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Systems Organize Information in Mind and Nature: Empirical Findings of Part-Whole Systems (S) in Cognitive and Material Complexity

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Abstract: Part-whole Systems (S) structure is foundational to a diverse array of phenomena such as belonging and containment, networks, statistics, reductionism, holism, etc. and is extremely similar if not synonymous with sets, sorts, groups, combinations and combinatorics, clusters, etc. In Cabrera (1998), *part-whole Systems* (S) or "S-rule" is established as one of four universals for the organization of information and thus is foundational to systems and systems thinking as well as the consilience of knowledge. In this paper, seven empirical studies are presented in which (unless otherwise noted) subjects completed a task. Ranging from $n = 407$ to $n = 34{,}398$, the sample sizes vary for each study but are generalizeable to a normal distribution of the US population. With *high statistical significance*, the results of these studies support the predictions made by DSRP Theory regarding *part-whole Systems* (a.k.a., "S-rule") including: the universality of S-rule as an observable phenomenon in both mind (cognitive complexity) and nature (ontological complexity) (i.e., parallelism); the internal structures and dynamics of S-rule; S-rule's mutual dependencies on other universals of DSRP (Distinctions, Systems, Relationships, and Perspectives (i.e., Distinctions, Relationships, and Perspectives); the role S-rule plays in making structural predictions; and, S-rule's efficacy as a metacognitive skill. In conclusion, these data suggest the observable and empirical existence, universality, efficacy, and parallelism (between cognitive and ontological complexity) of *part-whole Systems* (S).

Keywords: systems; part-whole; reductionism; holism; universals; cognitive complexity; systems thinking; DSRP Theory; ontological complexity; systems science

1. Introduction

This research affirms the existence of the part-whole Systems (S) construct as is shown in several prior research studies. In his part-whole categorization studies, Anderson [1] found that groupings of objects occurred as a result of linguistic, feature, or function. Our research extends this idea to generalize how people utilize *any idea* (not merely linguistic, form or function) into meaningful groupings—that is that part-whole groupings (S) are co-created along with perspective (P). In our studies, this is the case when the perspectival cue was imposed by the researchers as well as when no cue was provided. This research also builds on Moony (1951) [2] by showing that relationships (R) are necessary for part-whole Systems (S) to occur and therefore must be considered as necessary and sufficient "simple rules" required for part-whole to exist (i.e., expanding content validity criteria). Building off of Liberman et al.'s study [3], we see further evidence that part-whole Systems (S) are not dependent on language only. These studies also provide additional support to the *existence* of part-whole groupings as shown by Muehlhuas et al.'s research [4] and Pellegrino (2001) [5]. Furthermore, these studies build upon Baron-Cohen et al.'s (2009) [6] research showing the possible beneficial effects of part-whole Systems (S) to what would be

considered "positive" aspects of cognitive function. Thus, the studies outlined in this paper specify that additional elements are required for the part-whole Systems (S) construct (i.e., D, R, and P), extending the requirements of content validity. The consistency with these previous research studies increases our confidence in the reliability and validity of our results.

1.1. Empirical Findings of Systems across the Disciplines

Cabrera [7] writes that:

The literature on part-whole Systems [1–6,8–18] (a.k.a., grouping, sorting, categorization, organization, etc.) is well established, both in the cognitive sciences and systems thinking contexts. In the cognitive sciences (as well as the physical and natural sciences), it is clear that part-whole Systems are ever present [1,3–6,15,17]. In systems thinking literature, categorization has been said to be "(...) predicted from the structure of the environment at least as well as it can from the structure of the mind [1]". While categorization is more limited than part-whole Systems, the research done on categorization [1,3–5,16,17,19–28] has shown the fundamental existence of the Systems rule. It is not new that categories are made through sorting parts into wholes, but what is new is that categories also imply a perspective, integrating the part-whole Systems rule into the rest of the DSRP theory. This critical insight—part of DSRP Theory—exposes the universality of part-whole systems at the theoretical level. In a review of literature, a number of empirical studies illustrate the universality of part-whole Systems across the disciplines [1–6,10–18] and part-whole Systems integrated with other universals (Distinctions, Relationships, Perspectives) [19–25,29–54].

Figure 1 shows the disciplinary distribution of this research which is documented in Cabrera et al. [55] and which used the rubric for literature reviews in Boote and Biele [56] as a methodology.

BY DISCIPLINE (N=40)
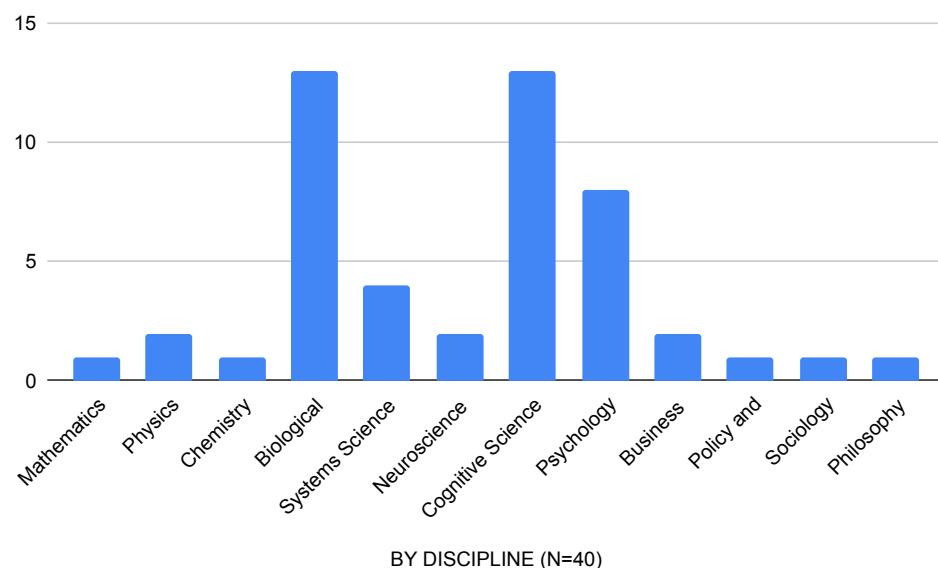
Figure 1. Part-whole systems (S) research across the disciplines.

Across the disciplines, both the mind and nature systematize things by breaking them down into parts or combining them into wholes. In nature, we call these 'natural kinds' or 'systems'—collections of things that go together. In the mind, this often leads to the creation of "groupings" or what we often erroneously call "categories". However, categories are really part-whole groupings that require something else: a *Perspective*. By perspective, we refer to another rule of DSRP Theory called the P-rule, which is comprised of the interaction between elements, *point* and *view*. In short, we mean that, in order for a

part-whole grouping to form, a point–view interaction must also occur. In this research, we learn more about just how sensitively dependent these rules are on each other.

One empirical study contained in this literature review is Anderson (1991) [1] who analyzed the adaptive nature of human 'categorization' (an inaccurate synonym of part-whole Systems). In framing a cognitive problem, Anderson noted that categorization of the elements of a problem is an essential step towards building a complete frame. He listed three origin points of category formation: *linguistic*, *feature overlap*, and *similar function*. These three origin points (alone or together) make up the perspective that frames and subsequently forms the category. Anderson found that, when categorizing, *linguistics* are derived from the label of the object. For example, all of the things below are grouped because they start with the letter O, Ostrich, Orange, Octopus, Octagon, etc.

Anderson found that *Feature overlap* occurs when we identify similar physical or conceptual features in a group of objects. As shown in Figure 2, these objects are grouped into a category as "all red objects". It might be helpful to think of categories using a metaphor like a bouncer at a nightclub. When we form categories, we create a frame (using a perspective) which decides what objects get into the club and which ones do not. In the case in Figure 3, you only get into the club if you start with the letter "O". The bouncer is the perspective that creates the category and decides who is in and out.

Figure 2. Example of the feature overlap categorization origin point.

Figure 3. Example of the linguistic categorization origin point.

Finally, Anderson identifies categories based on *similar function* by simply grouping objects that function similarly, as shown by the musical instruments in Figure 4.

Figure 4. Example of the similar function categorization origin point.

According to Anderson, the origin of 'categorization' therefore does not have to be only one of these; it can be all three. He goes on to conclude that, "categorization behavior can be predicted from the structure of the environment at least as well as it can from the structure of the mind". In other words, the mind naturally categorizes the world

around it, and the Systems pattern is therefore embedded into the nature of thought itself. Understanding part-whole systems will give insight into this fundamental aspect of our cognition. Note also that DSRP (in this case specifically S and P, but also R and D) shows us that Anderson's three originating points for a category (feature overlap, linguistics, and similar function) are somewhat arbitrary and not complete, as absolutely *anything* could be used as the framing perspective that leads to a category forming, such as: how objects make you feel, color (not a feature of object but an interaction effect), random assignment, or sounds you might associate with the object(s), etc. In addition, in Anderson's research, it is unclear which comes first, the chicken or the egg? That is, utilizing our bouncer metaphor, does the bouncer decide that only those who start with an 'O' get into the club first—or, does he look at at a bunch of items and notice *relationships* between them (in this case that two or three of them begin with the letter 'O') and then notice more (the relationship is *excitatory*) and only then do they decide to use 'O' as a framing *perspective* that *distinguishes* those who get in the category club (*system*) and those who do not? In this example, we see that sorting things into part-whole Systems (S) is quite a bit more complex, while, at the same time, it relies on very simple underlying rules (DSRP).

There is an old saying that, even though there are many types of scientists from many disciplines that really, "there are just two kinds of scientists, *splitters* and *lumpers*". Indeed, this is not a new concept. It is found both in the Western and Eastern Philosophers, and it is still relayed in populist explanations of Systems Thinking (e.g., erroneously: *Systems Thinking is about holism, not reductionism*). You may have heard of the myth of the left brain and right brain. It is a myth in relation to how the brain works, but it is a sticky and pervasive idea in human history dating back centuries and popularized by Friedrich Nietzsche's Apollonian-Dionysian dichotomy. Apollonians tend to favor logic, rationality, and analysis (analytic distinctions). They are Reductionists and *Splitters*. They split stuff up and then split up the stuff they split up. They are born of Aristotle, student of Plato, student of Socrates—the Great Greek Philosophers. On the other side of the spectrum are the "right brainers", the Dionysians (Dionysius was also the "party" God Bacchus). Dionysians favor intuition, feeling, and synthesis and are often unable or unwilling to make analytic distinctions. These are the holists and *Lumpers*. As authors, we reside in Ithaca, New York, home of Cornell University. However, it is apropos that Ithaca, in Greek Mythology, was home to Odysseus. You will remember that it was to Ithaca that Odysseus returned after the Trojan Wars and the "Odysseys". On his return to his homelands, he went unrecognized by his people, even his wife—only his trusted dog knew him right away. Odysseus is the in between thinker. The chooser of the middle way. The one who, instead of choosing EITHER/OR, chooses AND/BOTH. In Eastern thought and Philosophy, there is a similar idea called the Vinegar Tasters. The three great Eastern Philosophers Confucius, Lao Tzu, and Buddha are tasting from a cauldron of vinegar. Vinegar metaphorically represents the essence of life. Upon tasting the vinegar, each makes a face: Confucius has a sour face, Buddha has a bitter face, Lao Tsu, the author of the *Tao Te Ching*, literally translated as the *middle way*, has a face of smiling satisfaction. The point is that systems thinking and complex cognition require us not to choose either/or but both/and. Nobel Laureate, Murray Gell-Mann, speaking to an audience of some of the great systems scientists, states:

> We all know that, in most situations, theory has to advance along two tracks: the fundamental search for dynamical explanations on the one hand, and, on the other, the phenomenological search for pattern in the laws of Nature. There are associated experimental domains in each case...There is always a reductionist bridge between these two kinds of explanation, the fundamental and the phenomenological. (I assume all of us are in principle reductionists.) However, it often takes a very long time to construct such a bridge, such as the one between the brain and the mind, even though great strides are being made. While the construction is going on, it is necessary to pursue both approaches, which means in this case to study both the brain and the mind [57] (p. 8).

