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# Common Biases in Systems Thinking

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ABSTRACT: This study investigates biases in systems thinking, utilizing the DSRP model to analyze cognitive complexity in written language. We tested three hypotheses regarding the prevalence of DSRP elements and patterns in both systems thinking-trained and untrained individuals. Our results confirmed that systems thinking commonly exhibits significant biases in relation to the ideal even prevalence of DSRP elements and patterns, with notable differences between systems thinking trained and untrained groups. While training positively impacts the efficiency of systems thinking, it shows a lack of influence on mitigating systems thinking biases. Our study highlighted a remarkable relationship between critical systems thinking and systems thinking efficiency and parallelism. It also revealed a pronounced lack of relational and perspectival patterns in our study cohort responses. The study contributes to the understanding of cognitive biases in systems thinking and suggests the need for more systematic integration of bias-awareness in systems thinking theories, training, and practice[1].

KEYWORDS: Cognitive complexity | DSRP | systems | systems thinking | mental model | cognitive biases

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# 1. Introduction

In the face of the complex challenges of the 21st century, systems thinking has emerged as an indispensable tool in fields as diverse as engineering, education, or politics. This holistic approach enables us to effectively navigate the complexities of interdependent systems in our world. However, even this efficient process is not immune to cognitive biases. Cognitive biases impact our perception and decision-making, sometimes leading to erroneous, incomplete analyses, or counterproductive decisions. Therefore, understanding 'biases in systems thinking' is critical to ensure the integrity and efficiency of systems thinking.

Cognitive bias is defined as “a systematic pattern of deviation from norm or rationality in judgment” [1]. They can occur in any thought process. In the context of systems thinking, they can manifest as an unconscious preference or neglect of certain system patterns, thus disrupting the balance necessary for a comprehensive and objective systems thinking process [2–6].

The DSRP Theory, developed by Derek Cabrera [2–10], is structured around four binary systems – called patterns – of paired-base, co-implying elements. This model provides a valuable framework for examining cognitive systems thinking biases (ST-Biases). The DSRP Theory posits that effective

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systems thinking requires not only awareness and training but also a balanced activation of these elements and patterns [2–10]. However, a crucial question arises: Is this balance maintained in actual systems thinking practice?

Our study uses the DSRP Model to map individual responses to a test, enabling us to identify the activation of DSRP elements, and determine a systems thinking DSRP profile. In this paper, we define ST-Biases as '*any deviation from an even distribution of DSRP patterns or elements in systemic markers stemming from a DSRP processes*'. This study serves a dual purpose: firstly, to enhance our understanding of the patterns of 'biased' systems thinking, and secondly, to discuss their potential impact on systems thinking theories, training, and practice.

This study primarily aims to deepen our understanding of cognitive biases, from a systems thinking perspective, and address their potential impact in areas such as communication, management, or leadership. It is founded on three core hypotheses: firstly, that ST-biases are prevalent in systems thinking; secondly, that these biases can be evidenced using the DSRP Model; and thirdly, that the distribution of DSRP elements in language – specifically in its written form – reveals patterns of ST-Biases. The following sections will explore these objectives and hypotheses in greater detail.

## 1.1. The DSRP Model

The DSRP Theory has been a pivotal development in understanding cognitive processes within systems science. This theory delineates cognitive processes that underlie the emergence of complexity in both the mind and nature. At its core, the DSRP Theory articulates universal structures and dynamics for organizing information.

### Formulation

Cabrera & Cabrera [10] provide an extensive and detailed description of the DSRP Theory. This theory is grounded on the concept that natural Reality ($\mathbb{R}$) is a complex product of Information ($\mathbb{I}$) and Organization ($\mathbb{O}$); likewise, Mental Models ($\mathbb{M}$) are a complex product of Information ($\mathbb{I}$) and Thinking ($\mathbb{T}$). The theory posits that organizational principles are fundamentally based on four cognitive processes[2]:

- Making distinctions (D),
- Organizing information into parts-wholes systems (S),
- Establishing relationships (R), and
- Considering perspectives (P) involved in making boundary distinctions.

In the DSRP framework, these four fundamental cognitive processes are referred to as 'Patterns' ($\mathbb{P}$). Each pattern represents a binary system, characterized by the interaction of two paired-base 'Elements' ($\mathbb{E}$) that co-imply each other. Figure 1 illustrates how the eight interacting elements ($\mathbb{E}$) are organized into four essential patterns ($\mathbb{P}$) of cognition. These are:

- Distinctions: Involving the interaction between Identity (Di) and Other (Do).
- Systems: Constituted by the interaction between Part (Sp) and Whole (Sw).
- Relations: Defined by the interaction between Action (Ra) and Reaction (Rr).

[2] In this context, the term 'cognition' is used in its etymological sense derived from Latin, combining 'co-' (together) and '-gnoscere' (to know). This interpretation extends the conventional understanding as a "mental action or process of acquiring knowledge and understanding through thought, experience, and the senses" (https://en.wikipedia.org/wiki/Cognition). It more broadly encompasses the concept of one thing 'getting to know' another, thereby highlighting a process of mutual recognition or interaction in the natural world.

- Perspectives: Comprising the interaction between Point (Pꞵ) and View (Pv).[3]

Hence, cognition in nature ($\mathbb{O}$) produces ontological complexity ($\mathbb{R}$) through an organizing function $f_O\,[D, S, R, P]$ applied to natural information ($\mathbb{I}$). Similarly, cognition in the mind ($\mathbb{T}$)[4] leads to cognitive complexity ($\mathbb{M}$) through an organizing function $f_T\,[D, S, R, P]$ applied to mental information ($\mathbb{I}$). These parallel processes can be mathematically formulated as follows (Equation 1):

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*Equation 1: Simplified formulation of the cognition function in nature and the mind, involving DSRP patterns as four essential variables (adapted from Cabrera & Cabrera [10])*

$$\text{Nature:} \quad \mathbb{R} = \mathbb{I} \otimes \mathbb{O} \text{ where } \mathbb{O} = f_O\,[D, S, R, P]$$

$$\text{Mind:} \quad \mathbb{M} = \mathbb{I} \otimes \mathbb{T} \text{ where } \mathbb{T} = f_T\,[D, S, R, P]$$

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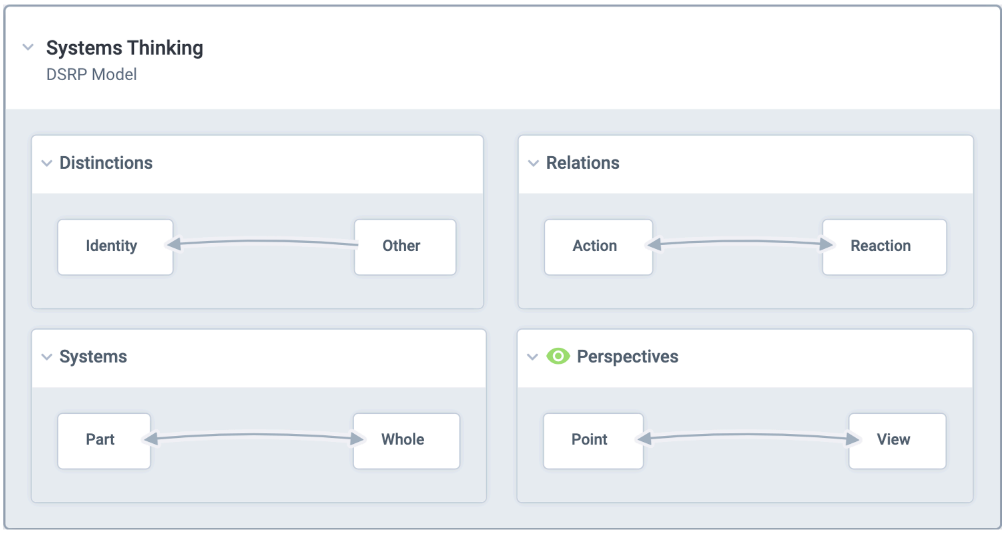


Figure 1: The DSRP model, highlighting four cognitive patterns—Distinctions, Systems, Relations, and Perspectives—each comprising base-paired, co-implying elements.

## Overview of DSRP Patterns and Elements

The primary focus of this paper is not an exhaustive exposition of the DSRP Model. However, this section will succinctly delineate the four patterns of the DSRP model, laying the groundwork for the subsequent introduction and elucidation of our DSRP-Scoring methodology (see Section 3.2).

- **Distinctions** [4]**:** This pattern entails distinguishing 'Identity' from 'Other'. It involves drawing boundaries to define what a ‘thing’, ‘idea’, or ‘concept’ is (‘Identity’) and what it is not (‘Other’). This pattern is crucial for forming concepts and ideas, underpinning our ability to differentiate, name, and define. Distinctions, of course, play a major role in language; elements like letters, words, sentences, etc., encapsulate numerous processes of Distinctions.

[3] DSRP’s internal dynamics include two if-then statements. The first between the pattern ($\mathbb{P}$) and its elements ($\mathbb{E}$) such that $\mathbb{P}\leftrightarrow(\mathbb{E}1\leftrightarrow\mathbb{E}2)$. The second if-then is between 8-fold elements stating that if any element exists, then it may act as all other elements or if $i \vee o \vee p \vee w \vee a \vee r \vee \beta \vee v$ exist then an $i \wedge o \wedge p \wedge w \wedge a \wedge r \wedge \beta \wedge v$ exists.
[4] where $\mathbb{T} = D\leftrightarrow(i\leftrightarrow o) \wedge S\leftrightarrow(p\leftrightarrow w) \wedge R\leftrightarrow(a\leftrightarrow r) \wedge P\leftrightarrow(\beta\leftrightarrow v)$

- **Systems** [3]**:** Everything, be it things, ideas, or sentences, is a system composed of various parts, and simultaneously a part nested in a larger system. The Systems pattern focuses on either breaking down a whole into its constituent parts or organizing these parts into a coherent whole. It also involves viewing any whole as a part of a larger system. Understanding systems involves recognizing how parts interact within the whole and how the whole gives context to its parts. This understanding is crucial for comprehending the complexity of any system. In written language, this principle is exemplified by how letters form words and words form sentences, thereby giving rise to meaning through emerging part-whole systems.
- **Relationships** [6]**:** This pattern emphasizes the significance of understanding relationships between elements within a system. It involves identifying action and reaction dynamics, and how these interactions influence the overall system. This understanding is vital for analyzing cause-and-effect dynamics within any system. In written language, relations play a pivotal role in ordering and structuring letters, words, and sentences to ensure communication aligns with its intended meaning. Certain language markers function specifically to relate words or ideas and provide structure to the message, which is fundamental for delving deeper into the intended meaning.
- **Perspectives** [5]**:** This pattern involves viewing a system or a relationship from a specific standpoint. It acknowledges that our perception of a system can profoundly influence our understanding of it. Adopting different perspectives can lead to new insights and a deeper comprehension of the system's dynamics. In language, perspective taking translates into subject-object interplays. Looking for perspective patterns in a text means looking for subjects who have a particular view of the objects described in the narrative.

Each Pattern is a binary system, characterized by the interaction of two Elements. These elements can be detailed as follows:

- **Identity and Other (Distinctions):** 'Identity' defines what an element is, while 'Other' encompasses everything it is not. This distinction is crucial for understanding an element's role and place within a broader context.
- **Part and Whole (Systems):** 'Part' refers to the individual components of a system, while 'Whole' denotes the system in its entirety. This distinction is fundamental for understanding how parts function individually and how they interact to form the system.
- **Action and Reaction (Relations):** 'Action' represents an initiating force or influence, while 'Reaction' is the subsequent response or effect. This distinction is essential for examining the relational dynamics and interactions within a system.
- **Point and View (Perspectives):** 'Point' indicates the position from which an observation is made, and 'View' represents the resulting perception or interpretation. This distinction underscores the importance of considering different viewpoints in understanding and analyzing systems. In language, any text formulation should be considered as ‘a-view-from-a-point’. However it is important to differentiate a view encompassing an awareness of its subjectivity from views that don’t. On the side of the subject of this subject-object interplay, the author’s viewpoint is generally conveyed through the use of first-person pronouns. Alternatively, the viewpoint may be embedded in the narrative, reflecting the perspective of another potential observer – holder of a subjective view – within the story.

## The Interactive Loop between Reality and Mental Model

In psychology, a mental model represents an internal construct mirroring the external world, a concept pivotal in understanding cognition, reasoning, and decision-making. Kenneth Craik first introduced this in 1943 [11], suggesting that the human mind constructs 'small-scale models' of reality to anticipate future events. These models significantly influence behavior, problem-solving, and task execution, functioning akin to a ‘personalized algorithm' or ‘ego-systemic paradigm'. The influence of systemic paradigms on worldviews and sociocultural dynamics has been explored by Thomas Kuhn in his seminal theory about scientific revolutions [12]. It was subsequently explored in the field of sociocultural evolutions by theorists like Clare Graves [13], Cowan and Beck [14,15], Ken Wilber [16,17], or Frederic Laloux [18]. They, along with others focusing more on the individuals like Jean Piaget [19–22], Erik Erikson [23], Jane Loevinger [24,25], and William Torbert [26–28], have explored paradigm shifts at both collective and individual levels, and proposed a variety of theories and frameworks.

