexts. Flowers in a funeral home mean one thing, flowers with candy mean another. Likewise, in the artificial world of human-produced symbols, meaning is guided by context. To illustrate this, I have asked, "what do the three letters "BOW" mean? The answer is that you don't exactly know. There is a range of possibilities that can only be clarified by context. BOW in the context of SHIP means one thing, BOW in the context of ARROW means another, BOW in the context of DOWN means something else entirely. The meaning we infer to symbols is governed by context. This is the first and fundamental principle of hermeneutics: the science or study of meaning-making.

Hermeneutics and language received a lot of thought in the 20th century. Debates raged about whether people could, or should, understand the meaning an author intended. Michele Foucault famously proclaimed the disappearance of the author (Foucault, 1977, p. 121). Whether the focus should be on authors or the readers as the determiners of meaning, was in some ways a debate about whether people should primarily use their own context to assign meaning to symbols (language or whatever), or whether people should strive to grasp the author's context (literary, social/cultural, historical) in order to perceive the author's intended meaning. Overlay this with semiotic theories about how people communicate ideas to each other using symbols to represent things and the role of metaphor which links one thing to another by shared features, and you have a complex field of play. This may sound complex enough, but current ideas about how interaction with objects shapes our minds, the impact communication genres and media types have on thought, the ways preconceptions and cultural worldviews impact our interpretation of communication objects further complicate meaning-making.

Multiple symbols define and refine context.

The thread that ties all of this together is that meaning-making is guided by context. The author's context matters, the receivers' contexts matter, the symbols' context matters, the cultural and media contexts matter. This means that the most crucial principle in hermeneutics, the science of interpretation, is that meaning is governed by context. As you might guess from above, context is not simple but multi-dimensional. Exegetes, those who practice hermeneutics, envision context in layers visualized as a series of concentric contextual circles, each of which has less

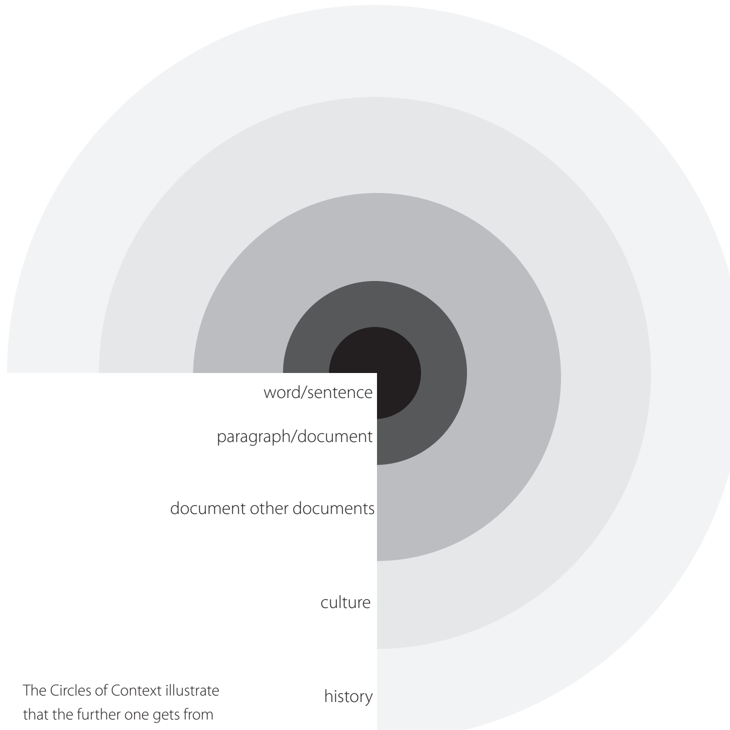


Figure 10.

Context

The Circles of Context illustrate that the further one gets from the immediate context, a word in a sentence, for example, the less influence that context has on determining the correct meaning.

significance for meaning-making as you move from the center outward (Figure 10). As a general rule, the immediate text has the most significant impact, the genre has less importance, the cultural context even less, and so on.

The importance of interpretive context also applies to icons. As already noted, in the 21st century, a door in a public place with a *man* symbol on it evokes a particular meaning and does a *bag* symbol hanging in an airport. Knowing that people infer meaning from symbols depending on their physical context is a clue for icon designers to attend to context and control it. Indeed, combining several symbols in a bounding box to create an icon is itself an act of contextual control. Numerous icons in an icon system form a self-referential context that guides meaning-making. The icon exists in some physical context, whether that be an architectural space or a social setting, or an app on a smartphone, all of which add context that guides interpretation. I've called the symbols within an icon the Immediate context, icons in interaction with other symbols and icons in a system the Proximate context, and the icons' interaction with places, people, and cultures, the Environmental context (Zender, 2006, p.183-184). As the Circles of Context illustrates, each context impacts the icon's meaning.

Physical context changes meaning.