In the same discussion, which inaugurates the founding of the Santa Fe Institute (SFI)—a premier institute for the study of complex systems—Gell-Mann offers the following testament to both forms of thinking—reductionist and holist:

> There are some psychologists and pop psychologists who like to place people on a scale running from Appolonian to Dionysian, where, roughly speaking, Appolonians tend to favor logic, rationality, and analysis, while Dionysians go in more for intuition, feeling, and synthesis. In the middle are those tortured souls, the Odysseans, who strive for the union of both styles. The new institute would have to recruit a number of Odysseans to be successful! [57] (p. 8)

The part-whole Systems (S) universal of DSRP Theory is not merely describing a universal structure of mind and nature—a necessary unity as both Gell-Mann and Bateson point out. It is upsetting the apple cart of 2500 years of bi-valency and bivalent thinking. It makes part and whole inseparable *co-implications* from each other. It means that systems thinking is neither reductionist or holist but both. It means that the new era of scientists cannot be either splitters or lumpers but must be trained to be splumpers. Part-whole Systems (S) and its theoretical implications and predictions embody the middle way. The Odyssean way between Dionysian and Apollonian thought. The Laozi way between Buddhism and Confucianism. The middle way between Eastern and Western thought. Between reductionism and holism. Between splitters and lumpers. Between analysis and synthesis. Not the tyranny of EITHER/OR, but the genius of AND/BOTH.

This ecology of studies provides the empirical basis for the implications and predictions made by the Systems rule of DSRP Theory. Table 1 shows the structure of the part-whole Systems rule.
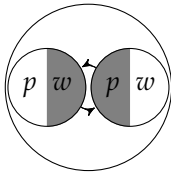
Table 1. Part-whole systems rule.

$S \equiv p \Longleftrightarrow w$	A *System* is defined as *part* co-implying *whole*		
A *part* exists	A *whole* exists	*part* co-implies *whole*	A *System* exists
p	w	$p \Longleftrightarrow w$	$\equiv S$

Cabrera's 2021 review of research [55] builds upon previous literature reviews [9,58], constitutes a proverbial "tip of the iceberg", and is part of an accumulating body of evidence in support of the predictions made by DSRP Theory generally, and part-whole Systems in particular. The findings, utility, and application of part-whole Systems (S) are pervasive and ubiquitous (see Table 2). A few highlights from this literature review [55] include:

- Pellegrino (2001) [5] measures a monkey's ability to part-whole morphs of dogs and cats;
- Baron-Cohen et al.'s (2009) [6] research highlights how savantism in autistic children is due to their ability to systematize;
- Moony (1951) [2] demonstrated that the overall comprehension of students is increased if teachers clearly explain parts, wholes, and the importance of the relationship between them;
- Liberman et al.'s 2017 study [3] on social categories explained that social categories are structural. Social categories are formed before verbal information is processed. This demonstrates that social categories are not dependent on cultural/stereotypical content but rather conceptual structure; and
- Muehlhuas et al.'s research [4] used fMRI technology to test and identify part-whole conceptual thinking in the brain.

Table 2. DSRP is necessary and sufficient for S-rule.

	Any part-whole **System** is also: • Two Distinctions [possible]: $\{p, \neg p\}$ and $\{w, \neg w\}$ • A Relationship (R_r^a): $p \xleftrightarrow[\text{belongs to}]{\text{contains}} w$ • A System with parts: p, w, and their relationship (R_r^a) • Two Perspectives [possible]: p and w • The System itself is distinct (D), a Relationship (R), and a Perspective (P).

1.2. Theoretical Work on Systems

Cabrera [7] explains that:

The simplest accurate statement of DSRP Theory is thus:

"the ways $\overbrace{\text{information}}^{\text{that which is Organized}}$ is/is not $\overbrace{\text{bounded,}}^{\text{Distinctions}}$ $\overbrace{\text{arranged,}}^{\text{Systems}}$

and $\underbrace{\text{interconnected}}_{\text{Relationships}}$ from $\underbrace{\text{frames of reference}}_{\text{Perspectives}}$ determines

$\underbrace{\text{what actually exists}}_{\text{Material Complexity (Nature)}}$ and $\underbrace{\text{what we think exists.}}_{\text{Cognitive Complexity (Mind)}}$"

DSRP Theory details quite a bit more than this simplification relays [9,58–62]. In addition, DSRP Theory has more empirical evidence supporting it than any existing systems theory (including frameworks, which are not theories) [7,9,55,63–70].

For more on DSRP Theory proper, the reader should see the citations mentioned as this paper focuses solely on the 'S' in DSRP: Systems (part-whole). As one of four DSRP Rules, part-whole Systems or S-rule is applicable across the disciplines from the physical and natural sciences to the social sciences. Their transdisciplinary importance cannot be over stated. Figure 5 illustrates the universality of nested part-whole structures ranging in size from the smallest known (10^{-35} m) phenomena to the biggest (10^{30} m).

1.3. Research Questions That Underlie the Hypotheses for S-Rule Studies

Cabrera [9] expanded on systems theoretically by proposing in DSRP Theory that: (1) Systems are universal to mind and nature and (2) all Systems (*S*) constitute an *belonging/containment* relationship between part (*p*) and whole (*w*) variables (what Cabrera calls *elements*). Cabrera [65] writes: "DSRP Theory further stipulates that awareness of this part-whole structure (metacognition of *S*-rule) can increase one's effectiveness in thinking about systems, modeling systems, or in increasing cognitive fluidity, complexity, and robustness.

Table 3, from [65], shows the research matrix upon which our hypotheses, null hypotheses, and research design and findings are based.

Table 3. Research questions that underlie the hypotheses for S-rule studies, *adapted from* [65].

|	Existential *(Basic Research)*	Efficacy *(Applied Research)*
Mind *(cognitive complexity)*	**Does DSRP Exist in Mind?** (i.e., Does DSRP exist as universal, material, observable cognitive phenomena?)	**Is Metacognitive Awareness of DSRP Effective?** (i.e., Does it increase ability to align cognitive complexity to real-world complexity? (a.k.a., parallelism)
Nature *(ontological complexity)*	**Does DSRP Exist in Nature?** (i.e., Does DSRP exist as universal, material, observable phenomena?)	
	EMPIRICAL BASIS	
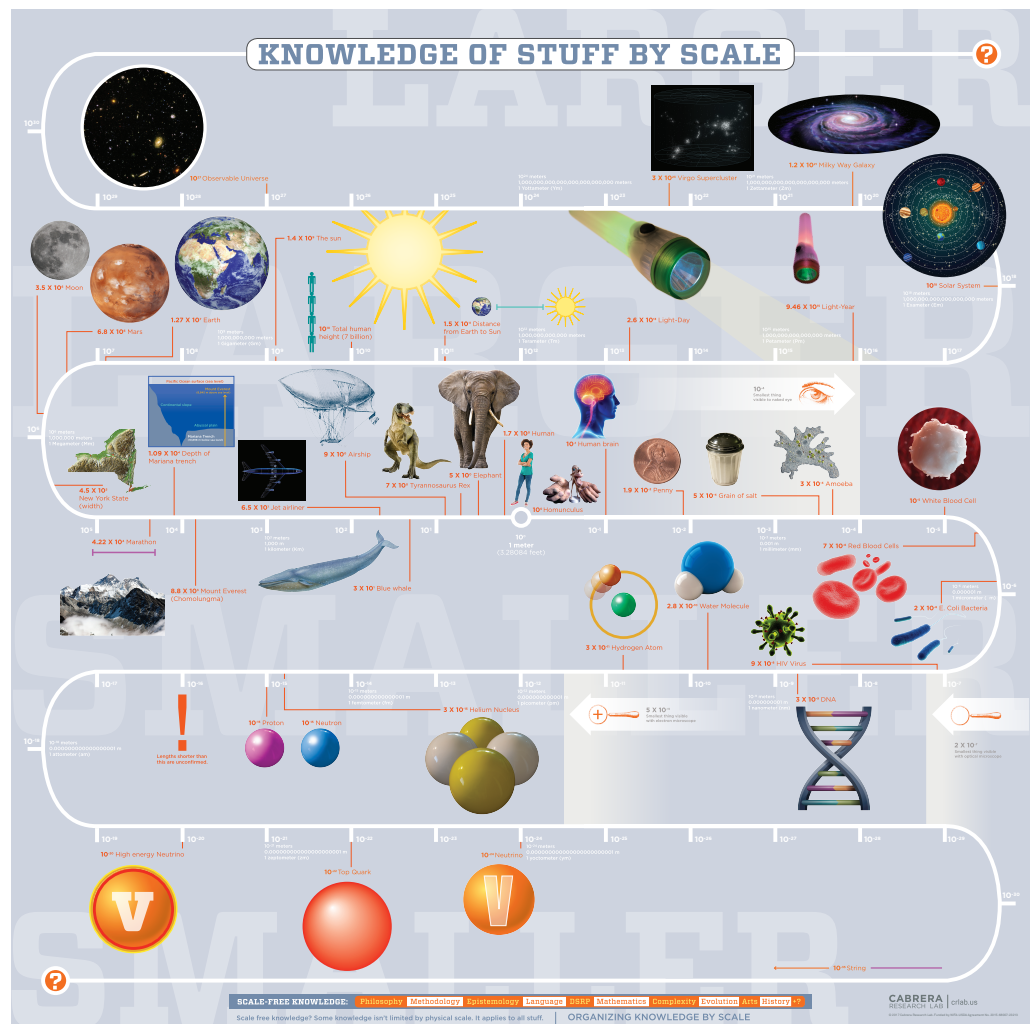
Figure 5. Part-whole structure across scale.

　　Thus, this collection of studies on the Systems rule of DSRP Theory aims to do two things. The first is to establish the *existence* of the Systems rule in Mind and Nature. The second is to apply the Systems rule to demonstrate the *efficacy* of the rule in understanding Mind and Nature. The research questions represented in the matrix above are as follows:

1. *Existential* (Basic research): focused on the question; Or as Cabrera [67] explains, "Does DSRP Exist? Does DSRP exist as a universal, material, observable phenomena?"

2. *Efficacy* (Applied research): focused on the question; Or as Cabrera [65] explains, "Is DSRP Effective? Does metacognition of DSRP increase effectiveness in navigating cognitive complexity in order to understand system (ontological) complexity? This gets at the critically important question of '*parallelism*'—defined as the probability that our cognitive organizational rules align with nature's organizational rules—which is central to the idea of the Systems Thinking/DSRP Loop[1]" (*footnote and image, Figure 6, included*).
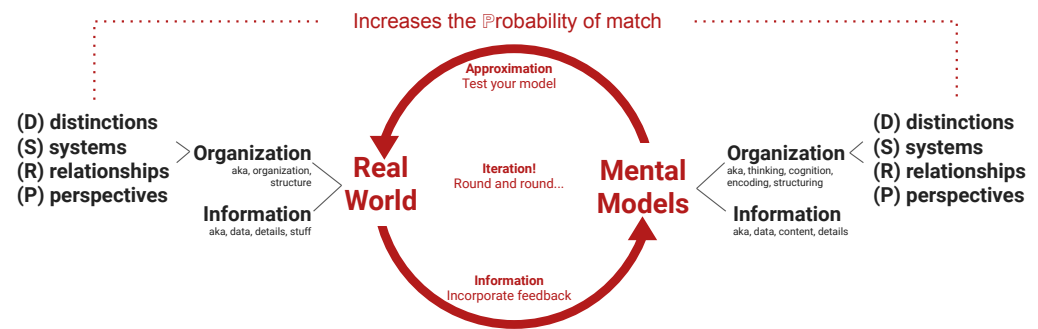
Figure 6. The ST/DSRP loop [65].

The seven studies in this publication are part of an "ecology of empirical studies" that consists of multiple meta-analytical literature reviews [9,55,69] and 26 new empirical studies on the existence and efficacy of DSRP Theory. The authors recommend the other three collections focused on: identity-other Distinctions (D) studies [67], action–reaction Relationships (R) studies [68], and point–view Perspectives (P) studies [66]. The reader can focus on these seven studies (herein) by reading them as a set of studies. The reader can also read each study one at a time. This can be accomplished by reading the Methods (Section 2.1), Results (Section 3.1), and Findings (Section 4.1) for each singular study.

This research empirically tests and—with highly statistically significant results—supports specific predictions about S-rule that are made by DSRP Theory (to be enumerated later). In what follows, we present seven empirical studies that together form an ecology of these findings.