Mental models are sometimes broadly referred to as mental simulations. This term is closely related to concepts such as 'schemas', and at times, it specifically pertains to the domain of mental models in ‘reasoning’, particularly in the theory developed by Philip Johnson-Laird and Ruth M.J. Byrne [29]. Indeed, mental models play a crucial role in human reasoning, serving as internal representations constructed from perceptions, imagination, or discourse comprehension [30]. They have been proven to play an important role in behaviors, personality traits, communication, and decision making. It is worth highlighting that our study, by analyzing systemic patterns in written language and the formulation of thoughts, delves precisely into this field of discourse comprehension. It aims to enhance our understanding of how cognitive paradigms shape our discourses – whether in written or spoken forms – and how the structure of our discourses reflecting our mental models impact our interactions with the world and with others.

Research shows that mental models are structurally analogous to the situations they represent, akin to an architect's scale models or physicists' diagrams. This analogy extends to their resemblance to the 'picture theory of language' as described by Ludwig Wittgenstein in 1922 [31]. Pioneers like Philip Johnson-Laird and Ruth M.J. Byrne further advanced the theory of reasoning based on mental models, emphasizing the individual and collective reliance on these models rather than on formal logical forms. Fundamental to mental models are a set of ‘axioms’ – relatively equivalent to mental algorithm or cognitive system’s paradigm [32] – that distinguish them in the psychology of reasoning [33]. They operate on a principle of truth, typically signifying feasible situations and truth within a given possibility, though they can also represent false assumptions temporarily held as true, as seen in counterfactual thinking [34]. In reasoning with mental models, people infer validity if a conclusion holds across all possibilities. The reasoning process involves using counterexamples to refute invalid inferences and confirming validity by ensuring the conclusion is consistent across all models of the premises. Theoretically, a conclusion should be rejected if a counterexample is found. However, cognitive biases demonstrate that this is generally not the case.

Karl Friston's Active Inference Theory and the Free Energy Principle deepen the understanding of the inference process [35–37]. They show that the inference-feedback loop is strongly influenced by energy balance assessment and bayes-optimal calculations. Friston's Active Inference Theory posits that the brain updates mental models to minimize discrepancies between expected and actual experiences, resonating with double-loop learning principles[5]. The Free Energy Principle highlights the brain's effort to reduce uncertainty, balancing existing model stability with necessary adaptation.

In conclusion, the interplay between mental models, learning processes, and environmental factors is crucial in human cognition. This dynamic is exemplified by a cyclic process that intertwines Mental Models with Real World, involving feedback loops (Figure 2). The DSRP patterns are instrumental within this loop, elucidating how DSRP functions contribute to the construction of both the Real World and Mental Models. This process governs the emergence of complexity in both nature and the mind. Within the DSRP framework, this dynamic process is referred to as the ST/DSRP loop [10].

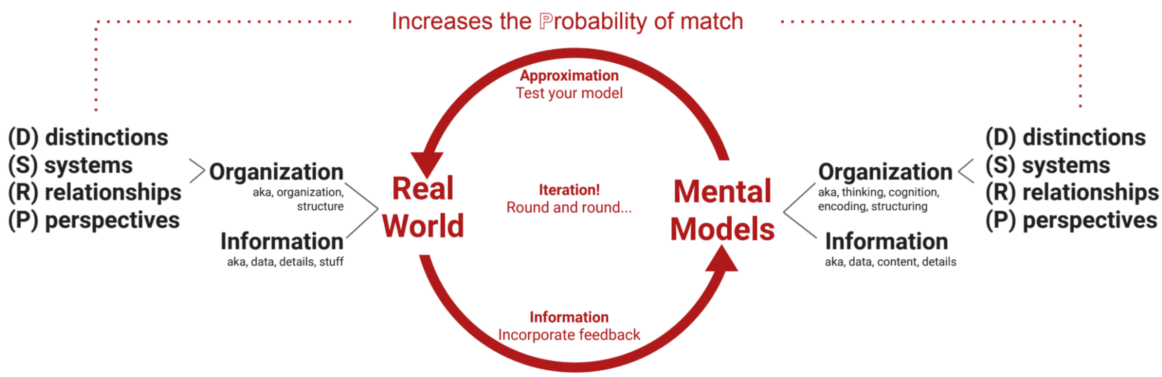


Figure 2: The ST/DSRP Loop.

## Prior Research in Existence and Effectiveness of DSRP Model

Over 25 years since its inception, the DSRP model has become a pivotal framework in systems thinking, with more empirical evidence supporting its effectiveness than any other systems thinking framework. In numerous publications, Derek and Laura Cabrera discuss the manifold implications of this pioneering model, while acknowledging that its impact on the evolution of systems thinking is still in its early stages [8].

Compared to all the other existing theories of systems thinking, DSRP theory has exponentially more empirical research supporting it. To start, Cabrera et al. 's 2021 literature review of research [40] demonstrates the existence of DSRP in nature. This review was done on 129 peer-reviewed papers and concluded that both the individual patterns of DSRP (D, S, R, & P) and DSRP theory exist in mind and nature. The publications reviewed spanned many disciplines and methodologies. The breadth of disciplines demonstrated that DSRP Theory can be applied to all disciplines, making it uniquely situated as a universal theory of cognition.

Along with the extensive literature review, an ecology of studies was done across 5 publications to empirically examine the existence and the efficacy of DSRP Theory. The first publication explored the

[5] The Double-loop Learning model was theorized by Chris Argyris in the early 90’ [38,39]. It claims that single-loop learning is a process where decisions change, but the underlying mental models do not. Double-loop learning necessitates a transformation of the mental models themselves. The double-loop approach is more dynamic and comprehensive, accounting for changes in the environment and the consequent need for alterations in mental models. Unlike single-loop learning, double-loop learning involves a fundamental shift in understanding. These learning processes are integral to how mental models are developed and modified, moving from a static perspective to a more fluid and adaptable one.

existence and efficacy of the Distinction pattern [4]. Seven individual experiments were performed to examine the Distinction pattern. With an N = 407, the ecology of studies concluded that ultimately, identity-other Distinctions exist and are effective. For a full summary of the conclusions, see Table 1. All conclusions were highly statistically significant.

| **Distinction (D) Studies Conclusions** | **Summary** |
|---|---|
| Globally and universally, identity-other distinctions exist. | $D_o^i$ exists. |
| Contrary to prevailing belief, things are defined not solely by their essence or accepted definitions, but also in relation to the *other* things they are with. | $D_o^i$ is relative. |
| Distinctions are made at the individual and collective level. | $D_o^i$ is universal. |
| At the individual level, people make a diversity of distinctions, collectively, they see things similarly. | In a pool of difference, we distinguish similarly. |
| We use: different names for different things; different names for the same things; same names for different things; and same names for the same things. | Left implicit, D confuses, made explicit D clarifies. |
| Cognitively speaking, there is a parallel invisible universe of not-things which provide the 'ether' for defining everything. | Negated identities matter. |
| Unstructured, people have a hard time getting their thinking started. | D-rule jump starts thinking. |
| Identity-other are both part-whole systems of is's and is-not's. | D is S-dependent. |
| We also know that the other is an identity. | $i$ and $o$ are interchangeable. |
| D-rule is dependent on S, R and P rules, and S, R and P rules are dependent on D-rule. | DSRP is massively parallel and fractal. |
| The more tangible and explicit things are, the easier it is for people to make identity-other Distinctions. People miss things when they are not tangible/explicit, which is a lot. | Awareness of D-rule decreases bias. |
| We know what people do and don't do that can help us improve thinking. Namely: Rarely consider the other; People rarely challenge existing distinctions; Rarely validate. | Awareness of D-rule improves thinking. |
| People have greater confidence than competence in Distinction making. | We are overconfident with $D_o^i$ |
| A relatively short treatment in D-rule can dramatically affect cognitive ability and complexity. | "D-rule" makes you smarter. |

Table 1: Adapted from [4].

The second publication explored the existence and efficacy of the Systems pattern [3]. Seven individual experiments were performed to examine the Systems pattern. With an N = 407, the ecology of studies concluded that ultimately, part-whole Systems exist and are effective when given a short treatment. For a full summary of the conclusions, see Table 2. All conclusions were highly statistically significant.

| Systems (S) Studies 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 don't challenge preexisting part-wholes; they don't scale up (+1) and down (-1); they don't 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. |

Table 2: Adapted from [3].

The third publication explored the existence and efficacy of the Relationships pattern [6]. Seven individual experiments were performed to examine the Relationships pattern. With an N = 407, the ecology of studies concluded that ultimately, action-reaction Relationships exist and are effective when given a short treatment. For a full summary of the conclusions, see Table 3. All conclusions were highly statistically significant.

| Relationships (R) Studies Conclusions | Summary |
|---|---|
| Globally and universally, action-reaction relationships exist. | $R_r^a$ exists. |
| Contrary to prevailing belief, things are defined not solely by their essence or accepted definitions, but also in relation to the *other* things they are with. Distinctions are relational. People define things relative to other things. | Meaning is literally, *relative*. |
| Relationships are made at the individual and collective level. | $R_r^a$ is universal. |
| At the individual level, people make a diversity of relationships, collectively, they see things similarly. | In a pool of difference, we relate things similarly. |
| Whenever two things share the same physical or conceptual space they have a potential for a relationship. This has big implications for bias, teaching & learning, marketing manipulation, etc. | Metacognition of R matters. |
| In the process of making Distinctions, people rely on relationships. The way they make relationships changes the Distinction they make. The relationality of ideas and objects can completely transform the ideas and objects. | Relationships are *transformative*. |
| Every relationship has an *action* and *reaction* variable where idea or object A has an A-like action on B; and vice versa. | I am a relationship. Hear me Rar. ($R_r^a$) |
| R-rule is dependent on D, S and P rules, and D, S and P rules are dependent on R-rule. | DSRP is massively parallel and fractal. |
| We know what people do and don't do with Relationships that can help us improve thinking. Namely: Rarely distinguish relationships; rarely challenge existing relationships; rarely systematize relationships; rarely think in webs of causality. | Awareness of R-rule improves thinking. |
| People have greater confidence than competence in seeing and making Relationships. | We are overconfident with $R_r^a$ |
| A relatively short treatment in R-rule can dramatically affect cognitive ability and complexity. | "R-rule" makes you smarter. |

Table 3: Adapted from [6].

The fourth publication explored the existence and efficacy of the Perspectives pattern [5]. Seven individual experiments were performed to examine the Perspectives pattern. With an N = 407, the ecology of studies concluded that ultimately, point-view Perspectives exist and are effective when given a short treatment. For a full summary of the conclusions, see Table 4. All conclusions were highly statistically significant.

| **Perspectives (P) Studies Conclusions** | **Summary** |
|---|---|
| Globally and universally, point-view perspectives exist. Every perspective has a *point* and *view* variable. | $P_v^\rho$ exists and is universal. |
| When we change the perspective, we change the distinctions, systems and relationships that we see. Perspective can cause people to see things that are not visible. Perspectives are not static. They can change when the context in which they occur changes. And, they can change the context. | Perspective is *transformative*. |
| P-rule is dependent on D, S and R rules, and D, S and R rules are dependent on P-rule. | DSRP is massively parallel and fractal. |
| When a perspective aligns with our own it is easier to take. When a perspective does not aligns with our own it more difficult to see. | Metacognition of P matters. |
| Perspective plays a role in choice. The act of choice *requires* an act of Perspective taking. Provided a perspective, people are able to choose, find, discover the answer faster. Without a perspectival filter, they have more difficulty. | Awareness of P-rule aids decisions/choices. |
| Explicit use of perspectives can be used to *constrain* or *expand* thought. | P-rule *governs* convergent or divergent thinking. |
| We know what people do and don't do with Perspectives that can help us improve thinking. Namely: Rarely make perspectives explicit; rarely take multiple perspectives; rarely take conceptual perspectives. | Awareness of P-rule improves thinking. |
| People have greater confidence than competence in perspective taking. | We are overconfident with $P_v^\rho$ |
| People take both conceptual and physical perspectives but have more difficulty with conceptual ones. This difficulty limits their cognitive flexibility. | Increasing conceptual perspective taking increases cognitive flexibility. |
| Perspectives are made at the individual and collective level. At the collective level, the "wisdom of the crowd" emerges such that many perspectives are covered. We could improve individual cognition if we mimic the perspective-taking of this collective action. | P-rule is a powerful cognitive tool. |
| A relatively short treatment in P-rule can dramatically affect cognitive ability and complexity. | "P-rule" makes you smarter. |

Table 4: Adapted from [5].

The last publication was designed specifically to test the efficacy of a short DSRP treatment. With a total N = 1,400, the study [2] demonstrated that a short (less than one minute) treatment on DSRP greatly and significantly improved the cognitive complexity of the participant's responses. The paper concluded as follows:

"We can conclude that:

1. people trained in Distinction-making will have more detailed and specific thoughts, whereas;
2. people trained in Systems-organizing will create more hierarchical structures and scale their thoughts up and down past the visual/conceptual question;
3. people trained in Relationship building will create and identify more and better interrelationships, and;
4. people trained in seeing Perspectives will see the stimulus from multiple points of view. [2]"

## 1.2. Language: a systemic reflection of mental models

Behaviors are part of systems' outputs, and it has been proven that mental models significantly contribute to shaping behaviors [41]. Therefore, a particular behavior reflects the paradigm of the system that produces it. In this study, we focus on language in its written form as a human behavior, asserting that the structure of our thought formulations reflects the structure of our mental models.