People clearly use context to inform the meaning they derive from objects and symbols. But how much influence does context exert, how far can it change the meaning people assign to a symbol? Is the contextual influence in any way predictable? These were some of the questions that led us to study the impact of context. In 2017, we designed three icons: a *bookshelf*, a *toothbrush*, and a *clock*. Each of these icons had been used as a symbol in a previous icon and had been proven to be easily recognized and well understood. We put these three icons in a standard open-ended comprehension survey that showed each icon then asked participants, "Imagine that you are in a__________ . Exactly what do you think this icon is? What do you think it means." Different participants were given different contexts (in the blank) in which to interpret the icons: an Olympic venue, an airport, a university campus, a refugee camp. The locations were chosen to be diverse and not overtly associated with any individual icon. The three icons were each given a different context on a given survey. Contexts were randomized from form to form. Sixty-nine University students participated, resulting in between 16 and 18 students seeing a given symbol in each of the four contexts.

same ICON

different PHYSICAL CONTEXT	What object?	What meaning?
Olympic venue	*clock* - 44% *stopwatch* - 25%	timed sporting event - 38% time in general - 38%
airport	*clock* - 94%	flight times - 61%
university campus	*clock* - 94%	time in general - 44% class time - 38%
refugee camp	*clock* - 67% *time* - 11%	appointment time - 50% time in general - 33% no-answer - 17%

Figure 11.

Context changes meaning. A 2017 Design Thinking study: the same symbol, a *clock*, was given a different physical context: an Olympic venue, an airport, a university campus, a refugee camp. People inferred a different meaning in each context. Many people also inferred the clock to be a different object in the Olympic venue: a *stopwatch* instead of a *clock*.

In the Olympic venue, 44% of participants identified the *clock* icon as a clock, but 50% identified *clock* icon as a *timer* or *stopwatch*. In the Olympic venue, the *clock* was interpreted to mean "timed-sporting-events" by 37% and "time-in-general" by 37%. But in the airport context, 94% of the 18 participants identified the *clock* icon as a clock. The same symbol was seen as a different object depending on the context. In the airport it was a *clock*. In the Olympic venue it was a *stopwatch*. The *clock* was interpreted in the airport context to mean "flight-times" by 61% and "world-or-international-time" by 11% in the airport. These high levels of disagreement confirm that the same icon not only means something different depending on its context, but it can also be understood to represent a different object.

Cultural context impacts meaning.

It would be odd if you were not thinking that cultural context can change inferred meaning, and it can. Our 2010 study in Tanzania found that many icons designed to work across cultures didn't. You can see in Figure 12 that for some icons, there was a significant difference between Westerners and Africans (Zender & Cassedy, 2014). While this is not surprising, it is worth noting that more often than not, the misunderstanding was due more to a lack of familiarity with medical technologies and differing levels of medical knowledge than cultural practices. One notable exception was the use of a *stuffed bear* to represent "Pediatric/children's-healthcare." It turns out that despite the abundance of wild animals in Africa, there are no bears and few stuffed animals. Cultural context matters a lot, and there's a lot more to say about it, but this digression into context has gone too far already.

Conclusions: Symbols interact to evoke meaning in contexts; Managing context is key to guiding correct comprehension

To summarize, thus far, we have seen that findings support that people make meaning from the interaction of multiple symbols, that most icons contain multiple symbols, that adding symbols can improve comprehension, that adding the correct symbols – that is,