The norm is to provide an Introduction, Methods, Results, Discussion, and Conclusion for an empirical study. In this paper, we keep to this norm but rather than share one study, we share seven. The authors could certainly have benefited from publishing seven separate papers detailing each empirical study. However, after much debate, we chose to keep the studies together as an "ecology of empirical studies". The rational for this choice is that four of seven studies were relatively small (usually a single question) isolating a particular effect and testing a particular hypothesis. In addition, because the studies focus on specific aspects of the same phenomena (part-whole Systems Rule), the results are better understood as a whole rather than as isolated parts. We are hoping of course that such a rationale makes sense to a systems journal. That said, the reader may read each study in isolation simply by reading Sections 2.1, 3.1 and 4.1 together. Furthermore, for an explanation of DSRP Theory situated within the wider systems literature, please see [7].

2. Materials and Methods

The following is true for all studies (unless otherwise stated). Subjects were engaged in an experiment to complete the task and/or answer the question. Prior to deployment, the language and phrasing for the task was piloted with a convenience sample to identify and/or correct any confusion in language in the instrument. Sample sizes were chosen for generalizability (e.g., given confidence level CL = 95%), Confidence Interval (CI = 5), and a US population estimated at 350,000,000; the generalizable sample size is 384. We chose sample sizes larger than 384. Samples (N varies for each study; range of $N = 407$ to 34,398) are generalizable to the US population (not including minors) unless otherwise noted. Samples were based on a normal distribution of the US population and, unless otherwise noted, were identified using these demographics: US population; 50/50 gender split; between the ages of 22–65 years old; and splits that were representative of the census numbers for education (e.g., completion of high school, community college, college, masters, PhD). Data were collected and analyzed with incomplete data and/or nonsense data removed. Details of methods pertinent to each study are provided below for each study.

2.1. The Complete the Whole Study Methods

Analysis was performed using Chi-square and G test. Two-tailed hypothesis testing was performed at 5% level of significance.

2.2. The Not Red Circle Study Methods

Analysis was performed using Chi-square and G test. Two-tailed hypothesis testing was performed at 5% level of significance.

2.3. The Sort Stuff Study Methods

Statistical analysis was performed using R v 3.6.3. Counts and percentages were used to summarize the distribution of the included variables. Chi-square and G-test were used to assess whether the observed probabilities were significantly different from an expected probability of >99% for H_1 and equal expected probabilities for H2.

2.4. The Sort Buttons Study Methods

Statistical analysis was performed using R v 3.6.3. Counts and percentages were used to summarize the distribution of the included variables. Chi-square and G-test were used to assess whether the observed probabilities were significantly different from an expected probability of >99% for H_1 .

2.5. The S-Mapping Study Methods

The sample (n = 34,398) consisted of self-selecting software users. The data are from use patterns in the *Plectica Systems Mapping Software* developed by Cabrera [71] and were collected from a self-service web application. The data included all four DSRP patterns, but the results provided herein are for the Systems pattern only.

2.6. The S-STMI Study Methods

Data were gathered from the *Systems Thinking and Metacognition Indicator (STMI)* developed by Cabrera and Cabrera [64], the sample (n = 1059) was a "self-selecting sample of professionals between the ages of 18–65 who participated in beta version of STMI post-validation. Data were collected from a self-service web application that administers the STMI. Limited demographic data were collected. The data cuts across all four patterns of DSRP and "mix and match of DSRP patterns" on both competence and confidence measures" [67]. The results provided herein are for the Systems pattern only. See [64] for information on the wider data.

2.7. The S-Fishtank Study Methods

The sample (n = 1750 baseline; n = 350 Post) for the "Fish Tank" study cuts across all four patterns of DSRP" and was generalizable to the US population. The results provided herein are a summary of the Systems or S-rule only. See [65] for the entirety of this research.

3. Results

3.1. The Complete the Whole Study

Subjects (n = 395) were shown a patterned grid of colored shapes, shown in Figure 7 and then asked to choose the shape that completes the pattern. It is assumed that the 'correct' answer is the red square.

Table 4 shows that 88.86% of subjects, or 351 out of 395, chose the 'correct' answer, indicating that they constructed part-whole systems (sorting/grouping sets), even if it was unconscious to the subject.

Results showed that 88.9% of the subjects chose the correct answer. Hypothesis testing showed that the percentage of correct answers was significantly different from the expected 50% under the null hypothesis (X^2 = 238.61, P < 0.001 ***). Therefore, we can reject the null hypothesis.
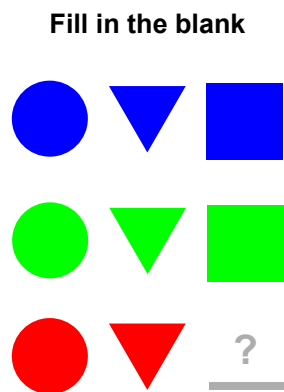
Fill in the blank

Figure 7. The Complete the Whole task.

Table 4. Answer choices for completing the pattern study.

Answer Choice	Percent	Responses
▮	88.86% (351/395)	351
▮	8.10% (32/395)	32
●	1.26% (5/395)	5
▼	0.7% (3/395)	3
●	0.5% (2/395)	2
▼	0.5% (2/395)	2

3.2. The Not Red Circle Study

Subjects (*n* = 395) were asked to complete the following task:

Subjects were told that the answer to the task was not ●. They were then given the following choices: ●●▮▼▮. They were also asked to state the reasoning for their answer. In addition, 395 subjects chose 463 answers as shown in Figure 8. This is because the task allowed for multiple responses (e.g., "choose all that apply").

Results showed that 46.1% of the subjects chose "Red square" and 37% chose "Blue circle". Interestingly, only 12.7% of the subjects chose "Blue square". Chi-square and G test showed that the probability of choosing "Blue square" was significantly different from 1 (X^2 = 542.28, *P* < 0.001 ***). Thus, the null hypothesis can be rejected.

Results showed that the majority of the subjects chose one answers (*n* = 357, 90.4%) while the remaining 9.6% chose more than one answer as shown in Figure 9
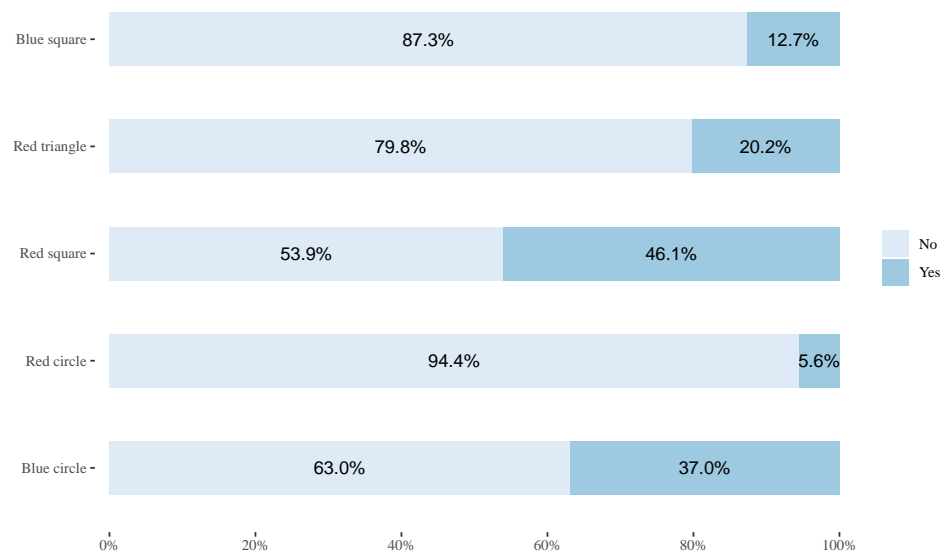
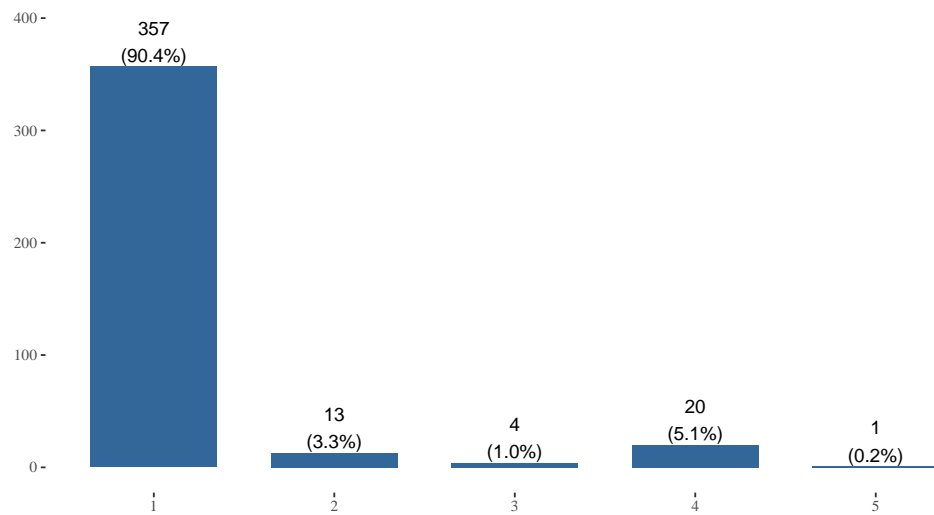**Figure 8.** Responses to Not Red Circle study.

Figure 9. Number of responses chosen by the subjects.

3.3. The Sort Stuff Study

In the null hypothesis, we assume the ability to make part-whole groupings. However, this time, we assume that, for a common set of familiar items, category theory [72] predicts that the items will be grouped the same way. Thus, the null hypothesis is that subjects will make the same number of wholes, with the same parts and same number of parts in each, and name the wholes the same $H_0 : pW_i \ni \{P_1, P_2, \cdots, P_n\} = 1$, where W is the Number of Wholes, P is the Number of Part, i is the identity or name given to each Whole, and p is the probability. The alternative hypotheses is that many groups with different names and different parts will be made $H_A : pW_i \ni \{P_1, P_2, \cdots, P_n\} \neq 1$ (see Table 5).

The current study was conducted to assess two hypotheses. We first hypothesized (H1) that there would be no universal agreement between the subjects regarding the classification of the included items. Secondly (H2), we hypothesized that there would be a statistically significant difference in the observed probabilities of the classification of the included items.

Subjects ($n = 320$) were asked to sort a list of items (identities) into groups of their own making and then name them as shown in Figure 10. Thus, transforming the items into parts that belonged to wholes and in turn naming the wholes that contained the parts. The list of six items included: wrench, pen, broom, hammer, mop, and pencil.

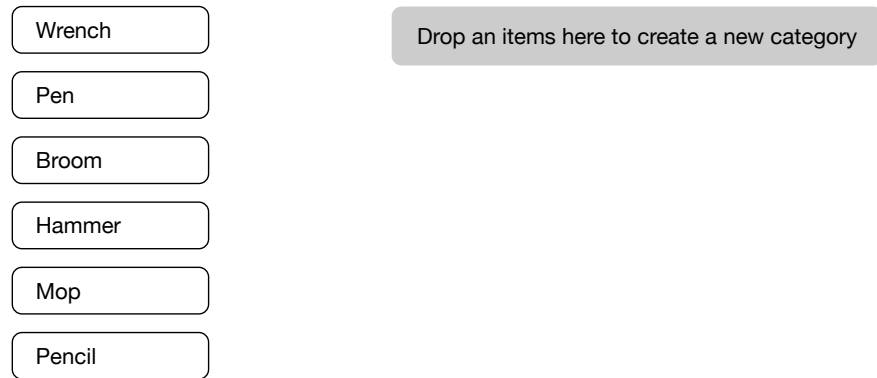Drag the items below into appropriate categories and name the categories.

| Wrench |
| Pen |
| Broom |
| Hammer |
| Mop |
| Pencil |

Drop an items here to create a new category

Figure 10. The sort stuff study task.

Table 5. Sort stuff study research hypotheses.

	Null Hypothesis	**Alternative Hypotheses**
H_1	$P1 \lor P2 \lor P3 \lor \cdots \lor Px = 1$	$(P1 \land P2 \land P3 \land P4 \land \cdots \land Px) \neq 1$
H_2	$P1 = P2 = P3 = P4 = Px$	$P1 \neq P2 \neq P3 \neq P4 \neq Px$

The original six items were chosen for relational similarity as well as their difference. For example, given the six items—wrench, pen, broom, hammer, mop, pencil—subjects would be expected to perceive relationships between wrench and hammer, pen and pencil, and broom and mop, respectively. In addition, the items are different enough that one might expect variance in sorting (e.g., one can imagine different whole groupings for pen and mop. Subjects sorted six items into 246 unique groups and named them. Table 6 provides examples of typical and atypical names for whole groups, illustrating that subjects' group items (e.g., part-whole systematization) in numerous ways based on the logic that underlies their own perspective. Table 6 illustrates that the way that subjects do part-whole grouping is a function of perspectives.