Written language can be analyzed as a system. Using the network theory framework, some instances in language correspond to 'nodes', representing the solid building blocks of meaning, while others act as 'edges', describing how the nodes connect. Since the early publications of the DSRP Theory, network frameworks have been used to illustrate the model. Typically, nodes represent Distinctions (Di or Do), and edges represent Relations (Ra or Rr). A set of related nodes forms a network where nodes represent Parts (Sp), and the complete network represents a Whole (Sw). A network model of 'something' or 'a process' is a system involving a perspective (Pꞵv). The entire network is a subjective view from a viewpoint, with the distinctions defining each element involving many boundary distinctions related to a subjective view (Pv) and a viewpoint (Pꞵ) of an observer.

Network approaches provide a useful framework for analyzing language. The parallelism between Network Theory and DSRP facilitates the interpretation of language as a manifestation of DSRP patterns. A specific protocol was developed for this study to relate instances of written language to DSRP elements, enabling the determination of the most relevant DSRP element for each language instance (see Section 3.2). This protocol facilitates the identification of DSRP elements in a script. The process of counting each element in a text, which we have termed 'DSRP-scoring', defines the DSRP profile of the script. Analyzing the DSRP profiles of a set of texts allows us to determine the DSRP patterns and elements of the script and thus infer the author's systems thinking DSRP pattern within the study context.

According to the 'even-distribution-principle' detailed in Section 5.3, the more evenly distributed the different variables are, the higher the degree of parallelism between the model and the real world. Conversely, a more uneven distribution of DSRP patterns indicates a more 'biased' systems thinking process.

# 2. Objectives of the Study and Hypotheses

## 2.1. Background and Hypothesis

Cabrera has reported that a strong hypothesis born of anecdotal experience is that there is bias in the normative use[6] of the elements. Cabrera states, "although we don't have specific empirical evidence yet of the clear bias to highlight certain elements and lowlight others, it is clear to me that such a bias exists[7]."

We propose that an individual's relationship to systems thinking often deviates from an ideal balanced model, leading to identifiable biases. The primary objective of this study is to empirically establish the presence of biases in individuals' cognitive complexity, based on the DSRP patterns revealed by their thought's formulations. Secondly, it aims to determine if such biases are mitigated through DSRP

[6] Where "use" in this case is defined by the explicit, purposeful, conscious creation of the structural pattern.
[7] Cabrera, personal communication, June 2023

training. This study seeks to quantify these deviations and lay the groundwork for a theory of common biases in systems thinking.

Our methodology involved analyzing participants' written language to determine the most probable DSRP patterns/elements to which their language markers best relate to, when they describe ‘What they think’ contemplating specific images.

The general hypothesis of this study is that systems thinking is biased in practice, implying that it does not respect the normative distribution of the different components of a theoretically balanced system. This general hypothesis was broken down into three analytical hypotheses (H), each with a null hypothesis ($H_N$), with statistical significance set at $p < 0.05$:

1. **Hypothesis H1:** We posited that within each pattern, certain elements (Identity, Part, Action, and View) would be represented more frequently than their counterparts (Other, Whole, Reaction, Point). The null-hypothesis is that there would be no significant differences between elements in each DSRP pattern, such that the bias between paired-base elements ($B_{\mathbb{E}}$) is:

$$\textbf{H1: } B_{\mathbb{E}} = (Di >> Do; Sp >> Sw; Ra > Rr; Pv > P\beta)$$

$$\textbf{H}_{\textbf{N}}\textbf{1: } B_{\mathbb{E}} = (Di \equiv Do; Sp \equiv Sw; Ra \equiv Rr; Pv \equiv P\beta)$$

1. **Hypothesis H2:** We hypothesized that the Distinctions pattern of the DSRP model would be the most represented cognitive pattern. We hypothesized that the activation of Distinctions would be significantly higher than Systems, Systems higher than Relations, and Relations higher than Perspectives[8]. The first null-hypothesis is that there would be no significant differences between the occurrence of Distinctions, Systems, Relations, and Perspectives, such that the bias between DSRP patterns ($B_{\mathbb{P}}$) is:

$$\textbf{H2: } B_{\mathbb{P}} = (Dio >> Spw > Rar > P\beta v)$$

$$\textbf{H}_{\textbf{N}}\textbf{2: } B_{\mathbb{P}} = (Dio \equiv Spw \equiv Rar \equiv P\beta v)$$

1. **Hypothesis H3:** We further hypothesized that DSRP training would reduce these biases (both $B_{\mathbb{P}}$ and $B_{\mathbb{E}}$). The null-hypothesis is that there would be no significant difference between biases in the trained population ($I_T$) versus the untrained ($I_U$), such that:

$$\textbf{H3: } B_{\mathbb{P}}\, B_{\mathbb{E}}\, (DSRP\text{-}I_T) < B_{\mathbb{P}}\, B_{\mathbb{E}}\, (DSRP\text{-}I_U)$$

$$\textbf{H}_{\textbf{N}}\textbf{3: } B_{\mathbb{P}}\, B_{\mathbb{E}}\, (DSRP\text{-}I_T) \equiv B_{\mathbb{P}}\, B_{\mathbb{E}}\, (DSRP\text{-}I_U)$$

Hypotheses H1 and H2 are summarized on Table 5a and 5b.

| Pattern | Element 1 | Bias Hypothesis | Element 2 |
|---|---|---|---|
| Distinctions | identity | >> | other |
| Systems | part | >> | whole |
| Relations | action | > | reaction |
| Perspectives | point | < | view |

Table 5a: Hypothesis for DSRP Element Biases

[8] The terms ‘higher’ respectively ‘much higher’ require clarification: they refer to orders in t-test values. ‘Higher’ means a t-test where $Pr(T>t) \leq 0.05$ (figured >), and ‘much higher’ to t-test where $Pr(T>t)<0.01$ (figured >>).

| Ranked 1 | Bias | Ranked 2 | Bias | Ranked 3 | Bias | Ranked 4 |
|---|---|---|---|---|---|---|
| Distinctions | >> | Systems | > | Relations | > | Perspectives |

Table 5b: Hypothesis H2 for DSRP Pattern Biases

## 2.2. Objectives

In this study, we propose that an individual's preference for certain cognitive patterns and elements over others is a reflection of their personality traits. These traits shape their mental models of the world, subsequently influencing their behaviors and decisions. Our primary aim is to elucidate these biases in systems thinking, comparing them against the ideal model of balanced activation of DSRP patterns and elements. Our study is driven by a fivefold objective:

1. To confirm the existence of biases in systems thinking by utilizing the DSRP model as a diagnostic tool.
2. To investigate whether systems thinking patterns in mental model formulations can be quantitatively measured using the DSRP Model.
3. To verify that the distribution of DSRP patterns and elements in mental model formulations is uneven.
4. To identify and elucidate common patterns of bias within systems thinking.
5. To explore key factors that could minimize biases in systems thinking.

# 3. Materials and Methods

## 3.1. Cohort and Data Collection

The study cohort comprised 27 volunteers, recruited from an initial pool of approximately 60-80 contacts, with no specific selection criteria. An invitation to participate in the study was extended to these contacts, and the respondents constituted the final participant group. Participants spanned a range of demographics and were asked to categorize themselves based on seven characteristics: Country of origin, Country of residence, Gender, Language, Age group, Education, and DSRP awareness. While DSRP training status (level of DSRP awareness) was a crucial factor for the study, other demographic information was collected as supplemental data (see Table 6 for demographics).

| Gender | | Language | | Age group | | Education | | DSRP awareness | |
|---|---|---|---|---|---|---|---|---|---|
| Female | 11 | ENG | 12 | 15-29 | 2 | Doctorate | 3 | High | 7 |
| Male | 16 | FR | 15 | 30-44 | 7 | Master's | 10 | Middle | 7 |
| Other | 0 | | | 45-59 | 14 | Bachelor's | 6 | Low | 4 |
| | | | | 60-74 | 4 | Secondary | 3 | Not familiar | 9 |
| | | | | | | Other | 5 | | |
| Total | 27 | | 27 | | 27 | | 27 | | 27 |

Table 6: Population characteristics distribution.

For data collection, participants were directed to a Google Form structured in three stages. Initially, the form provided an introduction, explaining the context and purpose of the study. Subsequently, participants were shown sequentially two images: the first, a simple object to gauge basic cognitive responses, and the second, a more complex scene depicting social interactions, to examine the influence of image complexity and human elements on systems thinking (Figure 3). For each image, participants were instructed to "Describe what you think!" allowing them to freely formulate their thoughts. After responding to both images, participants were thanked for their contribution and invited to provide demographic information. The responses were kept anonymous, ensuring privacy and confidentiality. Participants interested in the study's outcomes had the option to leave their email addresses for further communication. A total of fifty-four responses (n=54) were collected and analyzed.


Figure 3: Images presented to study participants.

## 3.2. Scoring Methodology

Twenty-seven participants (N=27) contributed to the study, with fifteen responding in French ($N_{fr}$=15) and twelve in English ($N_{en}$=12). The French responses were translated into English using DeepL translator application.

The development and application of the analysis protocol involved a multi-stage process, beginning with the first author presenting an initial version to Derek Cabrera, the originator of the DSRP model. Through iterative feedback and refinement, a consensus was reached on the initial protocol. This version was then subjected to practical testing by the first author, a co-evaluator, and a critical observer, using sample responses generated by the first author and ChatGPT. This practice highlighted various questions and identified ambiguities in the initial variable definitions, leading to an in-depth review and subsequent updates to the protocol. Following these improvements, the finalized protocol was applied by the first author and the co-evaluator to assess the study responses. The training process for the co-evaluator was thorough, ensuring a high degree of inter-scorer reliability. This ensures a clear, standardized approach to scoring the presence of DSRP elements in participants' responses. The analysis framework was enhanced by integrating concepts of 'Nuanced perspectives' and ‘Interactions’ in language markers (see Section 3.3). ‘Nuanced perspectives’ address the recognition of participants' awareness of their viewpoint's relativity, articulated as understanding one's perspective as one among many. This is a form of perspective taking that transcends a mere point or view. ‘Interactions' refer to verbs that embody combined action and reaction.

The peer review process of the protocol involved substantial contributions from Derek Cabrera and additional insights from Laura Cabrera. Their expertise was instrumental in reinforcing the protocol's validity and ensuring its alignment with the DSRP model's theoretical constructs. The finalized protocol, while briefly described here, is more comprehensively detailed in the following section.

## 3.3. Protocol for Identifying DSRP Patterns and Elements

**Distinctions (Dio)** are identified through language that indicates differentiation between fixed items in mental representations, analogous to nodes in network theory. We consider nouns, pronouns, and their attributes (adjectives or complements that add information to the distinction) as markers of Distinctions.

A priori, a distinction is categorized as an 'Identity' (Di). This classification changes to ‘Other’ (Do) if the distinction relates to, and distinguishes itself from, a prior identity. Such distinctions may either reinforce the ontology of the prior identity or abstractly define their own ontology. Distinctions defined by the absence of an identity are likewise categorized as 'Other'. A Distinction is considered as 'Other' if it defines:

- The context of a prior identity, for example, a tomato being classified as “a fruit”,
- The environment of a prior identity, such as four people “in a classroom”,
- A complementary, opposite, or inverse distinction that refers to a prior identity, together forming an implicit or explicit set. For instance, a man being congratulated by “another man”; shaking hands with the right hand and patting the shoulder with “the left hand”; a “negative atmosphere” - implying the existence of a positive in the context,
- The absence of an identity, as in scenarios where “no logos” are visible.

**Systems (Spw)** patterns emerge when language articulates the partitioning of a Distinction into parts, or the assembly of multiple Distinctions into a whole. If the evaluator deems the network pattern 'clear', each Distinction within the pattern is constituted as a 'Part' (Sp). Conversely, if a Distinction encompasses other distinctions, it is characterized as a 'Whole' (Sw).

**Relations (Rar)** patterns emerge when linguistic markers denote interactions between Distinctions. This emergence necessitates the formulation of an ‘Action’ (Ra) or a ‘Reaction’ (Rr), both originating from a distinction. Within language, actions and reactions are typically represented by verbs. The Rar pattern becomes apparent when an action and a reaction are explicitly linked, manifesting a cause-effect relationship. Additionally, language includes verbs that inherently express interactions, such as in instances of sharing or celebrating together. This observation has led us to introduce an additional variable, designated as Ri, to account for interactive verbs. Consequently, the Relations pattern is defined as Rtot, encompassing the sum of Ra, Rr, and Ri.

**Perspectives (Pþv)** patterns manifest in language through expressions that denote a viewpoint, encompassing 'Point' (Pþ) and 'View' (Pv). A Point is identified when language specifically refers to an observer or a distinct standpoint. This is typically evident when a response mentions an observer — either the respondent or another individual — who perceives or interprets a particular situation.

Any mental model of reality expressed in language may be regarded as a View. However, in the Perspectives pattern, the emphasis lies in recognizing and acknowledging the subjectivity inherent in this view, which originates from a point. To encompass the full breadth of perspective-taking in language, we have introduced the concept of language markers expressing nuances. Nuancing a perspective means that in expressing a view, there is an acknowledgment of uncertainty or alternative possibilities. Even in the absence of an explicit Point or View, this notion highlights instances where respondents show an understanding of the relativity of their viewpoints. They recognize that their perspective is just one among many, denoting a deeper contemplation on the complex nature of situations. 'Nuanced Perspectives' (nPϐv) were analyzed in our study and the variable considered as co-implying an explicit view.