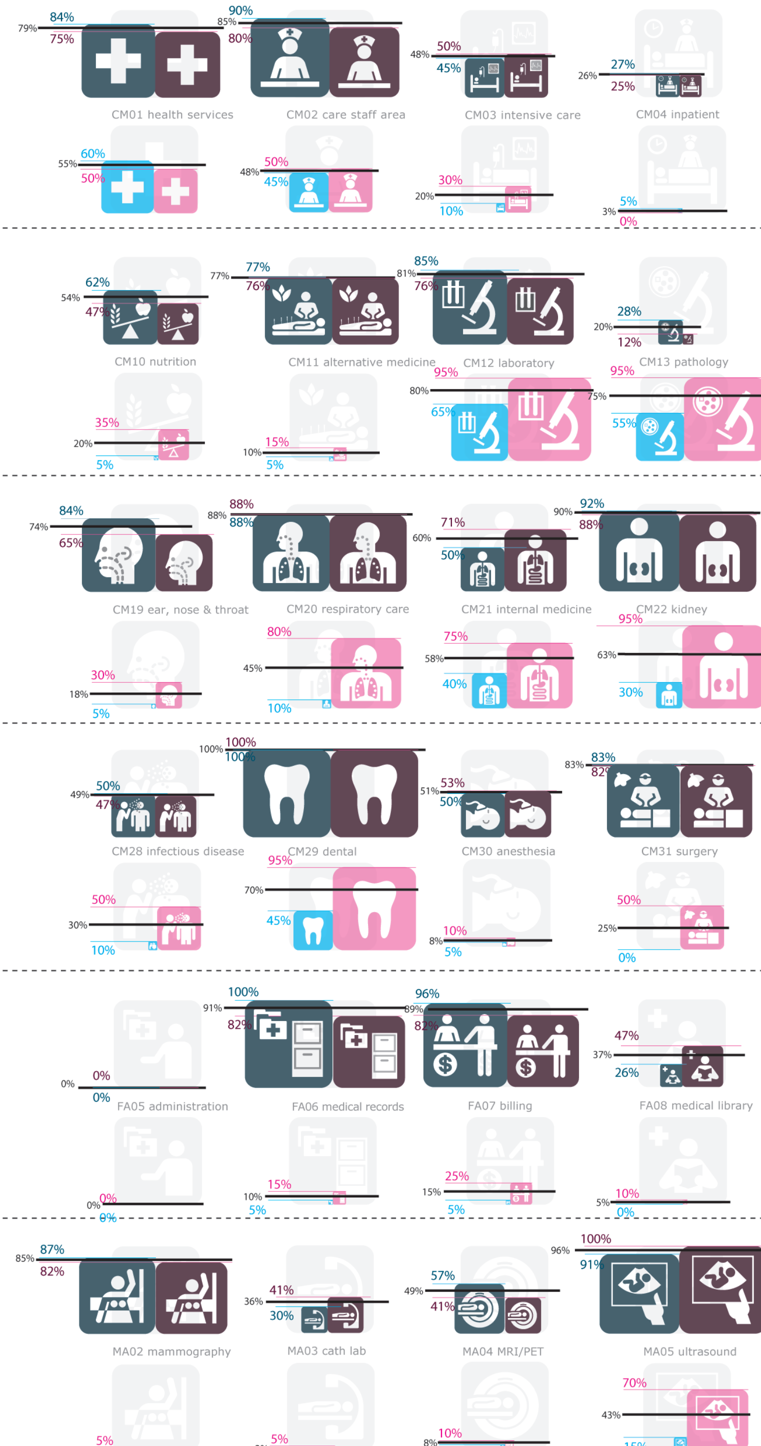
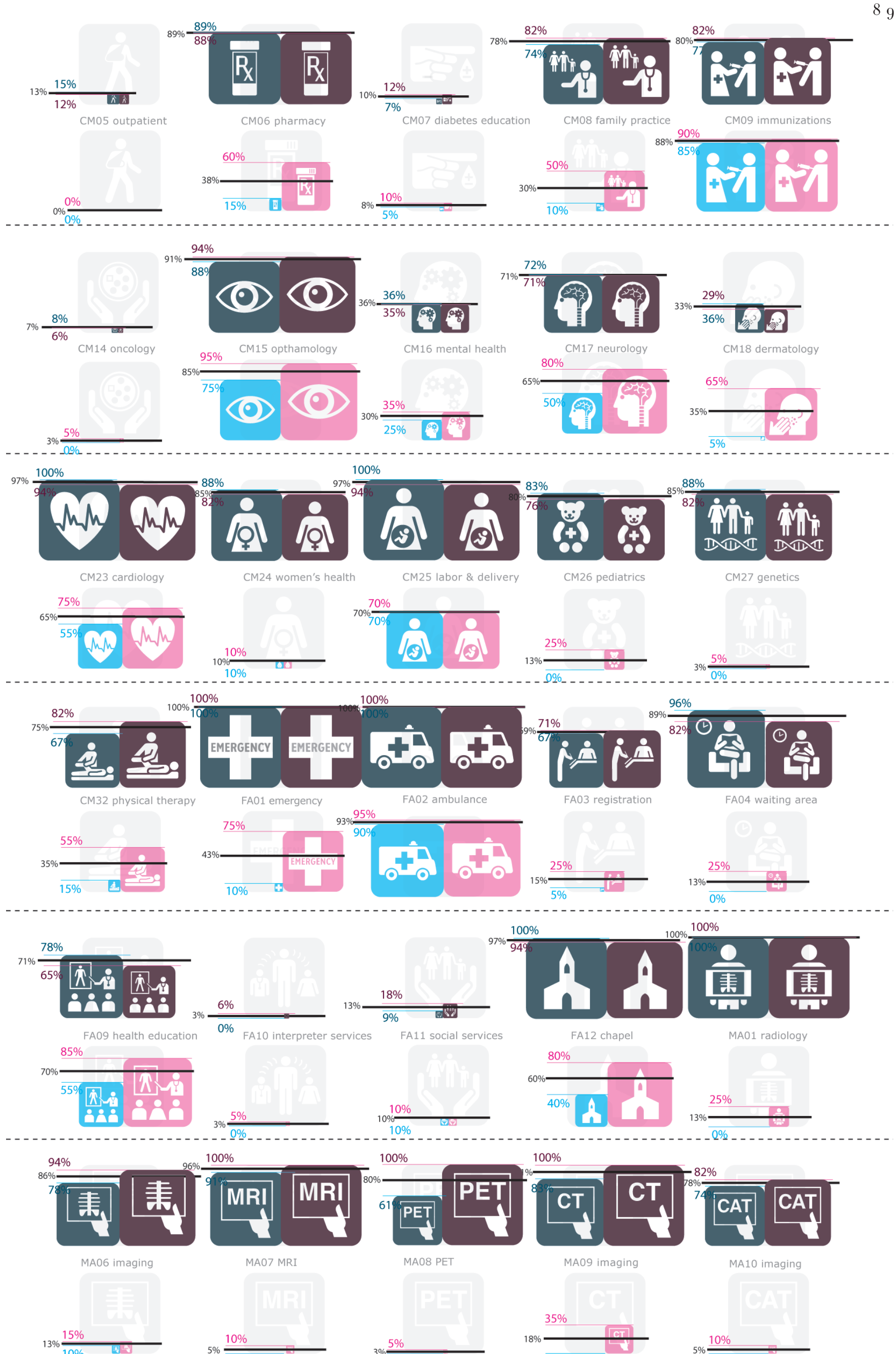


Figure 12. **Comparison of icon comprehension USA and Tanzania.** The top row (darker) shows comprehension by those with and without advanced medical knowledge in the USA. The bottom row (lighter) shows those with and without advanced medical knowledge in Tanzania.