Table 6. Typical and atypical whole group names.

Typical (Whole) Group Names	**Atypical (Whole) Group Names**
Tools	W words
	One subject named all groups after occupational
Office Equipment and Supplies	roles: Mechanics, Plumbers, Writers, Janitors,
	Handymen, Housewives
Writing utensils	Dual handed utilities or Single handed utilities
Cleaning equipment	Salmon
Metal	Tools that hit
Cleaning or repair tools	Mechanic
Stationary	Garage
	Clinch
	Closet
	Object

Table 7 shows that, for the number of named groups or "wholes" (246), the minimum number was 1, the maximum number was 6, and the average number was 2.86. For the number of items or "parts" in each of these groups/wholes, the minimum was 1, the maximum was 6, and the average was 2.55. One subject, for example, named all groups after occupational roles [sic]: "Mechanics, Plumbers, Writers, Janitors, Handymen, Housewives". The six items were then grouped according to these perspective roles. Similarly, other subjects chose groups named 'mechanic' (presumably for things a mechanic would use), 'tools that hit' and 'clinch' (presumably looking at the action associated with tools), 'closet' or 'garage' (presumably looking at where these tools might be found). Another subject

visualized the way the tools were used and determined whether they were dual or single handed utilities. Still other subjects did not focus on the tool-like nature at all, resorting to groups like 'W words' and 'object.'

**Table 7.** Minimum (Min), maximum (Max) and average (Avg) for part-whole structure.

Items or "Parts" (6)			Groups or "Wholes" (246)		
Min	Avg	Max	Min	Avg	Max
1	2.55	6	1	2.86	6

Of the six items subjects were asked to sort, each item was sorted as a part into a relatively large number of whole groups. Table 8 details how many unique group names each item was a part of. The average number of groups that a part belonged to was 63.33; the minimum was 42 and the maximum was 81.

Table 8. The number of wholes each part belonged to.

Sorted Items	Unique Group Names (246)
Broom	102
Pencil	98
Mop	98
Pen	86
Wrench	54
Hammer	51

Figure 11 is a word cloud of the 246 named whole groupings. These 246 unique whole group names were coded for similarity, yielding uniquely different coded groups. Coding included: correcting obvious misspellings such as 'Utensilfs' and 'Utensils'; plural and singular forms such as 'Tools' and 'Tool', and obvious associations such as 'clean', 'cleaning', and 'cleaning supplies'. In addition, less obvious but still obvious similarities, such as 'Housewives', and 'Household', and 'Household supplies' were grouped.
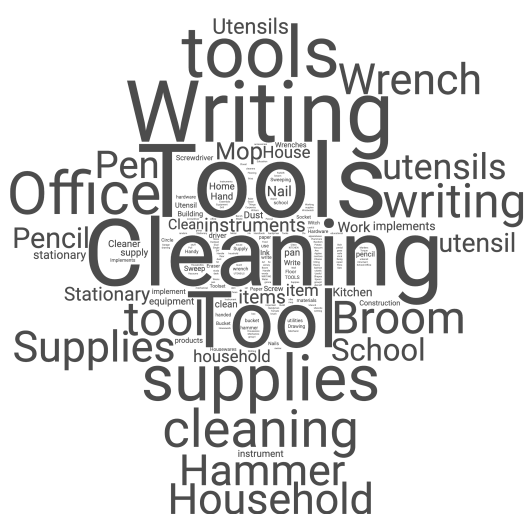
Figure 11. Word cloud of 246 named wholes.

This coding process utilized three separate coders for inter-rater reliability and yielded the seven group names in Table 9.

Table 9. Coded whole group names.

Writing Utensils
Tools
Office/School Supplies
Cleaning Supplies
Household
Related
Other

Coding for obvious similarities in answer choices shows what subjects did in terms of their part-whole organization. For example, while they may have named their groupings (wholes) differently, the meaning of each was relatively normative across these different naming conventions as shown in Table 10.

For all six items, some subjects made groups and named them in a manner that appears to be based on related items rather than on containment and belonging. For example, for 'wrench', one subject made the group named 'screwdriver'. Or, for 'pencil', another subject created a group named 'paper'. In these cases, which occurred between 6.25% and 11.56% of the time, it appears that subjects made the group and named it based on a relationship or association as shown in Table 11.

Table 10. Part/whole groupings of six Items in seven coded groups.

	Whole (Coded Group)						
Part (Item)	Writing	Tools	Office/ School Supplies	Cleaning	Household	Other	Related
Wrench	0.31% (1/320)	84.38% (270/320)		0.31% (1/320)	0.63% (2/320)	7.19% (23/320)	7.19% (23/320)
Pen	45.00% (144/320)	22.50% (72/320)	12.50% (40/320)		0.63% (2/320)	9.38% (30/320)	8.75% (28/320)
Broom	2.19% (7/320)	24.06% (77/320)	0.31% (1/320)	45.94% (147/320)	11.56% (37/320)	8.75% (28/320)	6.25% (20/320)
Hammer	0.94% (3/320)	81.88% (262/320)		2.19% (7/320)	0.31% (1/320)	6.25% (20/320)	8.44% (27/320)
Mop	0.63% (2/320)	20.00% (64/320)	0.63% (2/320)	49.06% (157/320)	13.44% (43/320)	8.13% (26/320)	7.19% (23/320)
Pencil	44.69% (143/320)	12.81% (41/320)	18.13% (58/320)	1.88% (6/320)	1.25% (4/320)	8.44% (27/320)	11.56% (37/320)

Table 11. Part-whole groupings conflated with relationships/associations.

| Part (Items)	Names of Whole Groups Based on Relationships	Percentage
Wrench	Torque Wrenches, Socket, Screwdriver	7.19% (23/320)
Pen	Stationary, Print, Paper, Ink	8.75% (28/320)
Broom	Vacuum, Dustpan, Chores, Witch	6.25% (20/320)
Hammer	Wrench, Saw, Nail	8.44% (27/320)
Mop	Cleaner, Brush, Bucket	7.19% (23/320)
Pencil	Art, Hand, Print, Paper	11.56% (37/320)

Table 12 shows the results for H_1 of the Sort Stuff Study where analysis was performed using a Chi-square G test. Statistical analysis showed that the observed probability for all items was significantly different from the expected probability of >99% for all classifications. Thus, the null hypothesis can be rejected, favoring the alternative hypothesis that part-whole grouping is perspectival and diversified rather than categorical.

Table 12. Results for H_1 of the sort stuff study.

	Cleaning	Household	Office	Other	Related	Tools	Writing
Broom	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Hammer	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mop	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Pen	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Pencil	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Wrench	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Exploratory analysis in Figure 12 was performed to assess how subjects group the various included items. Results showed that all items had more than one classification perceived by the subjects. However, there was a general agreement between the subjects regarding classifying the included items. For example, 46.4% of the subjects classified the broom as a "cleaning". Similarly, 49.5% of the subjects classified the mop as "cleaning". The majority of the subjects classified the hammer and wrench as tools, while 50% classified the pen and pencil as writing tools. These results support the initially proposed research hypotheses.
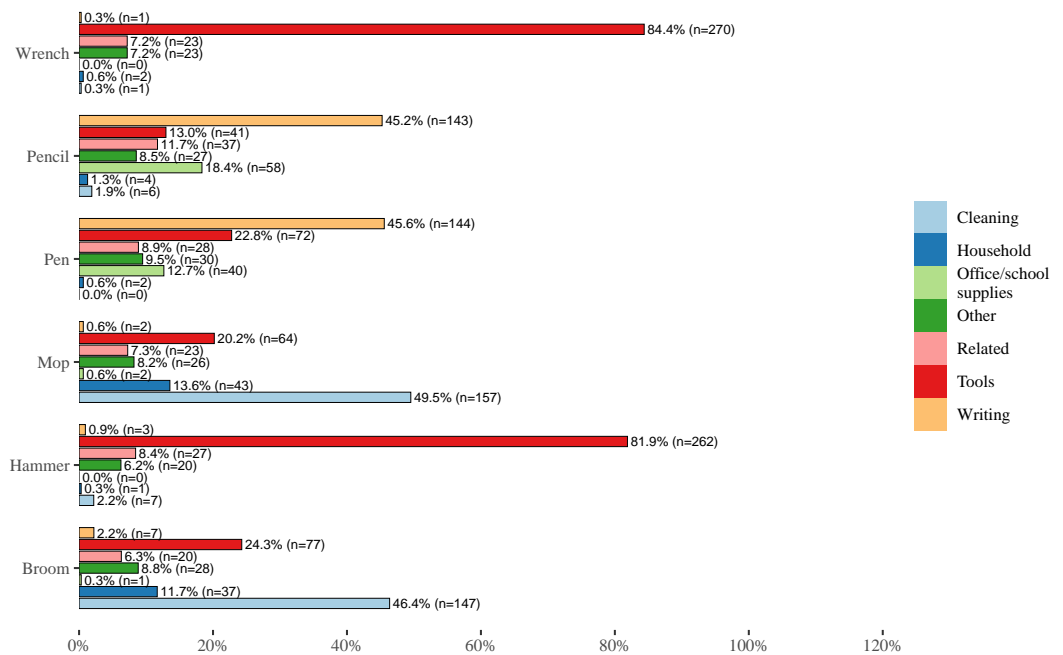
Figure 12. Coding of the included parts.

Table 13 shows the results for H_2 of the Sort Stuff Study where analysis was performed using Chi-square and G test. Results showed that the null hypothesis of equality was rejected at the 5% significance level, indicating an unequal distribution of probabilities for the various classes.

Table 13. Results for H_2 of the sort stuff study.

	X^2	P
Broom	348.57	<0.001
Hammer	989.35	<0.001
Mop	385.36	<0.001
Pen	238.58	<0.001
Pencil	296.37	<0.001
Wrench	1066.8	<0.001

3.4. The Sort Buttons Study

In a set of three tasks subjects (n = 395) were asked to sort images of buttons which differed by size, color, and number of holes.

In the first task, subjects were asked to drag and drop six different buttons into three *pre-existing* groups based on color: Red Buttons, Green Buttons, and Blue Buttons.

This study tests two hypotheses. We first hypothesized (H_1) that there would be a higher degree of agreement between subjects regarding grouping parts into wholes if both the parts and the wholes were provided for them (unlike in the *Sort Stuff Study* where the parts were provided, but the wholes were generated by the subject). Secondly (H_2), we hypothesized that there would be a statistically significant *difference* in the agreement between subjects answers in the *Sort Stuff Study* and *Sort Buttons Study*.

Table 14 shows the responses given based on color, and shows that it was an easy task, as more than 92% were correct for each instantiation.

Table 14. Part-whole grouping of buttons into predetermined wholes based on color.

Part/Whole	Red Buttons	Green Buttons	Blue Buttons
	96.45% (381/395)	2.02% (8/395)	1.51% (6/395)
	96.70% (382/395)	2.53% (10/395)	0.75% (3/395)
	2.02% (8/395)	95.69% (378/395)	2.27% (9/395)
	3.54% (14/395)	1.77% (7/395)	94.68% (374/395)
	2.87% (11/395)	95.18% (376/395)	2.02% (8/395)
	92.20% (380/395)	2.27% (9/395)	1.51% (6/395)

In the second task, subjects were asked to drag and drop a set of seven different buttons into three pre-existing groups based on size: Small Buttons, Medium Buttons, and Large Buttons. Table 15 shows the part-whole grouping of buttons into predetermined wholes based on size, and also illustrates that it was not as easy to do as the groupings made by color with correct responses ranging from 61–85% of the time.

Table 15. Part-whole grouping of buttons into predetermined wholes based on size.

Part/Whole	Large Buttons	Medium Buttons	Small Buttons
	69.87% (276/395)	28.83% (106/395)	3.29% (13/395)
	1.77% (7/395)	12.91% (51/395)	85.31% (337/395)
	15.69% (62/395)	73.41% (290/395)	10.88% (43/395)
	61.26% (242/395)	30.37% (120/395)	8.45% (33/395)
	2.02% (8/395)	13.92% (55/395)	84.05% (332/395)
	69.36% (274/395)	26.58% (105/395)	4.05% (16/395)
	63.79% (252/395)	26.58% (105/395)	9.62% (38/395)

In a third task, subjects were asked to drag and drop a set of eight different buttons into two pre-existing groups: 2-Holed Buttons and 4-Holed Buttons. Table 16 presents the results.