In our analysis, a response is deemed an explicit View only if it conveys a viewpoint, or when it is presented alongside alternative or nuanced perspectives. This suggests an awareness of multiple viewpoints or an acknowledgment of the respondent's perspective as one among various possibilities.

## 3.4. Variables Analyzed

The analytical process distilled participants' responses into thirteen distinct variables, each corresponding to a manifestation of a reference to one of the elements of the DSRP model's four patterns: Distinctions, Systems, Relations, and Perspectives. The variables are as follows:

- Di: The occurrence of an Identity formulation within Distinctions.
- Do: The occurrence of an Other formulation within Distinctions.
- Dio: The total Distinctions pattern, calculated as the sum of Di and Do. Dio is a dependent variable.
- Sp: The articulation of a Part within a System.
- Sw: The articulation of an explicit Whole within a System.
- Spw: The total Systems pattern, representing the sum of Sp and Sw. Spw is a dependent variable.
- Ra: The expression of Active-agency within Relations.
- Rr: The expression of Reactive-agency within Relations.
- Ri: The expression of an Interactive-agency or the depiction of action-reaction loops within Relations.
- Rtot: The total Relations pattern, encompassing Ra, Rr, and Ri. Rtot is a dependent variable.
- Pϐ: The articulation of a Point within Perspectives.
- Pv: The articulation of an explicit View within Perspectives.
- Pϐv: The total Perspectives pattern, consisting of Pϐ and Pv. Pϐv is a dependent variable.

Each response was independently scored for these variables by both the author and a co-evaluator. The final analysis utilizes the average scores from their separate evaluations to ensure objectivity and reliability.

# 4. Results

## 4.1. Summary of Descriptive Statistics

This subsection presents an overview of the descriptive statistical analysis performed on our dataset. Notably, our dataset was fully intact with no missing entries, yielding comprehensive results. A total of 54 valid responses were analyzed across nine independent variables (Di, Do, Sp, Sw, Ra, Rr, Rar, Pϐ, Pv) and four dependent variables (Dio, Spw, Rtot, Pϐv). This amounted to a significant dataset of 621 data points pertaining to language elements associated with DSRP elements. Detailed summaries and full descriptive statistics can be found in Table 7a and Table 7b.

| | Total | Std. err. | [95% conf. interval] | |
|---|---|---|---|---|
| Dio | 321 | 44.82229 | 231.0979 | 410.9021 |
| Spw | 170.5 | 37.67218 | 94.93917 | 246.0608 |
| Rtot | 80.5 | 19.11842 | 42.1533 | 118.8467 |
| Ppv | 49 | 10.22114 | 28.49899 | 69.50101 |
| Di | 280 | 33.19724 | 213.4148 | 346.5852 |
| Do | 41 | 15.11965 | 10.67383 | 71.32617 |
| Sp | 122.5 | 27.49279 | 67.35644 | 177.6436 |
| Sw | 48 | 10.86365 | 26.21028 | 69.78972 |
| Ra | 44 | 10.76069 | 22.41679 | 65.58321 |
| Rr | 26 | 8.652625 | 8.645031 | 43.35497 |
| Ri | 10.5 | 3.303086 | 3.874848 | 17.12515 |
| Pp | 13.5 | 3.328692 | 6.82349 | 20.17651 |
| Pv | 35.5 | 8.101071 | 19.25131 | 51.74869 |

Table 7a: Summary of variable occurrence.

| Variable | Obs | Mean | Std. dev. | Min | Max |
|---|---|---|---|---|---|
| Dio | 54 | 5.944444 | 6.099541 | 1 | 39 |
| Spw | 54 | 3.157407 | 5.126535 | 0 | 29 |
| Rtot | 54 | 1.490741 | 2.601688 | 0 | 13.5 |
| Ppv | 54 | .9074074 | 1.390921 | 0 | 6 |
| Di | 54 | 5.185185 | 4.517572 | 1 | 24.5 |
| Do | 54 | .7592593 | 2.057524 | 0 | 14.5 |
| Sp | 54 | 2.268519 | 3.741296 | 0 | 21.5 |
| Sw | 54 | .8888889 | 1.478355 | 0 | 7.5 |
| Ra | 54 | .8148148 | 1.464344 | 0 | 7 |
| Rr | 54 | .4814815 | 1.177473 | 0 | 5.5 |
| Ri | 54 | .1944444 | .4494931 | 0 | 2 |
| Pp | 54 | .25 | .4529776 | 0 | 1.5 |
| Pv | 54 | .6574074 | 1.102416 | 0 | 5 |

Table 7b: Variable Means and Distributions.

## Distinctions, Identity, and Other

In our analysis of the Distinctions pattern (Dio), comprising the elements of Identity (Di) and Other (Do), we observed the following occurrences: Identity (Di) was recorded 280 times in participants' responses, whereas Other (Do) appeared 41 times. On average, there were 5.19 instances of Identity and 0.76 instances of Other per response, with an overall average of 5.94 Dio per response.

About a quarter (24.1%) of the responses encapsulated a 'singular' Dio, that is, the formulation of only one distinction and nothing else. The remaining data exhibited a range of 2 to 12 Dio per response, with three responses exceeding this range (see Figure 4a). One third (33.3%) encapsulated only Dio's and any other patterns. When comparing occurrences by the ImageID (split analysis according to image), a lower average Dio for Image 1 (mean Dio=5.13) than for Image 2 (mean Dio=6.76) was observed, yet this variation was not statistically significant. It is, however, notable that Image 1 more frequently elicited a singular Dio (in approximately 33% of cases) as opposed to Image 2 (about 15% of cases), as shown in Figure 4b.

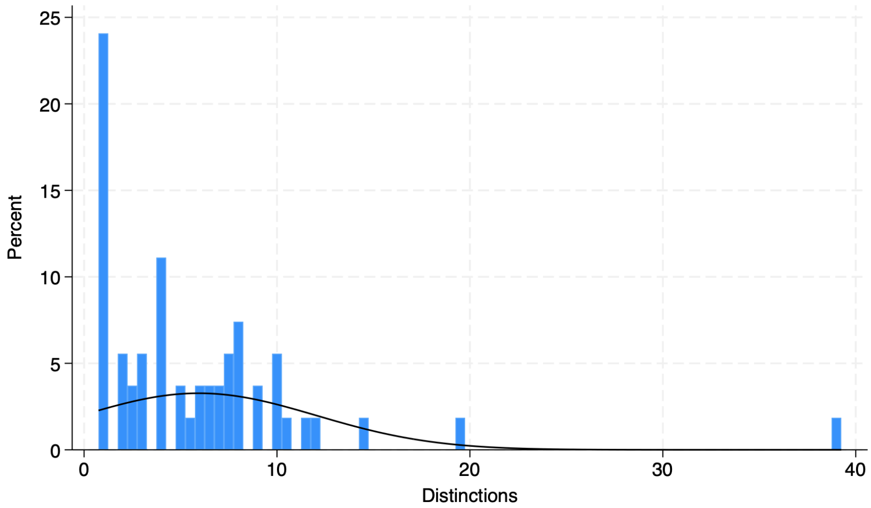


Figure 4a: Distribution of Distinctions (Dio) per response.

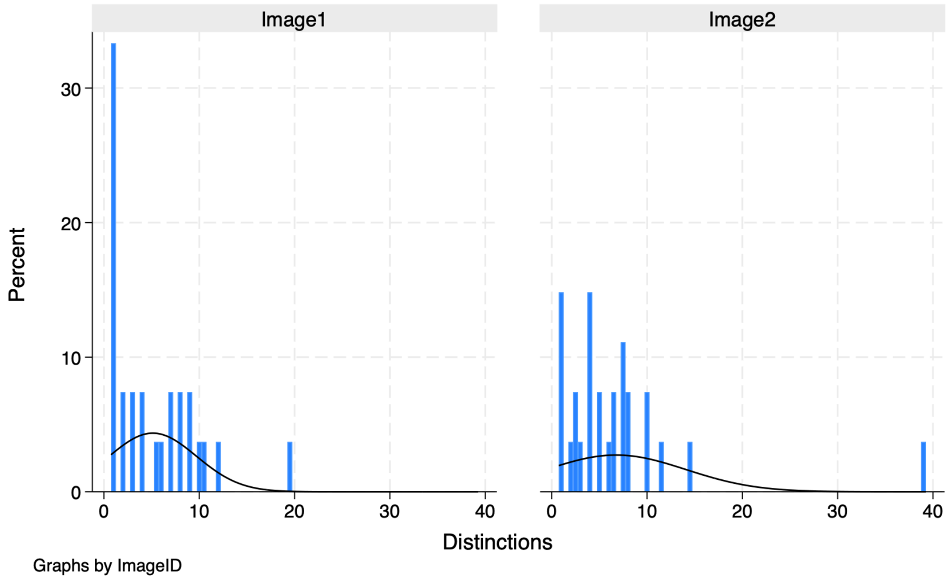


Figure 4b: Distribution of Distinctions (Dio) per response by ImageID.

## Systems, Part, and Whole

In the Systems pattern (Spw), which focuses on the interaction between Parts (Sp) and Whole (Sw) within a system, we found that responses included 122.5 mentions of Sp and 48 mentions of Sw. This resulted in an average of 2.27 Sp and 0.89 Sw per response, with an average of 3.16 Spw per response. An analysis of Spw distribution by ImageID did not reveal any significant differences. Notably, nearly 40% of responses contained no Systems pattern (Spw=0), as shown in Figure 5.

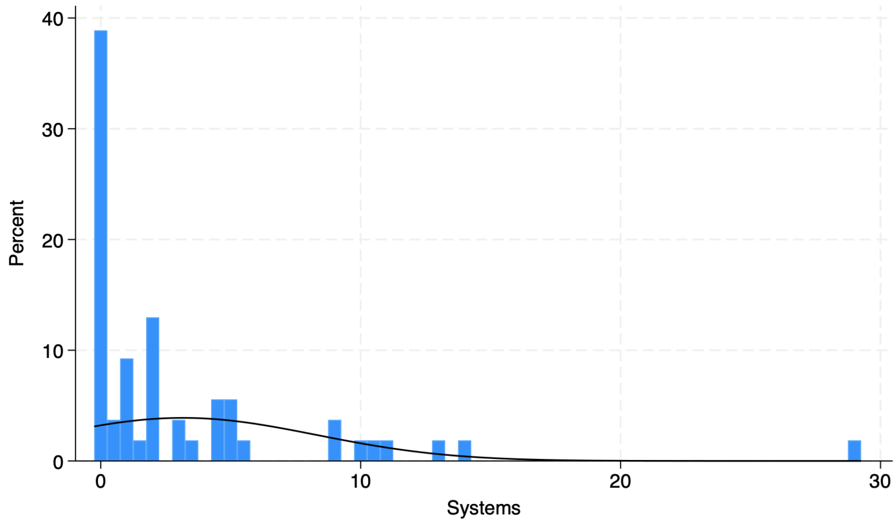


Figure 5: Distribution of Systems (Spw) per response.

## Relations, Action, Reaction, and Interaction

The Relations pattern (Rtot) in our study, which examines the dynamics of Active-agency (Ra), Reactive-agency (Rr), and Interactive-agency (Ri), was identified a total of 80.5 time, encompassing 44 instances of Active-agency (Ra), 26 of Reactive-agency (Rr), and only 10.5 of Interactive-agency (Ri). On average, responses exhibited 1.49 Rtot, broken down to 0.81 Ra, 0.48 Rr, and 0.19 Ri per response.

Over half of the responses (53.7%) did not express any form of agency (Rtot=0) as shown on Figure 6a. This absence was more pronounced for Image 1, where 66.6% of responses lacked agency, compared to 40.7% for Image 2. However, the difference between images was not statistically significant (Figure 6b).

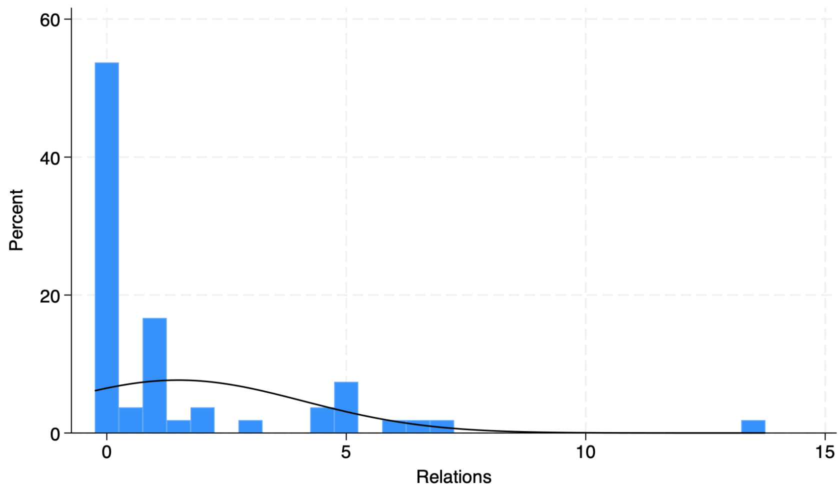


Figure 6a: Distribution of Relations (Rtot) per response.