One conclusion was that the amount of general medical knowledge had more impact on comprehension than differences in cultural practices or symbolism.

symbols that fit the definition of the referent – can improve comprehension, and that we need to know how to distinguish between a feature of a symbol and a symbol. To that, we've added knowledge that context guides meaning-making.

These facts provide the basis for a theory of icon design. Since multiple symbols interact in contexts that guide people's meaning-making, **if icon designers clarify context by combining the right symbols drawn in the right way, then good icon comprehension should result.** This takes us to the next point.

Know which symbols to draw.

Multiple symbols in an icon add important context, which can improve comprehension. This might suggest that adding more symbols is a kind of icon panacea. It was noted above that icon research in Medicine and Pharmacology (pictogram research) has focused on comprehension and adherence and that several pictogram studies have shown icons significantly improved both. But even so, the "Medical Library" and "In-Patient" icons performed poorly, and our research demonstrated that a poor combination of symbols misled the reader. So just combining any symbols that come to mind will not do. If the wrong combination of symbols is misleading, how does one find the right combination of symbols? Several studies explored this very question.

Processes and Methods.

It's a cliché that process governs product. Our current icon design process was established in the 1960s and '70s and described by Martin Krampen in his 1965 *Design Quarterly* article thus:

— a) Environmental problems arise;

— b) Signs or symbols are created, often anonymously and tentatively, to communicate about these problems;

— c) These signs or symbols are modified or corrected by collective experience;

— d) the modified versions are finally conventionalized;

— e) As new problems appear, the sign code is further amplified, modified, corrected, and so on. (Krampen, 1965, p. 19)

The AIGA/DOT symbol system enhanced the process described above by using a Delphi Panel of experts who reviewed existing icon designs and pooled their expertise to create new icons.

It could be argued that the process has not changed much since the '70s, and indeed, as recently as 2007, the ISO standard for the "Creation and design of public information symbols" laid out the following process:

— 4.1 Preliminary phase

— a) verify what is required for the symbol;

— b) identify the meaning of the required symbol;

— c) identify if a symbol for the required meaning already exists;

— d) assign the symbol meaning to an appropriate category;

— 4.2 Creation phase

— a) consider existing symbols with similar meanings

— b) design a new symbol.

If this process seems a little thin on methods, we would agree. To bring things up to date a bit, an informal 2017 interview with icon designers working for Microsoft confirmed that their icon design process relies on their own creative imagination to conceive an icon design which is then iteratively tested for effectiveness with users. Including user evaluation to measure effectiveness is a significant process improvement. Volumes of papers and books on user-centered design and evaluation support consultation with users. But if, as asserted here, most icons use multiple symbols and if the wrong symbols lead to miscomprehension, then a method for determining which symbol combination will evoke the referent is needed. Enter the social science methods for identifying shared ideas.

sociology, psychology, anthropology

The social sciences have developed methods for determining cultural consensus via Consensus Analysis. Alysa Strauss wrote,

— "Consensus analysis "specifies the conditions under which agreement between people can be seen as a sign of knowledge or 'getting it right" (Borgatti & Halgin, 2011). In other words, consensus analysis provides an empirical means by which a researcher can measure and describe the cultural knowledge of participants in a study (Romney, Weller, & Batchelder, 1986)." (Strauss & Zender, 2017).

Alysa, who has a Masters in Design and a Ph.D. in anthropology, theorized that consensus analysis could be used to learn from people for whom an icon was being designed what they would expect to see in such an icon. She then conducted a series of studies to test that hypothesis.

Free listing identifies candidate symbols.

One method for finding consensus is Free listing: a qualitative research method that determines what users expected to be associated with a concept, in this case, a referent. To test the applicability of Freelising, Strauss chose three referents whose icons, designed in 2009 using the standard icon design process, had poor comprehension in evaluation studies (Zender & Cassedy, 2014):

- "Oncology" the branch of Medicine specializing in the diagnosis and treatment of cancer;
- "Outpatient" a person who goes to a doctor's office or hospital for treatment but does not spend the night;
- "Psychiatry" the branch of Medicine specializing in the study and treatment of mental, emotional, and behavioral disorders.

These referents were chosen because their poor performance allowed for improvement, thus enabling comparative measurement of the effectiveness of a new method. Free listing "involves asking subjects from the same culture to list all of the things that they think are in the cultural domains of (in this case) oncology, outpatient, and psychology." (Strauss, p.12). Fifty-four participants were given the three referents and their definitions and asked to individually generate a list of things they associated with each referent, three lists, one for each referent. The 54 individual lists were combined and organized by which words/concepts were given by most participants. For example, for "Oncology," 22 people listed *person/patient* and *cells*, 13 listed *IV-therapy*, 12 *chemotherapy*, and so on, down to 2 mentions of *color/red*, *DNA*, and *heart*. This was followed by several other items mentioned only once. It did not matter whether the listed items were technically correct or not. *Heart*, for example, has little to do with "Oncology." What mattered was that several people <u>thought</u> something was correct. For "Oncology," 25 items were mentioned more than one time. The list for "Outpatient" yielded 23 items, while the list for "Psychiatry" was 22 items. Though these raw lists were all associated with the referents, they contained many overlapping ideas and were not structured to convey the referent definition. Another step was needed to understand how people would associate the ideas to represent the referent definition.

Pilesorting identifies related items.