Table 16. Part-whole grouping of buttons into wholes based on number of holes.

Part/Whole	2-Holed Buttons	4-Holed Buttons
	5.56% (22/395)	94.43% (373/395)
	95.18% (376/395)	4.81% (19/395)
	96.20% (380/395)	3.79% (15/395)
	95.44% (377/395)	4.55% (18/395)
	96.20% (380/395)	3.79% (15/395)
	4.81% (19/395)	95.18% (376/395)
	3.54% (14/395)	96.45% (381/395)
	3.79% (15/395)	96.20% (380/395)

Table 16 shows that 95% of subjects answered correctly when asked to sort buttons into pre-existing part-whole grouping based the number of holes.

Fleiss' Kappa was used to assess the agreement reliability between the included subjects. It can be used to assign categorical ratings to several items or classify items (six items in both studies). Fleiss' Kappa calculates the degree of agreement in classification over that which would be expected by chance. Fleiss' Kappa can be used with binary or multilevel categories. In addition, the percentage of agreement was calculated in each scenario. The following values in Table 17 were used for the interpretation of the results based on the study by Landis and Koch [73]:

Table 17. Interpretation of Fleiss' Kappa (κ) (from Landis and Koch 1977).

κ	Interpretation
<0	Poor agreement
0.0–0.20	Slight agreement
0.21–0.40	Fair agreement
0.41–0.60	Moderate agreement
0.61–0.80	Substantial agreement
0.81–1.0	Almost perfect agreement

3.4.1. Results for the Color Sub-Study

Results showed that 95% or more of the subjects correctly classified the included items, which is much higher than the percentage observed in the *Sort Stuff Study*. The observed probability of the correct answer for each of the included parts was >50% (see Figure 13), which is expected by chance under the null hypothesis ($P < 0.001$ *** for all six items). Therefore, the null can be rejected.

Analysis was performed using Chi-square and G test and results are shown in Table 18. Results showed that the observed probabilities were significantly different from an expected probability of >99% under the null hypothesis indicating no universal agreement between the subjects.
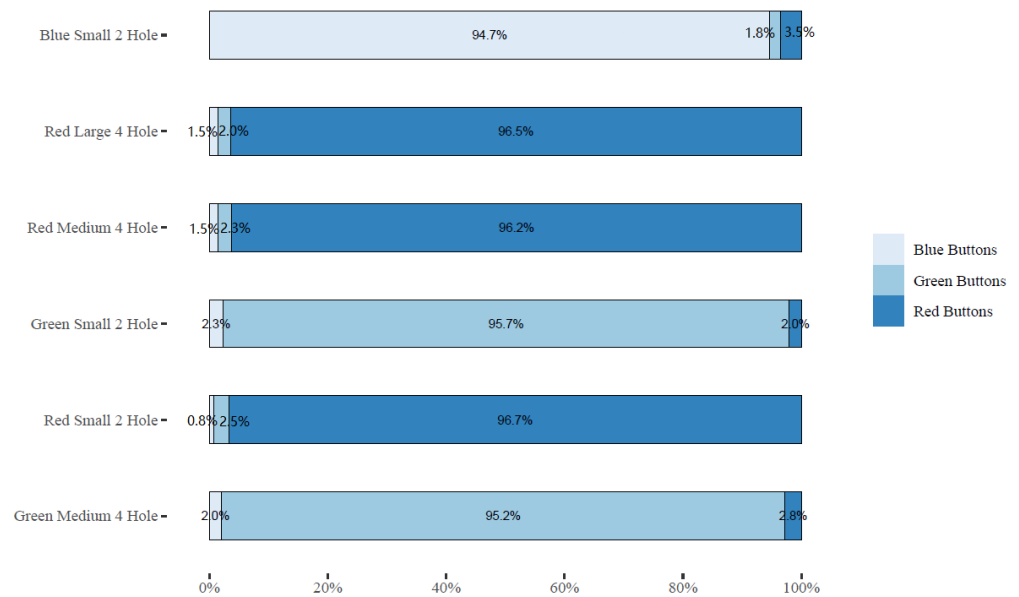
Figure 13. Color coding of included parts.

Table 18. H_1 test results for color.

	X^2	P
Green–Medium–4 holes	57.92	**<0.001**
Red–Small–2 holes	20.94	**<0.001**
Green–Small–2 holes	43.55	**<0.001**
Red–Medium–4 holes	31.22	**<0.001**
Red–Large–4 holes	25.83	**<0.001**
Blue–Small–2 holes	74.33	**<0.001**

3.4.2. Results for the Size Sub-Study

Results in Figure 14 showed that the probability of identifying small buttons was 90%, while there was some variation in the probability of identifying medium and large buttons.
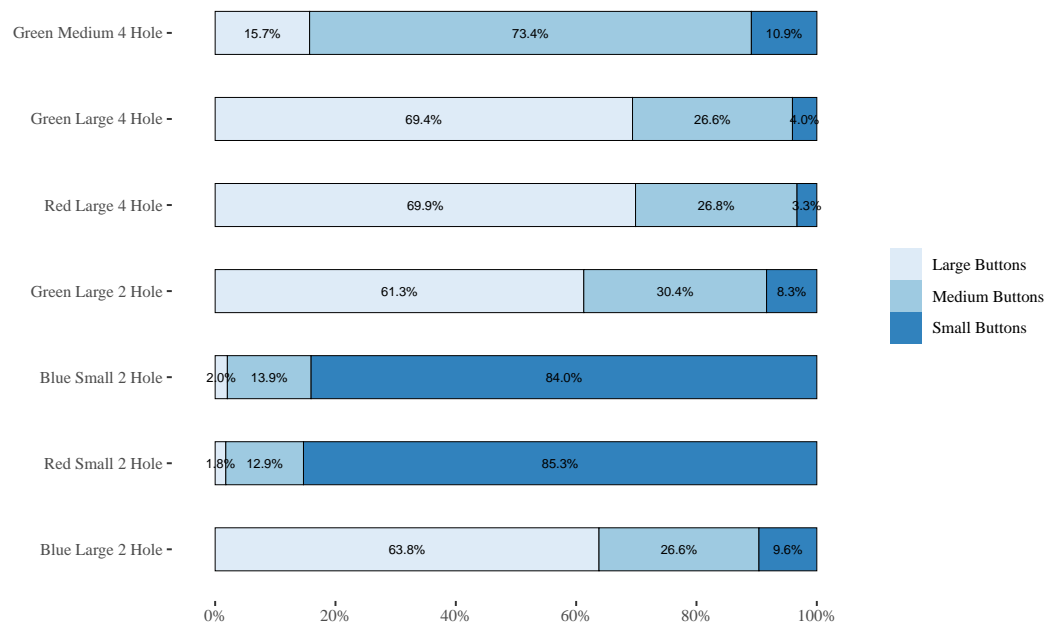
Figure 14. Size coding of included parts.

In Table 19, analysis was performed using Chi-square and G test to test the second hypothesis.

Table 19. H_2 test results for size.

	X^2	P
Blue–Large–2 holes	4944.36	**<0.001**
Red–Small–2 holes	747.07	**<0.001**
Blue–Small–2 holes	891.68	**<0.001**
Green–Large–2 holes	5681.09	**<0.001**
Red–Large–4 holes	3384.86	**<0.001**
Green–Large–4 holes	3503.57	**<0.001**
Green–Medium–4 holes	2611.2	**<0.001**

Results showed that the observed probabilities were significantly different from an expected probability of >99% under the null hypothesis indicating no universal agreement between the subjects.

3.4.3. Results for the Number of Holes Sub-Study

Figure 15 shows results for the Number of Holes. Results indicated significant agreement between the subjects for all items, with >95% of the subjects choosing the "correct" answer.
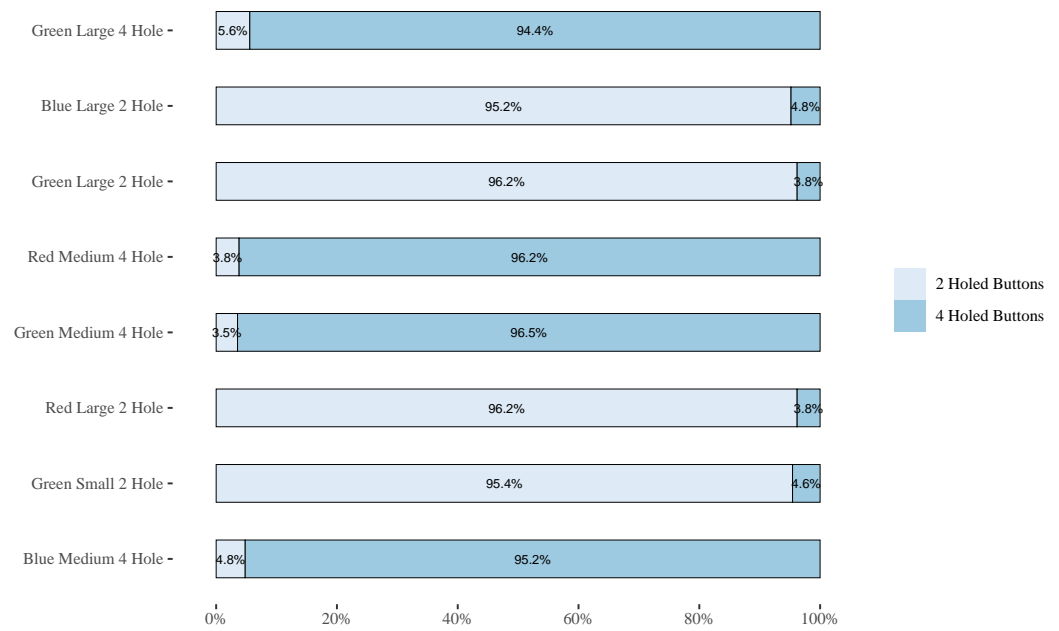
Figure 15. Number of holes coding of included parts.

Results in Table 20 showed that the observed probabilities differed significantly from an expected probability of >99% under the null hypothesis. Thus, the null can be rejected and the alternative supported.

Table 20. H_2 test results for number of holes.

	X^2	P
Blue–Medium–4 holes	57.92	**<0.001**
Green–Small–2 holes	50.48	**<0.001**
Red–Large–2 holes	31.22	**<0.001**
Green–Medium–4 holes	25.83	**<0.001**
Red–Medium–4 holes	31.22	**<0.001**
Green–Large–2 holes	31.22	**<0.001**
Blue–Large–2 holes	57.92	**<0.001**
Green–Large–4 holes	83.31	**<0.001**

3.4.4. Comparisons between Sort Stuff and Sort Buttons' Studies

Results showed that the percentage of agreement was higher for all sub-studies of the *Sort Buttons Study* than for the *Sort Stuff Study*. Similarly, the Kappa for the *Sort Stuff Study* indicated slight agreement between the subjects, whereas, in the *Sort Buttons Study*, responses indicated moderate to high agreement between the subjects. (see Table 21)

Table 21. Interrater agreement.

	% Agree	**Kappa**	*P*
Sort Stuff Study	43.1%	0.252	**0.02**
Sort Buttons Study: **Color**	80%	0.868	**<0.001**
Sort Buttons Study: **Size**	58.8%	0.38	**<0.001**
Sort Buttons Study: **Holes**	91.7%	0.834	**<0.001**

3.5. The S Mapping Study

To determine what people do and do not do when mapping a system, a study (n = 34,398) of aggregate data of software users in Plectica[2] systems mapping software was performed. In addition, 48% did *nothing* in the map canvas. This is consistent with

research where people faced with an open-ended problem or question (similar to a mapping prompt) and/or a blank page or screen (similar to a blank mapping area) had no response and took no action. Furthermore, 52% of people in the study made a total of 2,066,654 *identity* distinctions; 48% of people broke down their distinctions into 769,120 parts; 46% of people made 565,999 relationships between things; 25% of people distinguished 87,318 relationships by adding an identity (naming) the relational line; 16% of people took at least one explicit perspective (39,398 perspectives taken); 4% of people distinguished 16,668 perspectives; and 2% of people included 3265 relationships in the view of their perspective as shown in Table 22.