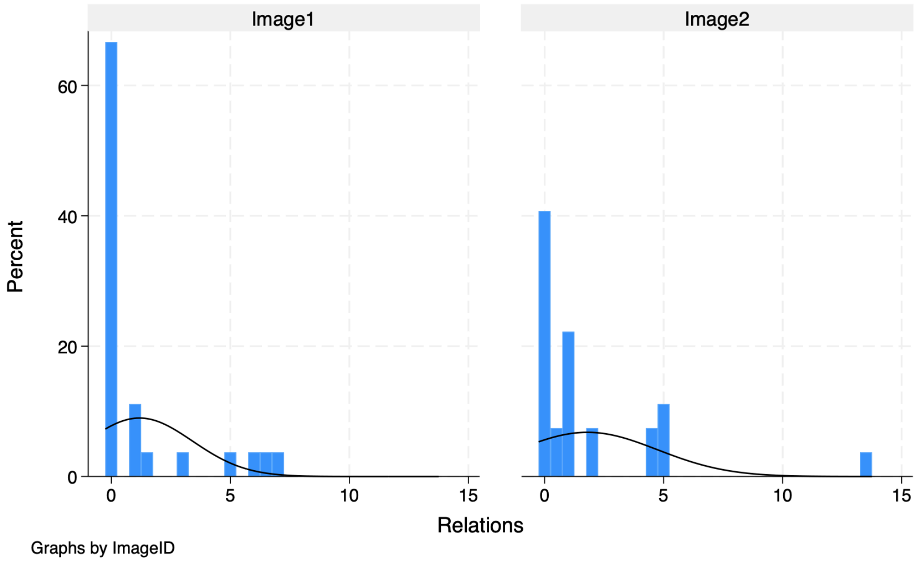


Figure 6b: Distribution of Relations (Rtot) per response by ImageID.

## Perspectives, Points, and View

Our findings for the Perspectives pattern (Pϐv), which entails the Points (Pϐ) and the Views (Pv), showed a total of 49 occurrences. This included 13.5 instances of Points (Pϐ) and 35.5 instances of Views (Pv). On average, Points of perspective were formulated in one out of every four responses (mean Pϐ=0.25), whereas an explicit View was identified more frequently, with an average occurrence of 0.66 per response (mean Pv=0.66). Consequently, the average occurrence of the Perspectives pattern stood at 0.91 per response (mean Ppv=0.91).

The distribution of Ppv did not show a statistically significant difference when analyzed by ImageID. Nonetheless, Image 1 was associated with a marginally higher frequency of null Ppv responses compared to Image 2. In general, 61.1% of the responses did not engage in perspective-taking (Figures 7a and 7b).

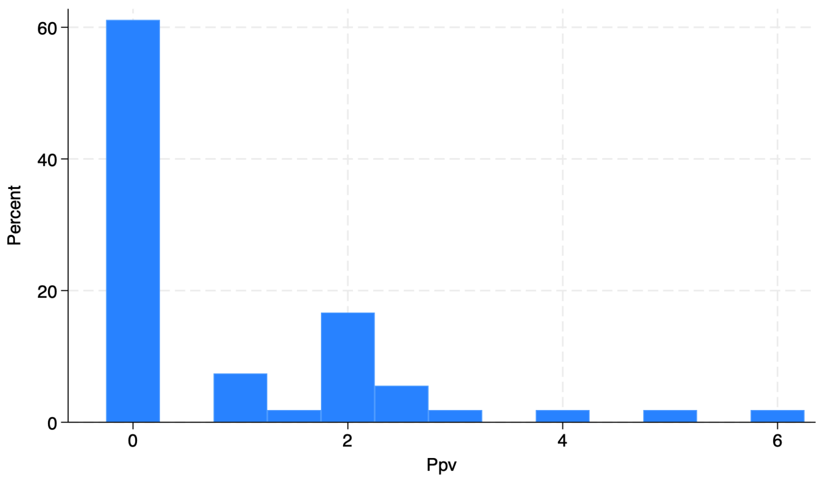


Figure 7a: Distribution of Perspectives (Pϐv) per response.

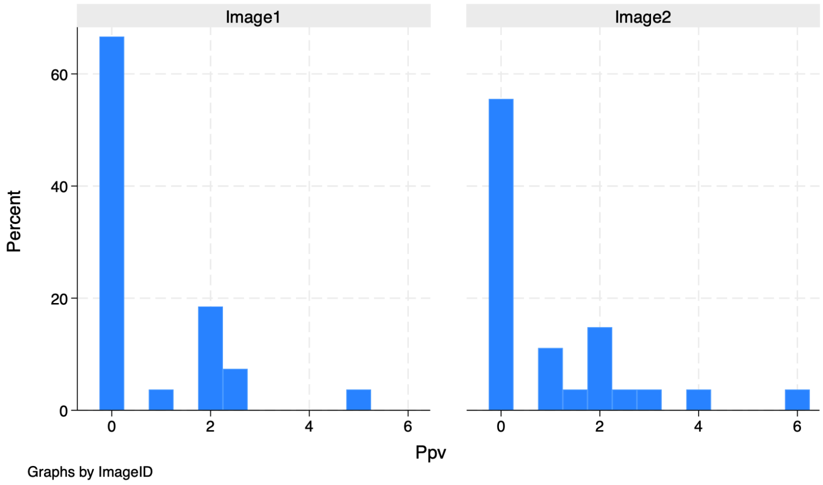


Figure 7b: Distribution of Perspectives (Ppv) per response by ImageID.

## 4.2. Observations about DSRP Element Biases

Pairwise mean-comparison t-tests were conducted to compare the mean occurrence of elements within the DSRP patterns (Di-Do; Sp-Sw; Ra-Rr-Ri; Pþ-Pv). The results, at a significant level of $p<0.05$, reveal the following:

- Di occurs more frequently than Do.
- Sp occurs more frequently than Sw.
- Ra and Rr have similar frequencies, both significantly higher than Ri.
- Pv occurs more frequently than Pþ.

A detailed summary of these mean-comparison tests among DSRP Elements is provided in Table 8.

| *Variable 1* | *Mean* | *Bias* | *Variable 2* | *Mean* | *Pr (T>t)* | *Bias confirmation* |
|---|---|---|---|---|---|---|
| *Di* | *5.19* | *>>* | *Do* | *0.76* | *0.0000* | *Yes* |
| *Sp* | *2.27* | *>* | *Sw* | *0.89* | *0.0066* | *Yes* |
| *Ra* | *0.81* | *≡* | *Rr* | *0.48* | *0.0976* | *No* |
| *Ra* | *0.81* | *>>* | *Ri* | *0.19* | *0.0018* | *Yes* |
| *Rr* | *0.48* | *>* | *Ri* | *0.19* | *0.0486* | *Yes* |
| *Pv* | *0.66* | *>>* | *Pp* | *0.25* | *0.0068* | *Yes* |

Table 8: Pairwise mean-comparison t-tests between opposed DSRP elements.

## 4.3 Observations about DSRP Pattern Biases

Our study shows that there are differences in the occurrence of patterns of the DSRP in thoughts' formulations. The most frequently observed pattern is Distinctions (Dio) with a mean occurrences per response of 5.94, followed by Systems (Spw) with 3.16 occurrences, Relations (Rtot) with 1.49, and last Perspectives with a mean of 0.91 occurrences per response (Table 3b; Figure 8).

Variables were tested using a classic mean-comparison test (t-test), to determine whether the apparent distinctions between their distributions were statistically significant at $p<0.05$.

T-tests confirm that the occurrence of Dio is significantly higher than all other variables, with a significance level set at $p<0.05$. Spw comes in second place and its distribution differentiates from Rtot and significantly from Pβv. The distributions of Rtot and Pβv are not statistically different.

A summary of the mean-comparison tests of DSRP Patterns is provided in Table 9, and illustrated on Figure 8.

| Variable 1 | Mean | t-test | Variable 2 | Mean | Pr (T>t) | Bias Confirmation |
|---|---|---|---|---|---|---|
| *Distinctions (Dio)* | *5.94* | >> | *Systems (Spw)* | *3.16* | *0.0058* | *Yes* |
| *Systems (Spw)* | *3.16* | > | *Relations (Rtot)* | *1.49* | *0.0177* | *Yes* |
| *Systems (Spw)* | *3.16* | >> | *Perspectives (Ppv)* | *0.91* | *0.0012* | *Yes* |
| *Relations (Rtot)* | *1.49* | ≡ | *Perspectives (Ppv)* | *0.91* | *0.0746* | *No* |

Table 9: Summary of mean-comparison t-test for DSRP patterns.

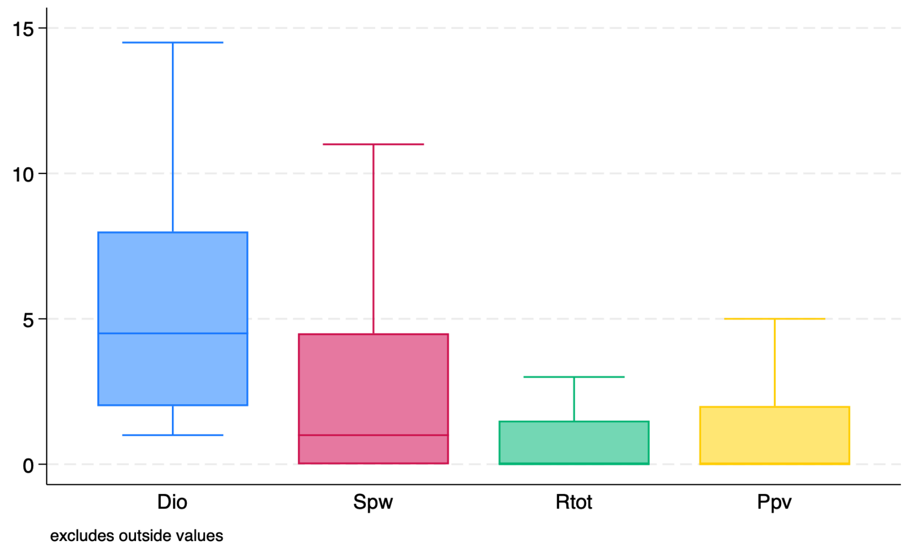


Figure 8: Comparison of the distributions of DSRP patterns in the study overall population

## 4.4 Systems Thinking Biases in Trained vs Untrained Populations

Participants were categorized based on their self-reported familiarity with the DSRP model: 'High', 'Middle', 'Low', or 'Not familiar'. Those reporting 'High' or 'Middle' were classified as 'Trained', while those indicating 'Low' or 'Not familiar' were labeled 'Untrained'. This classification resulted in twenty-eight study entries for the 'Trained' group ($N_{IT}$=28) and twenty-six for the 'Untrained' group ($N_{IU}$=26), as shown in Table 6. The distinctions between these groups yielded insightful results.

In the 'Trained' group, we observed a general increase in the total occurrence of all DSRP variables compared to the 'Untrained' group, as well as a consistent rise in mean values (Table 10; Figure 9). To ascertain if these differences are statistically significant, mean-comparison t-tests (t-tests) were performed at a significance level of $p<0.05$.

TRAINED

| Variable | Obs | Mean | Std. dev. | Min | Max |
|---|---|---|---|---|---|
| Dio | 28 | 7.5 | 7.07892 | 1 | 39 |
| Spw | 28 | 4.482143 | 6.051449 | 0 | 29 |
| Rtot | 28 | 2.267857 | 3.11651 | 0 | 13.5 |
| Ppv | 28 | 1.160714 | 1.374729 | 0 | 5 |
| Di | 28 | 6.357143 | 4.739232 | 1 | 24.5 |
| Do | 28 | 1.142857 | 2.707524 | 0 | 14.5 |
| Sp | 28 | 3.178571 | 4.386879 | 0 | 21.5 |
| Sw | 28 | 1.303571 | 1.781278 | 0 | 7.5 |
| Ra | 28 | 1.303571 | 1.812198 | 0 | 7 |
| Rr | 28 | .6964286 | 1.429447 | 0 | 5.5 |
| Ri | 28 | .2678571 | .4611207 | 0 | 1.5 |
| Pp | 28 | .3392857 | .5101483 | 0 | 1.5 |
| Pv | 28 | .8214286 | 1.081959 | 0 | 4 |

UNTRAINED

| Variable | Obs | Mean | Std. dev. | Min | Max |
|---|---|---|---|---|---|
| Dio | 26 | 4.269231 | 4.37317 | 1 | 19.5 |
| Spw | 26 | 1.730769 | 3.476293 | 0 | 14 |
| Rtot | 26 | .6538462 | 1.566967 | 0 | 6.5 |
| Ppv | 26 | .6346154 | 1.382445 | 0 | 6 |
| Di | 26 | 3.923077 | 3.976663 | 1 | 18.5 |
| Do | 26 | .3461538 | .8458041 | 0 | 4 |
| Sp | 26 | 1.288462 | 2.638837 | 0 | 11 |
| Sw | 26 | .4423077 | .8980749 | 0 | 3 |
| Ra | 26 | .2884615 | .6659291 | 0 | 3 |
| Rr | 26 | .25 | .7905694 | 0 | 3.5 |
| Ri | 26 | .1153846 | .4314555 | 0 | 2 |
| Pp | 26 | .1538462 | .3679465 | 0 | 1 |
| Pv | 26 | .4807692 | 1.117862 | 0 | 5 |