"Social scientists use Pilesorting as a means to show which items within a cultural domain are similar or related somehow" (Strauss, p.14).

— "Participants were given a set of cards for each referent. Every card in a set had a different item from the domain for a referent, as determined via freelisting, written on it. The sets of cards were randomly ordered so that no two participants received their cards in the same order. Each respondent was then told to simply, "group the cards into piles based on how similar they are." No instructions were given on the criteria that should be used to form piles and there were no minimum or maximum limits on the number of piles that could be created or how many cards could be in a pile, hence, free pilesorting." (ibid, p.15)

Forty participants sorted the list items. Participants' sorts were analyzed and compared to identify the most often associated items in piles. In this process, more than one cluster of items is generated. For example, for "Oncology," five piles emerged:

- doctor/nurse/patient-person
- head-scarf/bald-person
- tumor/cancerous-part/cancer/chemotherapy
- radiation-symbol/radiation-machine
- DNA/cells.

These participants' piles reveal potential individual symbols that should be considered for inclusion in an icon for "Oncology." The nature of the grouped items shows that each item need not be a separate symbol. "For example, in the domain of oncology, a bald person was closely tied to head-scarf, suggesting that bald people might be depicted wearing head-scarves" (Strauss p.16).

Following the Pilesorting activity, participants were asked to Rank the piles. Assisted by software, participants' rankings were weighted. For "Oncology" *tumor/cancerous-part/cancer/chemotherapy* was of first importance followed by *doctor/nurse/patient-person* then *radiation-symbol/radiation-machine*. Another way to rank these groups would be to compare them to the referent definition.

Results

The hypothesis tested in the Strauss study was whether methods used to study cultures could be used to determine what symbols should be included in an icon. Free listing and Pilesorting did reveal candidate symbols. The next question was whether icons whose design was informed by consensus analysis would outperform the icons whose design relied primarily on the designer's own reflection and imagination. An icon made of symbols identified through consensus analysis was created for each referent to explore this question. The comprehension of each consensus-informed icon was then compared to the comprehension of the existing icon using an open-ended comprehension survey. More than three times as many people correctly identified the new icon for "Oncology" as the icon designed using traditional methods, 21% for the new icon versus 7% for the original icon. Although the "Oncology" icon design based on Free listing and Pilesorting was correctly identified by only 21% of survey participants, results for "Psychiatry" exceeded ISO/ANSI comprehension standards for the first time, 72% correct compared to the original icon 35% correct. Based on this, we concluded that eliciting people's thoughts about what should be included in an icon was an effective means of designing multi-symbol icons that have significantly better comprehension. These findings supported our original observation that multiple symbols interact to evoke meaning.

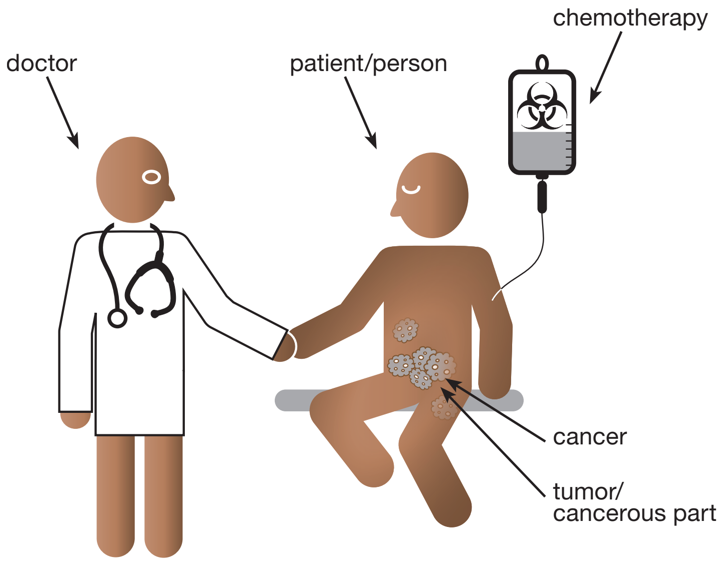


Figure 13.

"Oncology" icon.

"Oncology" icon whose design was guided by determining which symbols to include based on Free listing and Pilesorting.

Comprehension was three times better after using these methods.

Conclusion: learning from people which symbols to combine improved comprehension.

The design processes have evolved over the past few decades to more regularly involve "users." The ISO Standards cited above for safety symbol design did not require user input in creating the icon. Still, they do require that users be engaged to evaluate the effectiveness of icons before they are deployed. The studies above show that engaging with people during icon design to learn what items they associate with a referent can help a designer create an icon with better comprehension. The studies also contain a couple of caveats. First, the average person may not really understand a referent's meaning, and to that extent, their ideas may be incorrect. Making sure the users understand the definition can overcome this, but care is needed to ensure the definition does not influence people's associations. Second, designers need to be alert to synonyms in piles and aware of the possibility of combining what at first appear to be separate symbols into a single symbol, such as the *head-scarf/bald-person* noted above. Third, consulting experts might sort out which symbol to choose among near-synonyms. Whether it is best to include a *doctor*, a *nurse*, or both, along with the *patient/person*, might be determined by checking with medical professionals. User input is no easy recipe for success. But people have helpful input, even if that input only tells the designer the distance between the user's conception of a referent and the actual definition of a referent.