Table 22. Actions users take and do not take when system mapping (*n* = 34,398).

Percentages	Action Taken	Number
48% (*n* = 16,516)	distinguished nothing (i.e., didn't think)	0 times
52% (*n* = 17,882)	distinguished things	2,066,654 times
of those, 48%	broke down their distinctions into parts	769,120 times
of those 46%	related things	565,999 times
of those 25%	distinguished their relationships	87,318 times
of those 16%	took at least one perspective	39,398 times
of those 4%	distinguished their perspective taking	16,668 times

This data provides insight into both what people do and do not do when mapping using systems thinking. Table 23 distinguishes between what participants do and what they did not do (or could or should do). It provides a baseline for systems thinkers to see what they should continue to do and what they should do more of.

Table 23. What people do and do not do in systems mapping (*n* = 34,398) [67].

| What People Tend to Do	What People Tend Not to Do
Make identities (D^i)	Rarely consider the other (D_o)
	Rarely challenge or validate the identities (D_o^i) they make
Make part-whole systems (S_w^p)	Rarely challenge the way, or consider alternative ways that parts are organized into wholes ($S(P)$)
	Rarely think +1 and −1 from the level they are thinking about ($w = p$ or $p = w$)
	Rarely relate the parts of the whole ($p \stackrel{R}{\Longleftrightarrow} p$)
Occasionally relate things (R)	Almost never distinguish their relationships (RD) or zoom into them and add parts (RDS)
	Sometimes look for the *direct* cause (R), but rarely think in webs of causality (S of Rs)
Take only their own Perspective (P) [implicitly]	Almost never take explicit perspectives (P_v^ρ)
	Rarely take multiple perspectives ($n * P_v^\rho$)
	Rarely take conceptual perspectives (C_ρ)

A fair number of people will make part-whole Systems (48% of people broke down their distinctions into a total of 769,120 parts). At the same time, people will rarely consider alternative ways that parts are organized into wholes ($S(P)$), rarely think +1 and −1 (zoom in or out 1 or more levels) from the level they are operating from ($w = p$ or $p = w$), and they rarely relate the parts of the whole ($p \stackrel{R}{\Longleftrightarrow} p$).

3.6. The S STMI Study

In a study utilizing the Systems Thinking and Metacognition Indicator (STMI) [64] (*n* = 1059), subjects exhibited the well-known Dunning–Kruger Effect [74]. The subject's confidence was higher than their competence in the part-whole Systems (S) skill, shown in Figure 16. This phenomenon existed across all four universal patterns of DSRP Theory

(identity-other Distinctions, part-whole Systems, action–reaction Relationships, and point–view Perspectives), but, for this paper, we are focused on the results for part-whole Systems. Subjects' aggregate part-whole Systems competency/skill score was 58.5, whereas their Confidence score was 76.5—a difference of 18.

Dunning Kruger Effect on 5 Factors and Aggregate
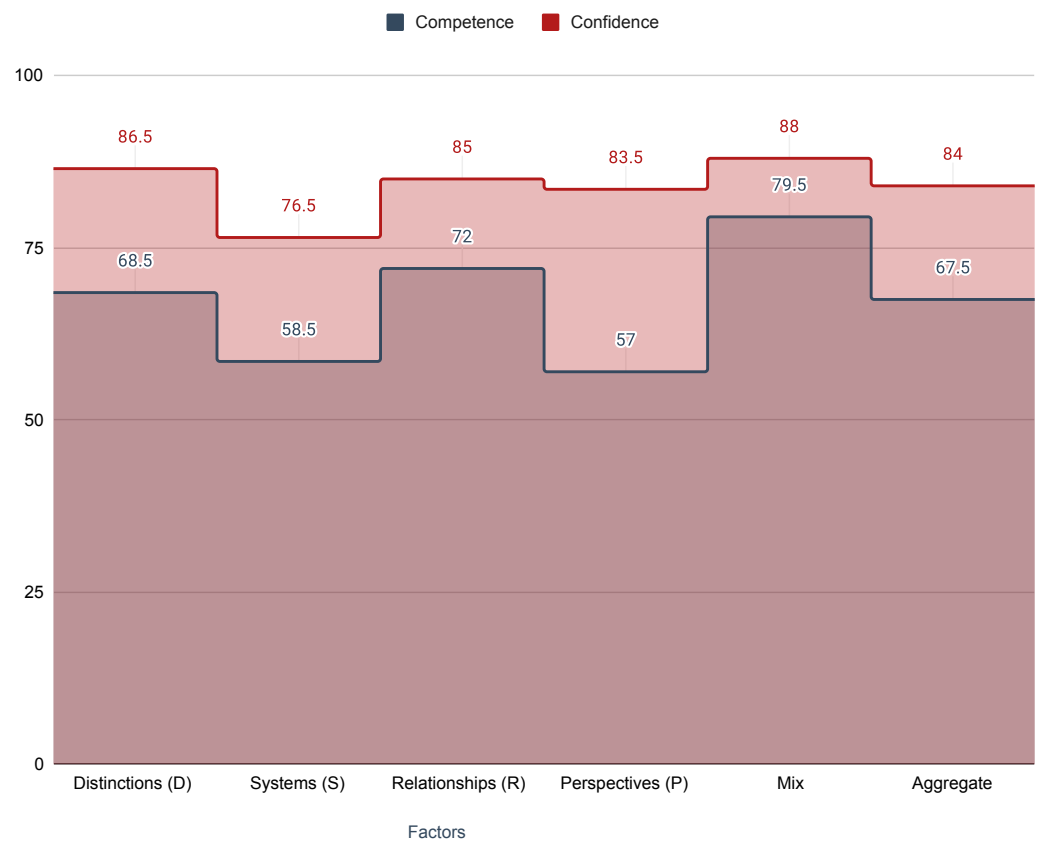
Figure 16. Dunning–Kruger effect in part-whole systems.

3.7. The S Fishtank Study

In the Fishtank Study [65], subjects (*n* = 1750) were asked to describe what they saw in a fishtank scene (the static image in Figure 17).

Figure 17. Describe what you see... [65].

For the Systems study, after the participants filled in their answers in the PreS section, they were asked to read a 'Systems-prime' that reads as the Table 24.

Table 24. Systems treatment with an average read-time 35.19 s (text from [65]).

Things to consider from the part-whole Systems Rule (S):

- Systems are all around us, it is how ideas or objects are organized, grouped or nested with one another.
- The part-whole structure of systems means that any object or idea is both a part and a whole simultaneously (e.g., a planet is comprised of land and water and is also part of the solar system).
- In any whole system, you want to identify the relevant parts to better understand that system.
- The systems rule tells us that we can "zoom in" to see more parts and "zoom out" to see more wholes (e.g., zoom in to see the land and water parts of a planet, zoom out to see that planet as part of the solar system).

Then, subjects were shown the same fish tank image again and asked, "Describe what you see in the image when applying the Systems Rule you just learned (text copied below the image)" [65]. This was called the Post-Systems-prime (also referred to as 'PostS').

The quantitative data for the Systems (S) study are shown visually in the comparison of word clouds. Below is the PreS and PostS word cloud comparisons (Table 25) [65].

Cabrera wrote [65], "The word clouds in Table 25 demonstrate the impact of the Systems prime. The PostS word cloud is more detailed and more descriptive than the unprimed PreS word cloud. The larger a word is, the more times it is used. Certain terminologies—such as *ecosystem, system, whole, zoom*, and *part*—are much more prevalent in the PostS and nonexistent in PreS. PostS also has more unique words overall. The same patterns shown visually in the word clouds are in the quantitative data as well. The responses in the PostS have significantly more words overall and those words are more complex. Table 26 shows the quantitative data analysis".

Table 25. Word cloud of response before and after system prompt [65].
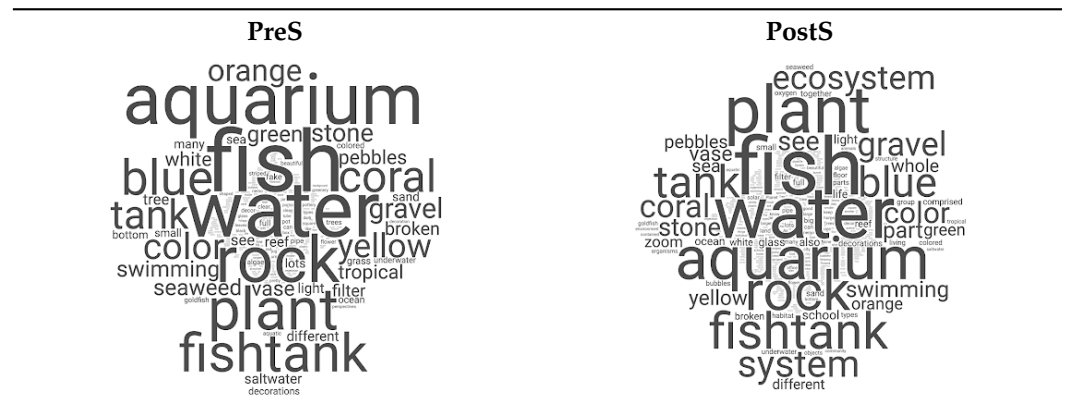
Cabrera writes [65], "Overall, the PostS responses were more 'systemic' than the unprimed PreS responses. This is shown in the words themselves including: *system (38), part (23), whole (16), contain (12), zoom (12), group (8), habitat (6), together (6), community (4), environment (4), organisms (4), organized (2), entirety (2), biosystem (1), gestalt (1), microscopic (1), neighborhood (1), population (1)*. These terms make up 7.44% of the total words in the PostS data. After being primed with the Systems pattern of mind, the participants used more systemic language. They were more focused on part-whole aspects of the fish tank image. After a very short <1 min read, the participants increased their focus on systems".

Table 26. PreS and Post S aggregate response data from [65].

	PreS	PostS	Difference
Number of characters (including spaces)	17061	19367	+11.91%
Number of characters (without spaces)	10318	11350	+9.09%
Number of words (including repeated words)	2092	2410	+13.20%
Number of syllables (including repeated words)	3207	3654	+12.23%
Unique words	243	416	+41.59%
Number of characters (no spaces) for Unique Words	1226	2414	+49.21%
Number of syllables for Unique Words	472	828	+43.00%
Total Unique Word Occurrence	1911	2009	+4.88%

4. Discussion

In the *Complete the Whole study*, we see that constructing part-whole systems (sorting/grouping sets), even if unconscious to the participant, occurs universally. The *Not Red Circle study* shows us that, while part-whole Systems are a universal structure, they are not applied universally. In other words, different people will construct different part-whole Systems for the same stimuli. The *Sort Stuff* and *Sort Buttons* studies arrive at similar conclusions: any set of identities can be grouped into any number of part-whole structures depending on the unique perspective taken by the participants. It means that a list of identities is not inherently part of a categorical whole but perspectively grouped according to the relationships highlighted by the participants' perspectives. This provides direct and reliable evidence that challenges the validity of category theory and should cause us to seriously question its influence. The *Sort Stuff* study shows us that, left to their own agency, people will generate their own perspectives upon which to group items, whereas the *Sort Buttons* study shows that a perspective can be imposed that influences people's sorting behavior. Additionally, the *Sort Buttons* study shows us that, at the same time that individual part-whole groupings can be wildly diverse, they can also be nominally, structurally, or statistically very similar. All of these studies indicate that part-whole Systems (S), while universal, is also *dependent* on the other universals predicted by DSRP Theory (identity-other Distinctions (D), action–reaction Relationships (R) and point–view

Perspectives (P)). Finally, the *STMI*, *Mapping*, and *Fishtank* studies illustrate the efficacy of part-whole Systems as a metacognitive skill.

4.1. The Complete the Whole Study

The task in this study may at first appear to be obvious and clear. However, it is not clear what the task requires to get it right and what must fail in order to get it wrong. Results show that, in order for subjects to identify the right answer, S-rule and its dependencies (D-rule, R-rule, and P-rule, a.k.a., DSRP Theory) explain what is occurring metacognitively. To understand the hypotheses in this study, we must suspend our deep and implicate dependence on part-whole Systems as universal cognitive patterns. Imagine for a moment that a brain was not wired to make part-whole. What could it do and not do?