Table 10: Summary of Variable Means and Distribution by DSRP Training

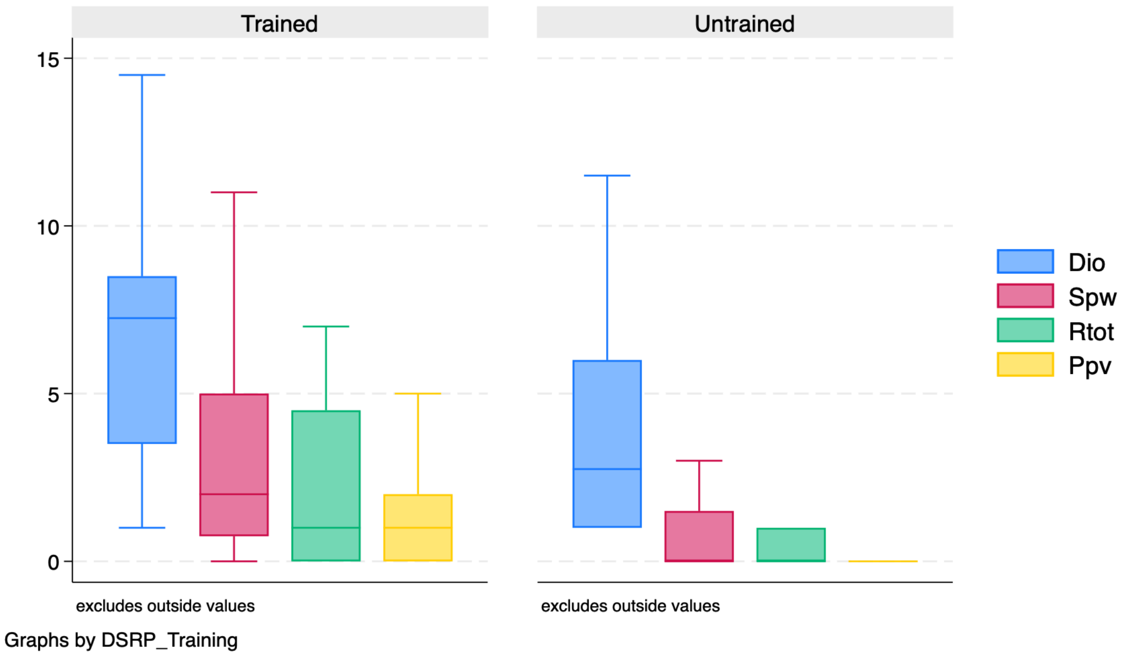


Figure 9: Distribution of DSRP patterns by DSRP Training

## Detailed Analysis of the Impact of Training on Pattern Biases

Mean-comparison tests were structured to examine the impact of training on DSRP activation through two distinct methods. Firstly, we evaluated each DSRP pattern individually by comparing its occurrence in trained versus untrained populations. This analysis revealed that the higher occurrence of DSRP patterns in the trained population is statistically significant for Dio, Spw, and Rtot, but not for Pβv (Table 11a).

Secondly, we undertook a separate analysis to discern how DSRP training influences biases between the patterns. This involved comparing the differences in occurrence per response of one pattern relative to another pairwise (Table 11b). This comprehensive analysis led to the following observations:

- The bias between Distinction and Systems (Dio>>Spw) remained consistent across both groups, albeit with a reduced t-test value in the 'Untrained' group.
- Training significantly impacted the bias between Systems and Relations (Spw>Rtot). This bias persisted in the 'Trained' group but was absent in the 'Untrained' group, indicating an alignment (Spw≡Rtot) in the latter.
- A similar trend was observed for the bias between Systems and Perspectives, which continued in the 'Trained' group (Spw>Pβv) but not in the 'Untrained' group (Spw≡Pβv).
- The relationship between Relations and Perspectives was altered by training; in the 'Trained' group, Relations significantly exceeded Perspectives (Rtot>Pβv), whereas in the 'Untrained' group, these two patterns showed overlapping occurrences (Rtot≡Pβv).

Overall, we observed that the occurrence of Distinctions (Dio) is consistently higher than other variables across all groups. Intriguingly, biases among the other three variables (Systems - Spw, Relations - Rtot, Perspectives - Pβv) were unexpectedly reinforced in the 'Trained' group, while they appeared attenuated in the 'Untrained' group. More specifically, in the 'Trained' group, Systems and Relations remained distinct, as observed in the overall population, whereas this distinction was not evidenced in the 'Untrained' group. The same pattern was observed for the distinction between Systems and Perspectives. Furthermore, while Relations and Perspectives were indistinguishable in the overall population, they became statistically distinct within the 'Trained' group (as illustrated in Tables 7b and 7c).

Table 11c distinctly portrays this trend in pattern biases. In the overall population, patterns are distinguishable from one another, with the exception of Relations and Perspectives (Table 11c top). In the trained population, not only do the previous distinctions hold, but even Relations and Perspectives become discernible from each other, resulting in a stair-like distribution of the four DSRP patterns (Table 11c middle). Conversely, in the untrained population, except for Distinctions, all other patterns blend into indistinctness.

This overlap in the untrained population may be attributed to the reduced number of data points, indicating a need to expand the participant pool for more definitive conclusions – a point that will be further explored in the Discussion section. However, the evident reinforcement of biased distribution in the trained population cannot be overlooked. Our analysis points to an intriguing phenomenon: while DSRP training seemingly increases the overall occurrences of patterns and elements, it does not necessarily mitigate biases within systems thinking. Contrarily, our findings suggest that individuals trained in the DSRP model may exhibit more pronounced biases in these patterns.

This counterintuitive outcome could imply that training in the DSRP model, while enhancing awareness and use of its patterns and elements, may simultaneously lead to a preferential or habitual reliance on certain aspects of the model over others. As a result, rather than equalizing the usage of various DSRP elements and patterns, training seems to accentuate certain tendencies. This observation raises important questions about the nature of systems thinking training and its impact on cognitive biases. Specifically, it suggests that while training can increase the frequency and awareness of DSRP elements in thought processes, it might also inadvertently reinforce existing predilections or biased systems thinking. This calls for further investigation of the nuances of how training influences these patterns is required, a point that underscores the necessity for a larger and more diverse study sample.

| Variable | Trained ($I_T$) | Untrained ($I_U$) | Pt (T>t) | Distinct |
|---|---|---|---|---|
| Distinctions (Dio) | *7.5* | *4.27* | *0.0254* | *Yes* |
| Systems (Spw) | *4.48* | *1.73* | *0.0239* | *Yes* |
| Relations (Rtot) | *2.27* | *0.65* | *0.0106* | *Yes* |
| Perspectives (Pβv) | *1.16* | *0.63* | *0.0835* | *No* |

Table 11a: Mean-comparison t-tests of DSRP patterns by DSRP training

| DSRP T/U | Variable 1 | Mean | Bias | Variable 2 | Mean | Pr (T>t) |
|---|---|---|---|---|---|---|
| $I_{ALL}$ | | 5.94 | >> | | 3.16 | 0.0058 |
| $I_T$ | Distinctions (Dio) | 7.5 | > | Systems (Spw) | 4.48 | 0.0461 |
| $I_U$ | | 4.27 | > | | 1.73 | 0.0123 |
| $I_{ALL}$ | | 3.16 | > | | 1.49 | 0.0177 |
| $I_T$ | Systems (Spw) | 4.48 | > | Relations (Rtot) | 2.27 | 0.0455 |
| $I_U$ | | 1.73 | ≡ | | 0.65 | 0.0780 |
| $I_{ALL}$ | | 3.16 | >> | | 0.91 | 0.0012 |
| $I_T$ | Systems (Spw) | 4.48 | >> | Perspectives (Pβv) | 1.16 | 0.0032 |
| $I_U$ | | 1.73 | ≡ | | 0.63 | 0.0707 |
| $I_{ALL}$ | | 1.49 | ≡ | | 0.91 | 0.0746 |
| $I_T$ | Relations (Rtot) | 2.27 | > | Perspectives (Pβv) | 1.16 | 0.0456 |
| $I_U$ | | 0.65 | ≡ | | 0.63 | 0.4814 |

Table 11b: Pairwise mean-comparison t-tests between patterns by DSRP Training groups

| | Rank 1 | Rank 2 | Rank 3 | Rank 4 |
|---|---|---|---|---|
| *All* | | | | |
| *Distinctions (Dio)* | mean=5.94 | | | |
| *Systems (Spw)* | | mean=3.16 | | |
| *Relations (Rtot)* | | | mean=1.49 | |

| | | | | |
|---|---|---|---|---|
| *Perspectives (Pβv)* | | | | mean=0.91 |
| *DSRP 'Trained' group* | | | | |
| *Distinctions (Dio)* | mean=7.5 | | | |
| *Systems (Spw)* | | mean=4.48 | | |
| *Relations (Rtot)* | | | mean=2.27 | |
| *Perspectives (Pβv)* | | | | mean=1.16 |
| *DSRP 'Untrained' group* | | | | |
| *Distinctions (Dio)* | mean=4.27 | | | |
| *Systems (Spw)* | | mean=1.73 | | |
| *Relations (Rtot)* | | mean=0.65 | | |
| *Perspectives (Pβv)* | | mean=0.63 | | |

Table 11c: Ranking of distributions of DSRP patterns by DSRP Training

## Detailed Analysis of the Impact of Training on Element Biases

While the primary emphasis of our study isn't on the isolated occurrences of DSRP elements in trained versus untrained populations, we nevertheless conducted t-tests to document the impact of DSRP training on these occurrences. More importantly, our study focused on analyzing the impact of DSRP training on the balance between DSRP elements.

Our analysis reveals that the frequency of all DSRP elements (Di, Do, Sp, Sw, Ra, Rr, Ri, Pβ, Pv) is consistently higher in the 'Trained' group compared to the 'Untrained' group. However, statistically significant differences at $p<0.05$ were found only for Di, Sp, Sw, and Ra (Table 12a).

More critically, our study analyzed the impact of DSRP training on the pairwise balance between elements in each DSRP pattern. The pairwise mean-comparison t-tests conducted between the trained and untrained populations revealed several key insights (Table 12b):

- The bias between Identity and Other remains unchanged; the significant difference favoring Identity over Other (Di>>Do) is consistently observed across all groups.
- In contrast, t-tests demonstrate that training influences the bias between Part and Whole. The statistically significant difference between Part and Whole is maintained in the 'Trained' group (Sp>Sw), as in the overall population, while it disappears in the 'Untrained' group (Sp≡Sw).
- Regarding Relations, training appears not to impact the balance between Action and Reaction (Ra≡Rr). They appear evenly distributed in any case. However, training seems to impact the distinction between Action-Reaction and Interaction (Ri) in the following way:
    - Ra, significantly higher than Ri in the overall population, remains so in the 'Trained' group (Ra>Ri), but this distinction vanishes in the untrained population (Ra≡Ri).
    - Rr and Ri, statistically distinct in the overall population, overlap in both trained and untrained groups (Rr≡Ri) when splitting the cohort according to training level.
- Regarding the bias in Perspectives, favoring View over Point, we note no change related to training level, and the bias remains strong (Pv>>Pβ) in all three populations.

In summary, the biases between opposing pairs of DSRP elements, observed at the overall level, are predominantly retained in the 'Trained' group. In contrast, a general attenuation of these biases is noted in the 'Untrained' group. This reduction in statistically significant biases may be influenced by the smaller data set in the 'Untrained' group. Therefore, it would be premature to conclude that untrained individuals exhibit a less biased DSRP profile compared to trained individuals. Nonetheless, our analysis suggests that thought formulations by individuals trained in the DSRP model demonstrate an imbalanced use of DSRP elements, leading to a biased profile in their utilization of DSRP patterns and elements.

| Variable | Trained ($I_T$) | Untrained ($I_U$) | Pt (T>t) | Distinct |
|---|---|---|---|---|
| Identity (Di) | *6.36* | *3.92* | *0.0234* | *Yes* |
| Other (Do) | *1.14* | *0.35* | *0.0785* | *No* |
| Part (Sp) | *3.18* | *1.29* | *0.0315* | *Yes* |
| Whole (Sw) | *1.30* | *0.44* | *0.0155* | *Yes* |
| Active-agency (Ra) | *1.30* | *0.29* | *0.0048* | *Yes* |
| Reactive-agency (Rr) | *0.70* | *0.25* | *0.0830* | *No* |
| Interactive-agency (Ri) | *0.27* | *0.12* | *0.1081* | *No* |
| Point (Pp) | *0.34* | *0.15* | *0.0671* | *No* |
| View (Pv) | *0.82* | *0.48* | *0.1302* | *No* |

Table 12a: Mean-comparison t-tests of DSRP elements by DSRP training

| DSRP | Variable 1 | Mean | Bias | Variable 2 | Mean | Pr (T>t) |
|---|---|---|---|---|---|---|
| $I_{ALL}$ | Di | 5.19 | >> | Do | 0.76 | 0.0000 |
| $I_T$ | | 6.36 | >> | | 1.14 | 0.0000 |
| $I_U$ | | 3.92 | >> | | 0.35 | 0.0000 |
| $I_{ALL}$ | Sp | 2.27 | >> | Sw | 0.89 | 0.0066 |
| $I_T$ | | 3.17 | > | | 1.30 | 0.0204 |
| $I_U$ | | 1.29 | ≡ | | 0.44 | 0.0640 |
| $I_{ALL}$ | Ra | 0.81 | ≡ | Rr | 0.48 | 0.0976 |
| $I_T$ | | 1.30 | ≡ | | 0.70 | 0.0848 |
| $I_U$ | | 0.29 | ≡ | | 0.25 | 0.4251 |
| $I_{ALL}$ | Ra | 0.81 | >> | Ri | 0.19 | 0.0018 |
| $I_T$ | | 1.30 | >> | | 0.27 | 0.0025 |
| $I_U$ | | 0.29 | ≡ | | 0.12 | 0.1357 |
| $I_{ALL}$ | Rr | 0.48 | > | Ri | 0.19 | 0.0486 |
| $I_T$ | | 0.70 | ≡ | | 0.27 | 0.0685 |
| $I_U$ | | 0.25 | ≡ | | 0.12 | 0.2248 |

| | | | | | | |
|---|---|---|---|---|---|---|
| $I_{ALL}$ | Pv | 1.27 | >> | Pp | 0.25 | 0.0000 |
| $I_T$ | | 1.29 | >> | | 0.34 | 0.0000 |
| $I_U$ | | 1.25 | >> | | 0.15 | 0.0000 |

Table 12b: Mean-comparison t-tests of DSRP element biases by DSRP training

# 5. Discussion

This section provides a critical examination of our study's findings on biases in systems thinking, as viewed through the DSRP model lens. It delves into insights on cognitive biases as revealed through language analysis. The discussion commences with a candid examination of the limitations inherent in the DSRP-Scoring and data sample, to ensure transparency in our research process. It further analyzes the study's methodology and results, including the conceptualization of language as a system.