Once the designer knows which symbols to draw, they then need to know how to draw the necessary symbols so that people will recognize them. So that is the next step.

Know how to draw symbols that people will recognize.

In 2017 I wrote, "How do designers know the best way to draw a symbol for an icon? In my experience, they mostly guess." By guessing, I meant that designers mostly work from memory, a personal clip file, or an online search. Designers then draw a representation that they feel captures the essence of the object/symbol. This approach works so long as the designer's sources happen to match what's in the user's mind. The problem is that as soon as the designer starts thinking about how to draw an object like a *tire*, their consideration of tires has separated them from the average person for whom the *tire* symbol is being drawn. Designerly reflection makes the designer an expert of sorts, and in their pondering, designers are just as likely over-think as to think more as the average person thinks. For example, in the "Inflation Pressure" icon in Figure 3 above, the *tire* was drawn from the point of view of a squirrel before being run over. Fortunately, this is not a point of view many people have experienced. In addition, designers' general inclination towards creativity can erect a wall of novelty between the symbols they draw and what users expect to see. In short, designers do not naturally draw symbols that the average person readily recognizes.

Basis

Eminent Professor of Psychology Rudolf Arnheim observed in 1974 that a good picture left out a lot. He wrote, "This means not only not that the better picture is one that omits unnecessary detail and chooses telling characteristics, but also that facts must be unambiguously conveyed to the eye" (Arnheim, 1974, p.157). His insight that a picture excluded irrelevant details and included key object features and essential details to the eye was a prescient insight that later studies in visual perception would verify.

Visual object recognition

We see what is in the world with our eyes and brain. And we can also see the world in our brain without using our eyes. Seeing with the mind's eye is called "mental imaging." Think of the front of your house. With a bit of effort, you can picture your house in your mind and count the number of windows that face the street. You have just pulled up a visual memory of your house and looked at it in your brain. The concept of mental images and whether they were visually or conceptually based was debated hotly through the 1990s. Stephen Kosslyn, William L. Thompson, and Giorgio Ganis' book *The Case for Mental Imagery* set about settling the debate. They wrote, "A mental image occurs when a representation of the type created during the initial stages of perception is present, but the stimulus is not actually being perceived" (Kosslyn et al., 2006, p. 4). Their breakthrough was that mental images are stored representations of objects in our brains, that these representations are visual, and that we can look at these images by pulling them from memory and literally pushing them into the part of our brain that processes the input from our eyes. We see them only in our minds. There is not only solid evidence that this happens, but recently computer scanning has been used to see what people are looking at in their "mind's eye." (Cowen, Chun, & Kuhl, 2014).

Psychology

We can see in our minds because images are stored in our brains. But to store every individual image of every house we ever saw would be horribly inefficient, so our brains form object categories which are a composite of the essential features that every object in a category shares: *tire* or *chair* or *clock*. We previously introduced Eleanor J. Gibson's and Barbara Tversky's pioneering published work which associated visual object recognition with mental categorization. Years of additional study have clarified that our mental object categories are visual in form and that object categories are stored as clusters of key visual features. This process of perception and categorization is shared by everyone who can see. Visual perception is integral to learning.

key features/activation patterns

The key features of all familiar objects are stored in the brain as activation patterns that can be observed by fMRI (see Cowen reference above). These visual patterns knit together the key visual features typical of an object, such as straight lines, curves, circles, rectangles, and their relationships to each other. These activation patterns are used in object recognition (Kosslyn, p.137). You might think of activation patterns as "brain symbols." By their nature, brain symbols integrate features that all objects in a category share and leave out details unique to individual instances. These may be the "telling characteristics" that Arnheim said constituted a "good picture."

Take a chair, for example. Our research has shown that the brain symbol of a chair is a seat, four legs, and a back (see also Tversky 1984 above). We have asked hundreds of people worldwide to draw what comes to mind when they think of a chair. We have found that what they draw is consistent, even to sharing a common point of view - 3/4 from slightly above (Zender, 2017, pp. 39-40). If a designer could "see" the brain symbols in their users' heads, that designer would know how to draw a symbol that matched their users' brain symbol, in other words, a symbol that all people would recognize.

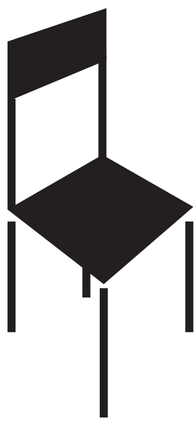


Figure 14.

Typical *chair*.

Chair drawing is typical of those drawn by people from many cultures and countries.

Perception-based symbol design

“If” is a big word for having just two letters. “IF” a designer knew peoples’ brain symbols, the designer could draw a recognizable symbol. But how can one get inside another’s head and see what’s there? Like charades but with pictures, the game Pictionary was popular some years ago. Its popularity suggested that asking several people to quickly draw what they thought would represent a concept might reveal their brain symbol. To explore this approach, in 2010, UC graduate students and faculty created the Draw-It processes to reveal people’s brain symbols. The process asks participants to draw what immediately comes to mind for an object or concept. For example, participants might be asked to draw what comes to mind when they think of *a clock*. After collecting drawings done by many individuals, usually 40-50, researchers analyze the drawings to identify the features that appear most often. For *clock*, we found 98% agreement that a *clock* is a round-face + hands, and 83% agreement that a *clock* consists of a round-face + hands + numbers/tick-marks (Zender, 2017, p. 45). This level of agreement strongly suggests what a *clock* is in most peoples’ minds and therefore what a good *clock* symbol should include and leave out. For example, it suggests that a nice, creative drawing of a digital clock would be wholly wrong to represent *clock*. Indeed, of the 41 *clock* drawings collected (see Figure 15), one included a grandfather clock and a mouse, people are creative after all, but not one showed a digital clock. We have used the *Draw-It* method repeatedly to draw symbols for icons.