Thus, the null hypothesis in this study is that subjects will not be able to complete the task. This means that, if part-whole Systems did not exist, subjects will either get it wrong, or have a 50/50, or random, chance of getting it right? Thus, the null hypothesis is $H_0 : p\,\blacksquare \leq 0.5$ and the alternative hypothesis is $H_A : p\,\blacksquare \gg 0.5$, where p is the probability and $\blacksquare$ is the red square or "right answer" that completes the part-whole grouping.

The *Complete the Whole Study* reveals that, in order to perform even a relatively simple task (which 88.86% completed correctly), one must make use of distinctions, relationships, and part-whole structure. Figure 18 shows two such relational part-whole systems (of distinct identities, i.e., square, red, etc.). There are, of course, numerous others that could be used (e.g., diagonal, L-shaped, etc.).

Fill in the blank
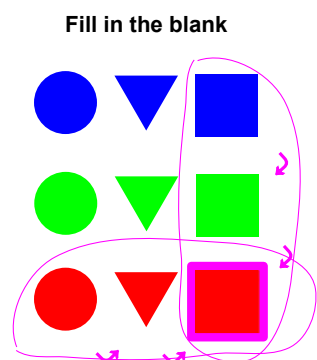
Figure 18. Completing the Whole requires distinctions, relationships, and part-whole structure.

In this paper, we are specifically focused on the implications for part-whole Systems, but it is clear that there are also implications for the other three rules (D, R, and P). Thus, we can see that the correct answer (red square) completes both the vertical part-whole grouping of 'squareness' ⬛ and the horizontal part-whole grouping of 'redness' ●▼◼. It also completes the diagonal part-whole grouping of 'other colorness AND other shapeness', ▾◼ as seen in Figure 18. In order to choose the right answer, subjects needed to see at least one of several part-whole groupings: ●▼◼, ●▼◼, ●▼◼; ⬛, ▾, ⬛; and/or ▾◼. Thus, without being explicitly instructed to do so, and likely without knowing that they had done so, subjects who answered correctly created part-whole groupings to identify the correct response.

4.2. The Not Red Circle Study

The task in this study may at first appear to be obvious and clear. In addition, the astute reader may notice that this task resembles that of one one might find on an IQ or similar styled test. However, the results are anything but obvious and clear. In addition, S-rule and its dependencies (D-rule, R-rule, and P-rule, a.k.a., DSRP Theory) provide a rationale for why people who got it "wrong" also got it right, in that they used a totally defensible logic. The **Not Red Circle Study** asked subjects to complete the task in Figure 19.

The answer is not ●.
The answer must be:

Answer choices

Figure 19. The Not Red Circle study task.

　　Unlike the previous *Complete the Whole* study, to understand the hypotheses in this *Not Red Circle* study, we will assume that subjects *can* make part-whole groupings, but that they will make different ones and end up getting a range of answers rather than 100% choosing the "correct" answer (which is ■).

　　Thus, the null hypothesis in this study is that subjects will complete the task by making a single, universal part-whole grouping (a *category* in common terms). This means that subjects will choose the right answer. Thus, the null hypothesis is $H_0 : p■ = 1$ and the alternative hypothesis is $H_A : p■ \ll 1$ where p is the probability and ■ is the "right answer" that completes the part-whole grouping. Figure 20 shows the aggregate results for each answer choice, but also indicates why subjects chose the answer.
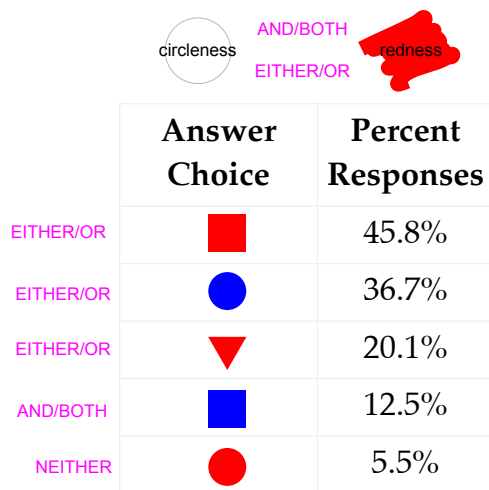

	Answer Choice	Percent Responses
EITHER/OR	■	45.8%
EITHER/OR	●	36.7%
EITHER/OR	▼	20.1%
AND/BOTH	■	12.5%
NEITHER	●	5.5%

Figure 20. EITHER/OR or AND/BOTH of part-whole determines the answer.

　　If the answer *is not* red circle ●, then there are several options that the answer could be—all of which indicate the subconscious (or conscious) application of part-whole. The options are as follows:

1. if the subject decides that the answer is not circleness **AND** not redness, they will choose the blue square—12.5% chose this option.
2. if the subject decides that the answer is not circleness **OR** not redness they will choose the red-square (45.8%), blue-circle (36.7%), or red-triangle (20.1%).

　　It is common in logical tests to assume that the *correct* answer is blue square because the question explained that the answer could not be a red circle, and all other answers were either red or circle or both. As is so often the case, 'logic' may be in the eye of the beholder (i.e., perspectival). Subjects arrived at different responses based on the different part-whole groupings of the elements of red + circle. The data show that subjects used a part-whole strategy to identify answers that could be determined to be correct, depending on which part-whole strategy was being utilized. Thus, on a relatively simple task with five solution choices, subjects chose multiple solutions (MIN = 21, MAX = 176, MEAN = 92.6) because subjects were using different part-whole strategies to determine their choices[3].

- *If* the subject used the part-whole strategy, "the answer cannot be a red-circle", where red-circle is taken literally as inseparable, then *any* answer that is not ● is possibly correct. Thus, ●, ■, ▼, and ■ can all be correct.

- However, *if* the subject used the part-whole strategy, "the answer cannot be red *or* cannot be circle"—where red and circle are separable parts of red-circle such that the answer could either *not be red or not be circle*—then answers ●, ■, ▼, and ■ could be correct.

- Alternatively, *if* the subject used the part-whole strategy, "the answer can neither be red nor circle"—where red and circle are inseparable parts of red-circle such that the answer must be *not-red and not-a-circle*—then *only* answer ■ could be correct.

This study shows us that, while part-whole Systems are a universal structure, they are applied in a diversity of ways. In other words, given the *same informational stimuli*, and using the same universal part-whole Systems (S) structure, different people will construct both similar and different part-whole Systems. These findings, and others in this ecology of studies, dispel us of our popular notions of *categories* as well as misinterpreted categorization research (in mind) but aligns with the idea of natural kinds (in nature). It shows us that, along with every part-whole grouping is the need for distinction-making, relationships, but most importantly, a perspective that governs what gets grouped and what does not.

4.3. The Sort Stuff Study

The *Sort Stuff Study* reveals that, when subjects are asked to sort things into part-whole groupings of their own choosing, there is substantial diversity in the wholes (246 wholes for six items). The original six items were chosen for relational similarity as well as their difference. For example, given the six items—wrench, pen, broom, hammer, mop, pencil—subjects would be expected to perceive relationships between wrench and hammer, pen and pencil, and broom and mop, respectively. In addition, the items are different enough that one might expect variance in sorting (e.g., one can imagine different whole groupings for pen and mop. At the same time, one could imagine pen and mop being perceived as part of the same coded group/whole (e.g., both are tools, both are long and slender, etc.). This combination of similarity and difference is what underlies the complex cognitive task of sorting parts into wholes and is also what underlies the variance. The various hypotheses associated with this study (predictions of DSRP Theory about part-whole structures) were confirmed. These include: (1) a rejection of categories theory and its influence; (2) the universality of part-whole Systems structure; (3) the dependencies of the Systems rule (S) on the Distinctions (D) rule and Relationships (R) rule; and (4) that individual and social cognition are different but also show patterns of similarity in part-whole grouping (likely a function of Perspective (P).

Subjects sorted six items into 246 unique groups and named them. Table 8 shows that each of six parts (items) were grouped into between min. 51 and max. 102 unique named wholes. The fact that the wholes were named (see Figure 21) indicates that they take on a distinct identity and that part-whole Systems (S) is *dependent* on identity-other Distinctions (D). Because (as Table 7 illustrates) the number of named wholes that ranged between 1 and 6 (M = 2.86) wholes were also others to each other locally (and to any other identities globally). This again illustrates the simultaneity rule predicted by DSRP Theory—in this case that both parts and wholes also simultaneously take on identity and other facets. Table 10 illustrates that, even though there are many ways to organize parts into wholes, coded for similarity, there are patterns of similarity underneath for common items. In addition, Table 6 illustrates some of the diversity and similarity (see Table 9) of these groups. Table 11 illustrates the tendency to name (and create) groups based on the relationships between parts (by item, between 6.25% and 11.56% of the time). This of course demonstrates that part-whole Systems are not only a function of action–reaction Relationships in order to establish a relationship between belonging and containment (the

essential relationship between part and whole) also may be used in dynamical ways, similar to coupled oscillators, where the existence of two items causes a a relational back-and-forth from which a pattern of wholeness emerges and then is distinguished. Remarkably, this study indicates all of these things to be the case. However, as we will see, when we combine the results of this study (based on wholes created by the subject) with the results of other sorting tasks (where pre-existing wholes were used), we get insight into the very nature of part-whole grouping and the flaws in categorical theory and its influences.

This design of the *Sort Buttons Study* utilized *pre-existing* wholes in the sort (both created and named by the researchers), whereas the *Sort Stuff Study* left the wholes open ended (both created and named by the subject).

The data also show that a set of identities (6) can be grouped into any number of part-whole System structures (243) depending on the unique perspective taken by the subjects when sorting items. It means that a list of items or identities is not inherently part of a category but is grouped according to the relationships highlighted by the subjects' perspectives. Thus, part-whole grouping into systems is also a function of relationships and perspectives.
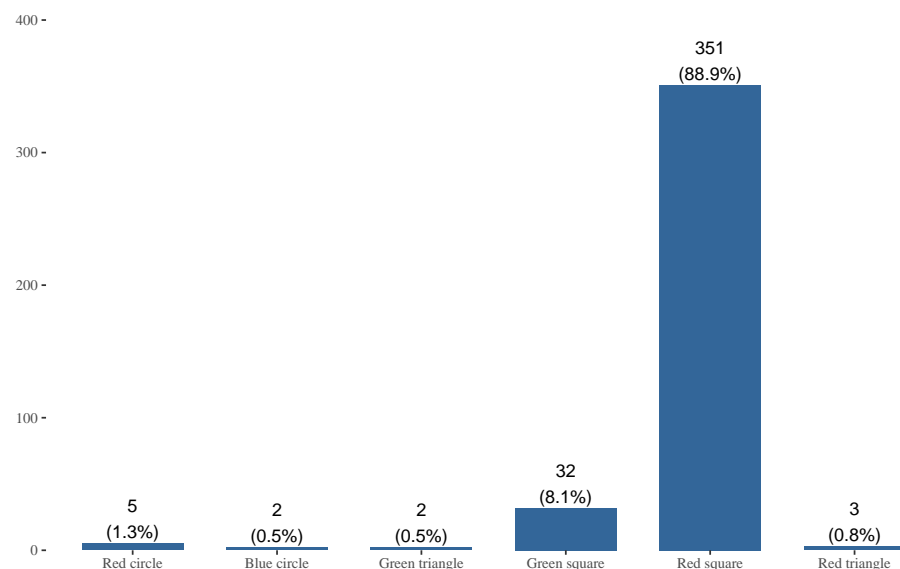
Figure 21. Responses to Complete the Whole study.

4.4. The Sort Buttons Study

The *Sort Buttons Study* reveals much more about the structure and dynamics of part-whole as a universal. Several aspects of these button studies illustrate that the way that subjects do part-whole grouping is a function of relationships. At the same time that part-whole grouping forms as a function of individual perspectives, they can also be suggested, where the whole serves as a prompt the sorter uses to identify qualities in the identities themselves. In this case, the prescribed wholes cause the grouping/sorting to occur. Additionally, it appears that the grouping of parts into wholes as a cognitive task is conflated with the cognitive task of drawing relationships between two or more identities. It is unclear which comes first: a relationship that leads to a part-whole grouping; or part-whole grouping leading to the recognition of relationships among things. In the two cases of grouping items (e.g., wrench, pen, etc.) into new named groups, relationships lead to groupings. However, in the case of the button grouping, we see predetermined wholes leading to the identification of relationships of similarities among buttons. This latter example actually means that prenamed wholes are utilized as perspectives to identify relational characteristics in the buttons. Thus, part-whole grouping occurs in both directions and is much more likely to be the emergent property of both in unison, much like a coupled oscillator, than of any linear decision process.