Insights into average DSRP pattern and element biases are presented, revealing significant findings about the predominance of certain cognitive functions in our participants' responses and their implications for systems thinking. This section also juxtaposes our study's findings with those from the Mapping Study, offering broader context and validation of our results within the larger landscape of systems thinking research.

We eventually propose to integrate our findings in a reflection about systems thinking classification, considering the primary occurrence of Distinctions, and emphasizing the crucial role of critical systems thinking and relational thinking in enhancing systems thinking competencies. This section culminates in a set of concluding remarks, synthesizing the implications of our study for future research and practice in the field.

## 5.1. Evaluation of Study Limitations

### Limitations of DSRP-Scoring

The DSRP-Scoring protocol used in this study was developed specifically for this project and has undergone several stages of refinement. We maintain that the current version is coherent and objective. However, we acknowledge areas where the definition of variables could still be improved to more effectively highlight key information revealed by the study's results.

Furthermore, when participants are prompted to articulate their thoughts in response to an image, their responses are the product of a complex process influenced by numerous factors. These include their mental models, the information they process, and how this information is organized through DSRP patterns, but also external factors not captured in the study (like time constraints, motivation, the environment, etc.). Therefore, the DSRP-Scoring of the responses does not aim to determine the 'systemic-quality-of-the-candidates' thoughts' per se, but rather to assess the systemic quality of the articulated responses in the very context of theirs doing the study.

Despite these nuances, we posit that the response profiles provide valuable insights into the cognitive functions (DSRP patterns and elements) participants generally favor when engaging their cognitive processes.

### Limitations of the Data Sample

The study's results are based on the responses of a relatively small group of participants (N=27), about half of whom had reasonable knowledge of the DSRP model. Consequently, the cohort is not representative of a general population. Additionally, some results of the statistical analyses and population comparisons are based on a limited number of data points. All results have been statistically tested and are statistically significant at $p<0.05$. However, we acknowledge that a larger participant pool might yield variations in some results and consequently impact actual findings and conclusions.

In discussing these results, we are cognizant of the study's methodological and interpretative limitations. Despite these constraints, the insights gleaned from this research are both reliable and intriguing. They undeniably encourage further investigation in this field, ideally involving a significantly larger and more diverse participant base.

## 5.2. Insights from the Comparison with the Mapping Study

Biases in DSRP Pattern activation in task performance were analyzed in the recently published Mapping Study. The Mapping Study analyzes another type of behavior: it looked at preferred functions in a software, in spite of preferred wording in a language. But its approach is similar to ours. Results of the Mapping Study are presented and commented on in four parts, each dedicated to a different pattern [3–6].

The Mapping Study is a large-scale study (N=34,398). It is based on usage data of the Plectica software, a program that allows for mapping a system using components whose functions are based on the DSRP model. The use of a particular component of the program can thus be associated with the mobilization of a specific cognitive function related to the DSRP model. Despite their differences (protocol, dataset size, etc.), the Mapping Study and the one presented here have produced surprisingly similar results, when comparing two by two 'comparable' variables (Table 13a).

For example, taking the number of times a distinction has been made as a reference (Dio=100%), we observe in both studies that:

- Dividing a distinction into parts seems to be an action 2.5 to 3 times less common (Sp occurs in approximately 35-40% of the cases),
- Establishing a relationship between different distinctions is about 4 times less common than Dio (undefined Rar occurs in approximately 25-30% of the cases),
- Describing an interaction system appears in less than one out of 20 cases (defined Rar / Ri occurs in approximately 3-5% of the cases),
- Formulating an explicit perspective point appears in less than one out of 20 cases (Pβ occurs in approximately 1-5% of the cases).

In addition to the global analysis of the preferred cognitive functions of a representative population, the Mapping Study also analyzed the individual prevalence of different cognitive functions. One interesting outcome of this large-scale study is revealing the percentage of people who activate certain DSRP functions more than others. Analyzing an individual's preferences was not a primary objective of our study. Nonetheless, to compare the results in both studies, we have calculated retrospectively what percentage of our cohort participants activated these same functions.

The comparison shows that the activation percentages are generally higher in our study than in the Mapping Study. However, it is important to consider that the two methodologies are very different. In the Mapping Study, participants were invited to draw a system using software, whereas in our study they were asked to formulate their thoughts in writing. Therefore, the task in the Mapping Study is more complex to execute than that of our study (since, formulating one's thoughts does not represent a particular challenge for an adult individual). The reduced recourse to certain DSRP patterns in the Mapping Study might be linked to the level of challenge of the task. Additionally, the protocols for linking a particular behavior to a specific function of the DSRP model in the two studies are significantly different. The actions performed in the Mapping Study are very directly linked to DSRP patterns. In our study, the link requires interpretation, which perhaps favors the attribution of a given cognitive function to a language element, while it would not have been explicitly drawn in the mapping software.

Nonetheless, it is still noteworthy that the order of preference among comparable cognitive functions remains broadly the same. Both studies show a marked preference for making Distinctions (Dio), which is 2.7 times higher than the second most frequent pattern in the Mapping Study, and 2.6 times higher than the second most frequent pattern in our study. 'Making parts' (Sp) comes second, 'relating things to each other' (Ra or Rr) third, and much less frequent 'distinguish their relationships' (Rar or Ri) or 'take at least one perspective' (Pβ) (Table 13b).

| DSRP function | Mapping Study (N=34'398) | | Our study (N=54) | |
|---|---|---|---|---|
| Dio | 2'066'654 | 100% | 321 | 100% |
| Sp | 769'120 | 37.2% | 122.5 | 38.2% |
| Rar (undefined) | 565'999 | 27.4% | 80.5 | 25.1% |
| Rar (defined) / Ri | 87'318 | 4.2% | 10.5 | 3.3% |
| Pp | 39'398 | 1.9% | 13.5 | 4.2% |

Table 13a: Comparing DSRP-related actions in the Mapping Study and our study

| Action taken | Mapping Study | Our Study |
|---|---|---|
| distinguished things (Dio) | 100% | 100% |
| broke down their distinctions into parts (Sp) | 48% | 70% |
| related things (Ra or Rr) | 46% | 63% |
| distinguish their relationships (Rar or Ri) | 25% | 30% |
| took at least one perspective (Pp) | 16% | 33% |

Table 13b: Comparing prevalence of DSRP-related actions in the Mapping Study and our study

The similarities between the two studies, despite the distinct methodologies, suggest a universal pattern of preferred cognitive functions, where 'making distinctions' is the primary action. 'Creating parts' and 'establishing relationships' come second, whereas 'taking at least one perspective' appears as a marginal behavior. This universality suggests that the DSRP model captures core aspects of cognitive functioning, which could have far-reaching implications for educational strategies, cognitive training programs, and even software design principles. Understanding the inherent preference for these functions could guide the development of tools and methods that align more closely with natural cognitive patterns, potentially leading to enhanced efficiency and effectiveness in both learning and problem-solving scenarios.

## 5.3. Nature's Symmetry vs. Cognitive Asymmetry

### Symmetry in Nature

The foundation of this research lies in a fundamental principle of nature: symmetry. Through the DSRP model, we see that nature's ontological complexity, represented by four patterns and eight systemic elements, inherently exhibits perfect symmetry. This symmetry, as detailed in Cabrera & Cabrera's work, stems from the model's core principles of co-implication and simultaneity [10]. This 'perfect symmetry' is inherent to the ontology of nature, where distinctions, systems, relations, and perspectives are not confined to cognitive categories. In nature, these systemic patterns are not isolated but operate simultaneously, applying universally across multiple dimensions to any given 'object.' This simultaneous operation results in a symmetrical application of the DSRP model, free from cognitive biases or preferences.

For example, in the natural world, a single entity like a tree simultaneously embodies multiple DSRP dimensions: it is an individual 'Identity' while also an ‘Other’ for neighboring trees; it is a 'Part' (a tree) of a 'Whole' (the forest), but simultaneously a ‘Whole’ involving ‘Parts’ like leaves and roots (other ‘Distinctions’); but the roots may be seen (’View’) from the perspective of the tree (’Point’) as a relationship (’Relations’) between the tree and the ground, an active relationship where roots absorb water when available (’Reaction’) and transport (’Action’) water and nutrients from the soil to the rest of the tree; the tree is viewed as a habitat (’View’) from birds, as a heating resource (’View’) or building resource (’alternative View’) from depending of individual’s perspectives and needs (’Points’ and ‘alternative Points’). This example illustrates in a “summer tale” creative style the inherent symmetry in DSRP applications.

### Transition to Asymmetry in the Cognitive Process

However, this natural symmetry is disrupted in cognitive processes. The human mind engages in a 'sampling' of information from reality, a well known process in cognitive science contributing to cognitive biases. The singularity of the organizing principles – each individual's unique DSRP processes – further compounds the loss of parallelism (i.e., the adequation between mental models and reality) inherent to cognitive biases.

This cognitive 'sampling' and the singular nature of systemic algorithms in individuals (which relate to the concept of paradigms or worldviews in human sciences) result in a loss of the natural symmetry of DSRP elements in mental models. Depending on one's cognitive preferences, certain DSRP variables become dominant, leading to an asymmetrical representation in cognitive processes.

Hence, compared to ‘reality’, our mental models are almost necessarily biased. This asymmetry in cognitive representation has significant implications. On the one hand, it creates the departure from the symmetrical reality of nature and generates the gap between mental models and the real world (i.e., a loss of parallelism). But on the other hand, it importantly has a major impact on our behaviors. Human behaviors are strongly rooted in our mental models. Behaviors are based on, react to, and build on our mental models. The asymmetric systemic nature of our mental representations hence shapes our actions, reactions, and interactions with the world and others. Unfortunately (or fortunately?), mental models remain hidden in each individual’s brain.

### Implications of Cognitive Asymmetry on Language

Though, the systemic nature of our mental representations shapes our behaviors. Notably, they shape the formulation of our thoughts, reflecting in one's speaking and writing. Our study focuses on language in its written form, as a structured system, to analyze the systemic organizing patterns embedded in someone's cognitive processes to produce a specific text.

Prevalence of some DSRP variables over others in texts informs us about individuals' paradigms. A text reflects the mental model it is based on. Therefore, the DSRP profile of a text reflects the DSRP profile of their mental model, hence reflecting the DSRP profile of their authors. Since even distribution of DSRP variables in nature is the theoretical principle, the more even the distribution of DSRP variables, the closer the mental model is compared to reality. The uneven prevalence of DSRP patterns in a text is a manifestation of cognitive biases, across a two step process: the bias in the text infers a bias in the mind's mental models, informing us on the nature of the bias involved in the cognitive operations processing natural complexity into the mind.

How the cognitive complexity and biases embedded in written language inform us about paradigms and worldviews is the essence of this research project. This is based on the validity of our analysis protocol for translating a text into a system, in which we can determine with a sufficient degree of objectivity the cognitive nature (which amounts to determining the DSRP element to which a linguistic formula best corresponds) of an expression or a word.

As we pointed out in the section devoted to the limitations of the current DSRP-Scoring protocol, this scoring technique has considerable room for improvement and refinement. But, as it stands, the consistency of the information it provides, in the light of other studies or knowledge, is very encouraging.

The method we use reveals cognitive paradigms. The role played by these paradigms in our interactions with the world and with others is crucial. They determine the importance we attach to certain problems, locally or globally. They condition our ability to provide answers to complex systemic problems. They determine the responses we give to these problems. In the face of the major challenges facing us in the 21st century, our ability to help reduce the cognitive biases that separate us from nature and from others is of major importance. Future research might explore interventions to mitigate the impact of these cognitive biases, aiming to align mental models more closely with the symmetrical reality of nature. Investigating the extent to which educational or cognitive interventions can influence the distribution of DSRP elements in cognitive processes could open new pathways for understanding and addressing cognitive biases.

In addition, our study has shown that it is not enough to improve our knowledge of systems science, or of the universal patterns of systems thinking, to reduce cognitive biases. It provides crucial information for improving the way we teach these sciences.

## 5.4. The Impact of Perspectives on DSRP profile: The Pivotal Role of Critical Systems Thinking

In this study, we demonstrated that, seen through the prism of the DSRP model, an individual performing a task favors certain cognitive functions over others. The form that their action takes thus reflects the cognitive functions that they prioritized. Written language is a network of information that can be interpreted as a system. Analyzing a text written by an individual, by linking the language elements of their text to the cognitive functions of the DSRP model associated with it, makes it possible to determine, as it were, the profile of their systems thinking.