Research findings

New methods may be good in theory but prove to be unprofitable in practice. So we incorporated the Draw-It method in several icon design projects. In conjunction with colleagues at Cincinnati Children’s Hospital Medical Center, we used Draw-It to inform the design of icons to explain to children basic medical procedures such as “drawing blood,” “taking a child’s temperature,” “taking blood pressure,” and “giving an injection.” A discerning reader will note that these are all processes and that processes are typically hard to communicate with icons. Beginning in 2015, UC students and faculty collaborated with Dr. Regis Vallencourt and his team at the Children’s Hospital of Eastern Ontario (CHEO) to design icons for a number of projects, all of which were informed by Draw-It. We collaborated with CHEO to design icons that would be used to inform parents how to care for children after surgery, specifically after a Tonsillectomy. Some of those referents were: “soft-food-diet,” “brush-teeth-gently,” and “rest.” We also

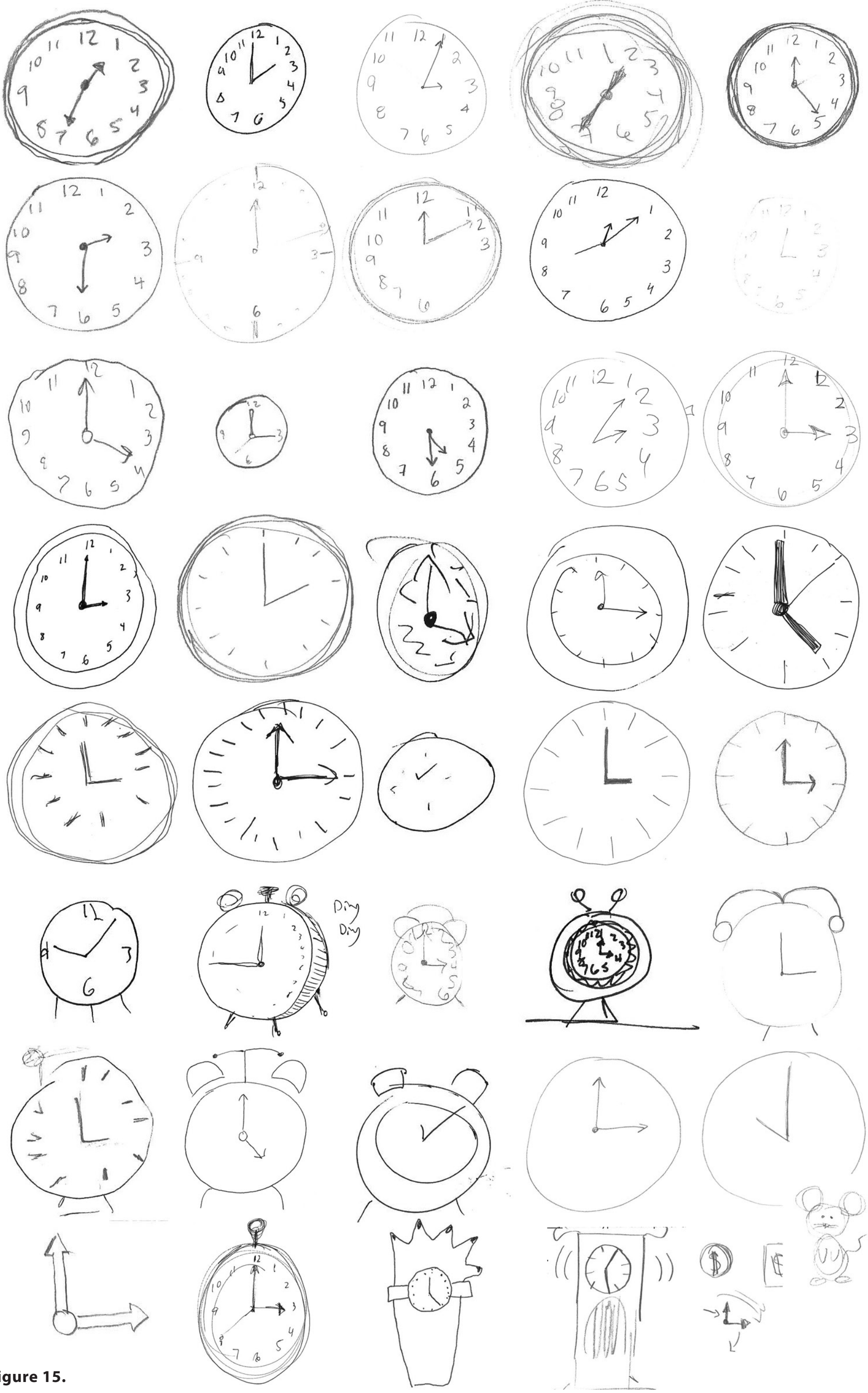


Figure 15.

"clock drawings from *Draw-It*.