This set of questions indicate that part-whole grouping is a function of distinctions—in other words, when people grouped an item (a part) into a newly named group (a whole). That is, the wrench-item becomes part of the whole named "tools", which is itself a new identity-other Distinction.

4.5. The Dependency Research Studies

In **other research studies**, the identity and other variables of Distinctions (D) [67], the action and reaction variables of Relationships (R) [68], and the point and view variables of Perspectives (P) [66] were all shown to be part-whole Systems (S). As part of research on Distinction making (D), Cabrera found [67] that both the identity and the other are part-whole systems. An example of this is shown in Figures 22 and 23.

Figure 23 illustrates (from the data in [67]) that identity is also a part-whole structure at both the levels or individual and social cognition.
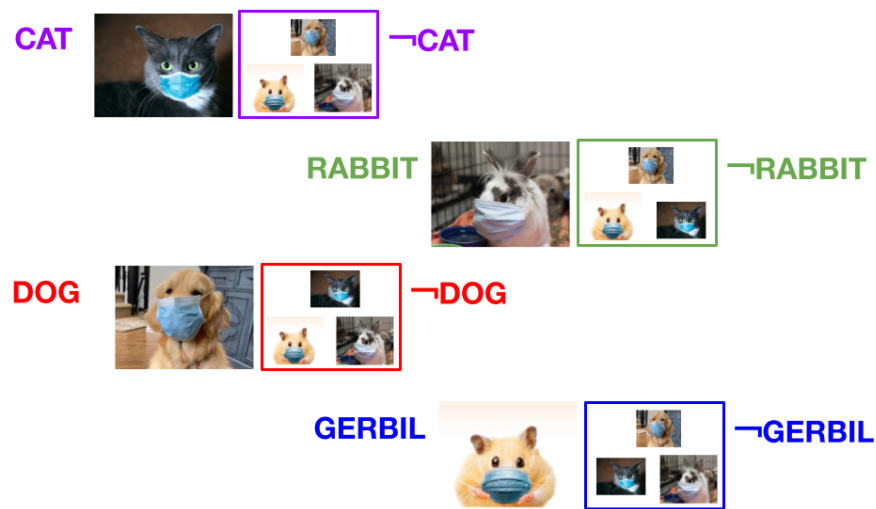

Figure 22. *Others* are part-whole systems.

is square	*is* triangle	*is* circle
is black	*is* black	*is* black
is hole	*is* inverted	*is* hole
is dark	*is* angle	*is* round
is cube	*is* corner	*is* sphere
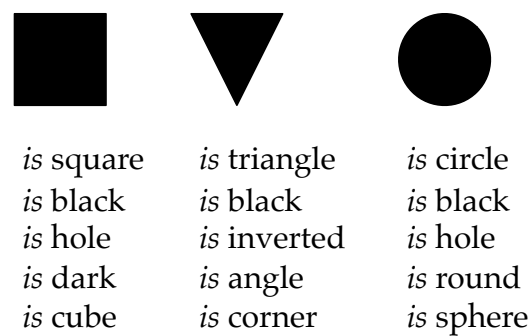
Figure 23. *Identities* are part-whole systems.

4.6. The S Mapping Study

The **S Mapping** data show that part-whole Systems exist and can be a metacognitive skill with highly statistically significant effect that can be measured in terms of competence and confidence. This is in comparison to the prior studies which get at the *existence* of part-whole Systems.

4.7. The STMI Study

In both the **Fishtank Study** and the **STMI Study**[4], we see that part-whole Systems can be utilized as a metacognitive skill that is measured in both competence/skill and confidence. We should be careful not to overestimate our competency in the part-whole Systems skill, demonstrated by the Dunning–Kruger effect shown in our sample.

4.8. The Fishtank Study

The **Fishtank Study** demonstrates with high statistical significance that a quick (less than 1 minute) intervention can have a positive effect on the complexity of cognition. People see not only quantitatively deeper, but qualitatively more as well. These findings indicate a statistically significant increase in the degree to which people made more detailed nesting and zooming occur, which is occurring after a limited exposure to treatment (on average, a 28.11 s read of bullets of text). One can imagine the effects may be transformative with a more substantive treatment (such as a short course). One critique is that we did not use a traditional control group in which the passage of time could be assessed for impact in the change in systemic words. Given that the passage of time between Pre and Post was so short (<1 min), we concluded that the passage of time was not a plausible alternative explanation.

4.9. Limitations

There are always limitations to research that are addressed over time. Several limitations exist in these studies. We did not correlate data from any of the studies with externally validated measures, scales, or other inventories for criterion validity. Control groups were not used in the Fishtank study and could be a future variation on this research. Our population is only generalized to the US population. Further research could be done to look across international cultures and language. In addition, studies could be created that rely even less on language cues or visual imagery.

4.10. Summary of Findings on Existence, Universality, Efficacy, and Parallelism

All of these findings confirm specific predictions made by DSRP Theory. The findings in this ecology of studies focusing specifically on *part-whole Systems* are detailed above. Each study adds a brick to the wall of our understanding of part-whole Systems (a.k.a., sorting, categories, sets, etc.) and answers important questions about: (1) how we make them, (2) the dynamics between part and whole, (3) their role in cognition, (4) the role they play in metacognition, and (5) the effects of awareness of part-whole Systems on cognitive complexity [67].

We see that the *part* and *whole* elements of the *Systems* pattern are *inextricably linked*, *co-implying* and *interchangeable*. That is, we see the following, where A is any information content:

$$\exists A_p$$
$$\exists A_p \xoverset{implies}{\Longrightarrow} \exists B_w$$
$$\exists B_w \xoverset{implies}{\Longrightarrow} \exists A_p \tag{1}$$
$$\exists A_p \xoverset{co\text{-}implies}{\Longleftrightarrow} \exists B_w$$

In Equation (1), we see that, if any content information A which is a *part* (p), A_p, *exists* ($\exists$), then it *implies* ($\Rightarrow$) that a *whole* (w) or B, must also exist, B_w (i.e., if a part exists, a whole must exist). The same is true in the reverse where B_w implies ($\Rightarrow$) A_p (i.e., if a whole exists, a part must exist). Thus, part and whole, as structural patterns of cognition, are *co-implying*.

Thus, in Equation (2), we see that the *part-whole* elements of *Systems* are *universal* to all forms of categories, sets, grouping, sorts, etc. In addition, these universal elements are *interchangeable* such that any *part* can also function as *whole* and vice versa:

$$S = p \xoverset{co\text{-}implies}{\Longleftrightarrow} w$$
$$f : p \to w \tag{2}$$
$$f : w \to p$$

In other research studies, the action and reaction variables of Relationships (R) [68], the identity-other variables of Distinctions (D) [67], and the point and view variables of Perspectives (P) [66], were all shown to be part-whole Systems (S), for example that the elements of D, R, and P themselves form part-whole systems, or that relationships can be made up of parts, perspectives are not homogeneous (they contain sub-perspectives), and even distinctions are sets of identities (is's) and others (is not's). Like the studies presented herein for part-whole Systems (S), an ecology of studies was undertaken to test the existence and efficacy of, respectively, D, R, and P rules. With high statistical validity, these studies show that part-whole Systems (S) is a factor in the formation of identity-other Distinctions, point–view Perspectives and action–reaction Relationships. From the results of these seven studies, we can conclude that part-whole Systems (S) are as follows. The universality of the four DSRP patterns allows us to draw the same conclusions as in the identity-other Distinction paper [67]. Cabrera [67] concluded:

1. Universal to the organization of Information:

    (a) in the *mind* (i.e., thinking, metacognition, encoding, knowledge formation, science, including both individual and social cognition, etc.; and

    (b) in *nature* (i.e., physical/material, observable systems, matter, scientific findings across the disciplines, etc.).

2. Made up of elements (part, whole) that are:

    (a) *co-implying* (i.e., if one exists, the other exists; called the co-implication rule);

    (b) related by a special[5] relationship: *belonging/containment*; and

    (c) act simultaneously as, and are therefore interchangeable with, the elements of Distinctions (identity, other), Relationships (action, reaction), and Perspectives (point, view). This is called the simultaneity rule.

3. Mutually-dependent on identity-other Distinctions (D), action–reaction Relationships (R), point–view Perspectives (P) such that D, S, R, and P are both necessary and sufficient; and

4. Taken metacognitively:

    (a) constitute the basis for making *structural predictions* about information (based on co-implication and simultaneity rules) of observable phenomena and are therefore a source of creativity, discovery, innovation, invention, and knowledge discovery; and

    (b) *effective* in navigating cognitive complexity to align with ontological systems complexity.

5. Conclusions

With these findings in mind, we can return to our table of research questions (Table 3) to summarize what was found. The literature reviews of S-rule show that it exists across the disciplines. We expect that future studies will only accumulate to show this trend. However, within this growing literature, the S-rule is relatively vague, existing only as part-whole and not showing empirically what these studies have show (summarized in Table 27). If we are to increase our technical prowess with systems thinking, we cannot remain at this vague interpretation of part-whole Systems but instead need to acknowledge the complexity and inter-dependencies of S-rule and the other DSRP rules.

In conclusion, these data suggest the observable and empirical *existence*, *universality*, *efficacy*, and *parallelism* (between cognitive and ontological complexity) of part-whole Systems (S) and with a high statistical significance point to the conclusions in Table 27.

Table 27. Summary table of conclusions.

Conclusions	Summary
People use part-whole thinking to navigate the world cognitively.	part-whole Systems (S) Rule exists.
The way people create part-wholes and the way they exist are not always aligned.	Awareness of S-rule can decrease bias.
Part-whole structures are not discrete (category theory) but fluid (DSRP theory).	Categories are not elemental. Part-whole is.
When people part-whole they use distinctions, relationships, and perspectives to do so.	S-rule is dependent on D, R, and P rules.
The Patterns and the Elements of D, S, R, and P are themselves, part-whole structures.	D, R, and P rules are dependent on S-rule.
Because part-whole groupings are DRP-dependent, there can be (and often is) a diversity of groupings.	People part-whole things differently.
At the same time (likely because we use the same human sensory apparatus to do so and nature has similar structure), we see patterns across part-whole groupings; they pick up on similar patterns that are likely part of our or natures' structure or both.	People part-whole things the same inside of their differences.
With regard to part-whole, we now know where people have ease and difficulty. Namely: they do not challenge preexisting part-wholes; they do not scale up (+1) and down (−1); they do not relate the parts (explicitly).	We can get better at doing part-whole thinking.
People overrate their abilities (competence/skill) in part-whole thinking.	We are overconfident.
Even a short metacognitive training in part-whole Systems ("S-rule") leads to increases in cognitive ability and cognitive complexity.	"S-rule" makes you smarter.

Abbreviations

The following abbreviations are used in this manuscript:

DSRP	DSRP Theory (Distinctions, Systems, Relationships, Perspectives)
D	identity-other Distinctions
S	part-whole Systems
R	action–reaction Relationships
P	point–view Perspectives
STMI	Systems Thinking and Metacognition Inventory
IQR	Interquartile Range
GLMM	Generalized Linear Mixed Modeling
RDS	Relate–Distinguish–Systematize Jig

Notes

[1] "It should be noted that the ST/DSRP Loop is the mirror opposite of confirmation bias. Confirmation bias reverses this loop, by *fitting* reality to one's mental models, whereas DSRP-Systems Thinking *fits* mental models to real-world observables and feedback. *Parallelism* is therefore the degree to which one's cognitive paradigm, style, or mindset, aligns with nature's. One purpose of this research program is to determine the degree to which DSRP Theory accomplishes this parallelism".

[2] Derek Cabrera invented Plectica Systems Mapping Software. It was used for years as pilot software program for research. Cabrera then co-founded Plectica to further develop the software further for consumers. Plectica was then sold to Frameable, and Cabrera is no longer actively involved in the company.

[3] (It is unclear what the ⬤ answer signifies. It is likely that the subject did not notice the word 'not' in the instructions: *The answer is NOT* ⬤. However, it is impossible to know for sure from the data. The other solutions to the task are more clear.

4   (Both the Fishtank [65] and the STMI Study focused on more than just the existence of part-whole Systems. See [64].

5   "Special" here refers to the specific systems, in contrast to general or universal relationships.

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