The clock images drawn by 41 university students in a *Draw-It* activity.

designed pharmaceutical safety icons warning Pharmacists and healthcare workers of safety issues associated with particular medications, such as a "drug-that-must-be-diluted," a "neuromuscular-blocking-agent," and "medication-that-can-be-given-only-by-central-line." Then again, in 2019, we worked with CHEO to design icons to indicate which kinds of pain children were experiencing. "Sharp-pain," "shooting-pain," "throbbing-pain," and "cramping-pain" were some of the referents. In each case, Draw-It was part of the design process, and in each case, the process yielded a significant number of successful candidate icons to evoke very challenging concepts. We specifically noted that Draw-It added to the number of viable icon candidates (Vaillancourt, Zender, Coulon, & Pouliot, 2018, p. 254). This large number was especially useful for successfully communicating challenging concepts such as "medication-that-requires-airway-management-before-administration."

We did not compare the effectiveness of Draw-It informed icons to the effectiveness of traditionally drawn icons in each of these studies because traditionally drawn icons did not exist in many cases. But where comparisons were possible, the Draw-It informed icons consistently performed better. The Safer Medication Handling Draw-It-based icon for "Medication-that-can-be-given-only-by-central-line" was preferred by 84% compared to 46% for the top-performing traditionally-drawn icon. The Draw-It-based "Neuromuscular-blocking-agent" icon was preferred by 59% compared to 31% for a standard version. These results are typical and show that Draw-It informed icons are routinely preferred. Draw-It has informed the symbol design process to create a large number of effective icons for very challenging concepts.

Conclusion: What to draw + How to draw it

We conclude from the above that having the right symbols is critical, and drawing those symbols so that users recognize them is essential to good icon comprehension.

Other issues

If multiple symbols interact to evoke meaning, then knowing which symbols to include and how to draw them so they'll be recognized are both critical to designing comprehensible icons. But odd as it might sound, there is more to communication than precise comprehension.

Metaphor

Not all communication is based on a straightforward correspondence between object and meaning. For example, in basketball, I might say "he missed by a mile," and the meaning might be clear even though the communication was not precisely accurate. He didn't miss by "a mile" but by a lot. He probably put up an "airball," and while "airball" might perfectly convey meaning, it too is not precisely accurate. The ball was not made of "air" but was a very solid vinyl rubber. These are, of course, examples of the use of metaphor to communicate. Lakoff and Johnson have claimed in "Metaphors We Live By" that metaphor is not only pervasive but essential. If icons are going to communicate using standard communication methods, then icons will undoubtedly need to occasionally use metaphor. But our studies have shown that mixing metaphoric and literal icons is a source of confusion.

Systems

One way to address iconic confusion is to make a system of icons in which individual icons provide their own disambiguating context and thus make each icon more comprehensible. Creating a comprehensive symbol system to enhance meaning-making is as old as the pyramids. Ancient Egyptians added marks, determinatives, to indicate whether a symbol was to be taken to represent an object or whether that same symbol was to be read photographically to represent a sound. More recently, containing shapes are used commonly in highway signs to clarify a sign's meaning, and modifiers such as the circle-and-diagonal negation symbol are placed over a cigarette to indicate "no-smoking."

Limitations

Metaphor and icons systems are mentioned briefly to illustrate that many issues impinge on clear communication with icons. Our findings, that most icons combine multiple symbols and that knowing which symbols to combine and how to draw them well are foundational to good comprehension, are accurate and valuable as far as they go. But they only provide a basis. Further study is needed to explore how metaphor can be made to work better, how systems can and cannot disambiguate, the possible clarifying role of modifiers and glyphs, how to scaffold onto existing knowledge to level the cultural field, and much more. To invoke a metaphor and quote a cliché, these are topics for another day.

Summary conclusions

To summarize what we have found, multiple symbols are better than one when it comes to clear communication of most concepts. Not only do most existing icons contain multiple symbols, but study after study has also shown that more accurate comprehension is evoked when the right symbols are brought together and drawn in a way that people expect. Combining multiple symbols is one way to control context, and controlling context is the key to guiding interpretation.

The interaction of symbols and the role of context are the foundation for a new and improved icon design process. Methods informing which symbols people associate with a concept will guide designers to select the right symbols to evoke a particular referent. Exposing peoples' brain icons will guide designers to draw symbols that people will recognize. Employing these processes individually and together has been proven to produce comprehensible icons. Informing these processes with social science methods and findings from human perception and cognition has provided a knowledge base from other disciplines upon which designers can build with confidence.

It can be helpful to summarize not only what we have found to be true but something we have debunked. A shibboleth is that simplicity is paramount in design generally and in icon design particularly. The findings presented here expose that fallacy. One still might say that "as simple as is effective" is true, but even that could send designers chasing after simplicity rather than seeking to determine from people which symbols need to be combined and how they need to be drawn. Designers need to appreciate that simplicity is a distortion of reality that has both benefits and negative consequences. It is clear that when communicating with symbols, simplicity is not the direct path to precise, sophisticated communication of complex concepts. Designers and design educators need to get over the-best-icon-is-the-simplest-icon mantra.

Combining symbols as one might combine letters was Neurath's dream. The ancients did this successfully, but we have neglected their knowledge. Icon's current usefulness and ubiquity suggest that it is time to build on the best of current scientific knowledge and improve our icon-design practice by adopting new design methods based on the interaction of symbols.

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