We have shown that, generally, the activation of the pairs of elements (Di-Do; Sp-Sw; Ra-Rr; Pϸ-Pv) that make up each pattern of the DSRP model is not balanced, i.e. one of the two poles is more activated than the other on average in systems thinking. We also showed that the language items in our cohort suggest an asymmetry in the prevalence of the different patterns in the model, which we called a systems thinking bias, with Distinctions appearing systematically and significantly more frequently than the other patterns; the Systems pattern is in second place, with an average occurrence half as frequent; followed by the Relations and Perspectives patterns, which are four to five times less represented. Finally, we saw that DSRP training significantly increased the activation of the various components of the DSRP model, but did not reduce systems thinking biases, on the contrary.

Intrigued by this counterintuitive finding, which contradicted the third of our hypotheses, we deepened our analysis by exploring the nature of the correlations between the different patterns. Predictably, the correlation analysis showed that the correlation between Relationships and Systems is high (correlation coefficient = 0.93) (Table 14); this seems logical, since it is in principle through relationships between parts that a system is formed. Probably for the same reason, the degree of correlation between the number of Distinctions and Systems, on the one hand, and between Distinctions of Relationships, on the other, is also relatively high (correlation coeff. = 0.90, respectively 0.85). The pattern ‘Perspectives’, on the other hand, is somewhat apart, showing correlation coefficient with other patterns ranging between 0.66 and 0.57 (Table 14).

```
. correlate Dio Spw Rtot Ppv
(obs=54)
```

| | Dio | Spw | Rtot | Ppv |
|---|---|---|---|---|
| Dio | 1.0000 | | | |
| Spw | 0.8953 | 1.0000 | | |
| Rtot | 0.8534 | 0.9285 | 1.0000 | |
| Ppv | 0.5659 | 0.6094 | 0.6554 | 1.0000 |

Table 14: Correlation factors between DSRP patterns

Yet the ability to establish a perspective is theoretically one of the key skills in systems thinking. It has given rise to the crucial field of ‘critical systems thinking’ science and occupies an important place in many social sciences, psychology and philosophy. Pushing our thinking further in this direction, we found that the Perspectives pattern acted not so much as a quantitative variable, but as a qualitative one. Empirically, we observed that it was not so much the number of Points and Views involved that influenced the formulation of the other variables of the DSRP model, but the occurrence of at least one element of the Perspectives pattern (Pϸ or Pv).

We therefore subdivided our data into two groups: responses with at least one Pϸv were labeled 'CST_Yes' (to emphasize the presence of Critical Systems Thinking); the others were labeled 'CST_No'. We then compared the DSRP profiles of the responses on the basis of this new categorisation. This cross analysis highlighted a remarkable insight.

As illustrated in Figure 10 below, and referred to in Table 15, the DRSP profile of the CST_Yes group shows that formulating an element of perspective in a thought formulation strongly correlates with an higher and more even occurrence of other DRSP patterns. We note that:

- The CST_Yes group formulates an average of 2.33 Pβv per response, compared with 1.16 for a DSRP-Trained participant and 0.63 for the others.
- The means of the fourteen variables analyzed were higher in the CST_Yes group than in all the other populations studied (qualitative assessment, without confirmation by t-test of the statistical significance of the differences).
- The bias between Dio and Spw disappeared. The Systems pattern, with an average occurrence/response of 6.5, became as frequent as Distinctions, which showed an average occurrence/response of 9.29.
- The bias between Rtot and Pβv disappeared, with mean occurrences/responses of 3.29 and 2.33 respectively, well above the mean occurrences/responses of the other populations.
- The biases between pairs of DSRP elements are marginally modified, but without any bias disappearing.

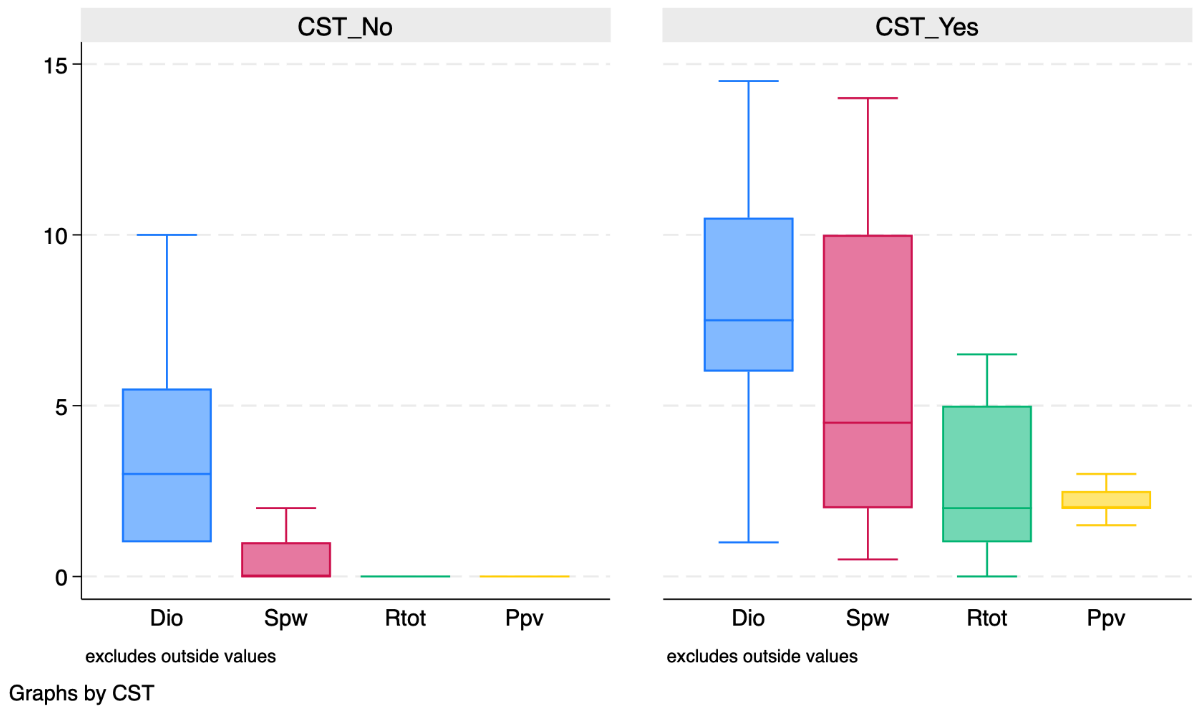


Figure 10: Occurrence of DSRP patterns in responses expressing Critical SystemsThinking or not.

| Variable | Untrained ($I_U$) | Trained ($I_T$) | CST_Yes |
|---|---|---|---|
| Distinctions (Dio) | *4.27* | *7.5* | *9.29* |
| Systems (Spw) | *1.73* | *4.48* | *6.5* |
| Relations (Rtot) | *0.65* | *2.27* | *3.29* |
| Perspectives (Ppv) | *0.63* | *1.16* | *2.33* |

| | | | |
|---|---|---|---|
| Identity (Di) | *3.92* | *6.36* | *7.60* |
| Other (Do) | *0.35* | *1.14* | *1.69* |
| Part (Sp) | *1.29* | *3.18* | *4.69* |
| Whole (Sw) | *0.44* | *1.30* | *1.81* |
| Active-agency (Ra) | *0.29* | *1.30* | *1.88* |
| Reactive-agency (Rr) | *0.25* | *0.70* | *0.98* |
| Interactive-agency (Ri) | *0.12* | *0.27* | *0.43* |
| Point (Pβ) | *0.15* | *0.34* | *0.64* |
| View (Pv) | *0.48* | *0.82* | *1.69* |

Table 15: Comparison of means occurrence/response of DSRP patterns by population category

## 5.5 Fostering Integration of ST-Biases in Systems Thinking Theories and Practice

This study's insights have illuminated the pivotal importance of acknowledging cognitive biases within systems thinking processes. We have demonstrated that ST-Biases are prevalent and can be diagnosed through thought formulation analysis, including written language, using 'language network analysis' and appropriate systems thinking frameworks. Echoing research on mental simulation and the role of mental models in reasoning (as discussed in Section 1.1 about the Interaction Loop between Reality and Mental Model), ST-Biases are likely to play a crucial role in various impactful human behaviors, such as interpersonal relationships, communication, ecosystemic consciousness, decision-making, and leadership. Our study paves the way for extensive research in this field. In light of the complex challenges of the 21st century and issues surrounding resistance to change, integrating a deeper understanding of ST-Biases into human behavior management and systems thinking is imperative.

We advocate for the necessity to integrate a more profound understanding and knowledge of ST-Biases, seen as an ontological systematic filter of reality, into both theories and practices of systems thinking and other related scientific disciplines. Although we recognize the limitations of our study related to its context and cohort size[9], the insights obtained are both consistent and significant. They highlight the need to develop more sophisticated 'systems-thinking-patterns' measurement methods. Currently, few such methods exist, and none specifically focus on elucidating cognitive biases from a systems thinking perspective [42–47].

From our study, we wish to emphasize four key learnings that inform further research and the development of systems thinking frameworks:

**The Distinctions pattern** (Dio) emerges as the primary cognitive function in the action of thinking, particularly in transcribing thought into text. Dio is the most frequently activated DSRP pattern in thought formulations, appearing in 100% of responses. We posit that this function is not strictly a cognitive function exclusive to systems thinking. Instead, it appears to operate quite independently from other systems thinking functions. This was highlighted notably by the observation that 33.3% of

[9] The study was originally aimed to be just the applied part of an advanced training program on systems thinking, mapping, and leadership and twenty-seven participants were involved generating 54 entries to analyze.

participants' responses involved only one or a little set of distinctive identities (Di) without incorporating any other DSRP patterns or elements. This indicates that while making distinctions is a fundamental cognitive process, its frequent occurrence in isolation from other systems thinking patterns suggests a level of operational independence within cognitive processes.

Our study demonstrated that the Distinctions predominates over other DSRP systemic functions, regardless of the participant's level of systems thinking training. However, our demonstration in Section 5.2 uncovered that individuals capable of incorporating criticality in their thought were overcoming this bias, particularly in relation to the Distinctions (Dio) versus Systems (Spw) patterns. Furthermore, these individuals showed a tendency to reduce the disparity between these more dominant patterns and the less common ones, such as Relations (Rar) and Perspectives (Pβv). This suggests that the development of critical systems thinking skills can play a significant role in balancing the use of various DSRP patterns, mitigating the tendency to overly focus on distinctions.

**Critical Systems Thinking**, which involves someone’s capacity to become aware of and explicitly articulating subjective viewpoints, appears consequently the most vital component of systems thinking. When individuals formulate at least one point or an uncertainty about their view, the other cognitive functions of systems thinking appear to be notably enhanced, leading to a more diverse and balanced (less biased) world representation and mental models more aligned to reality.

**Relational thinking**, while vital for conceptualizing complex adaptive systems, remains a weak link in systems thinking according to our study learnings. Although critical thinking aids in understanding ontological complexity, relational thinking is essential for perceiving the world dynamically. Strengthening this skill in systems thinking is urgent and necessary in the multi-crisis context of the 21st century. Our study highlights that while critical systems thinking enhances the overall richness and balance of systems thinking components, relational thinking plays a different yet equally vital role. The absence of relational thinking fosters a static mindset, which can contribute significantly to increasing resistance to change. This static thinking is the antithesis of the dynamic, adaptive view needed to effectively navigate contemporary challenges. By developing relational systems thinking in training and education, we can promote a perspective that sees the world as a network of interconnected, but also adaptive systems. Such a perspective is not only more aligned with the realities of complex systems but also crucial in overcoming the barriers to change. In essence, ‘Relational thinking’ may be the required 'antibody' of a ‘resistance-to-change sclerosing pathogen’[10] [47]. Cultivating relational systems thinking could be key to become more adaptive and engage in a more sustainable way with the world, its ecosystems, and others.

## 5.6. Relational Thinking and Critical Thinking Issues

### Considerations about the Lack of Relational Thinking

The first result that we want to discuss in detail is about the Relations pattern. Establishing relationships between the distinctions made by thought is an essential element of systems thinking. The world is a network of interactions. Everything in the world is the result of interactions between the parts that compose it. The entities they form interact with other entities and with their environment. Relationships

[10]This medical metaphor is a nod to the 'Immunity to Change' concept of the visionary developmental psychologist Robert Kegan. To crystallize the concept of resistance to change, Kegan metaphorically explained that change is like a pathogen and resistance to change is a form of immunity to this change ‘pathogen’ [47]. With deep respect for his work and his profound understanding of human psychology in the face of change, we seize the opportunity of this article to reverse the perspective. In our version of the metaphor adopted here, the pathogen is the 'resistance to change' of which practice of relational thinking would be the ‘vaccine’.

should constitute an essential component of our representations of reality. This is far from confirmed by our study.

The Relations pattern in the DSRP model focuses on what things do when they relate to other things through their action-reaction dynamics. It is a fundamental pattern of systems thinking. The agency of the Distinctions formulated in a text are expressed using verbs. These verbs describe what these things do, in the form of action, reaction or interaction. But none of these three forms of agency is isolated. One thing acts on something else, or reacts to the action of something else.

Yet, despite all the subtleties of the language available to describe what things do and how what they do relates them to each other, it is clear that the participants in our study made very little and very rare use of action-reaction systems or interactions to describe the reality they were expressing themselves about.

Out of 54 responses encompassing 321 Dio, 25 responses (46.3%) involve the description of an agency associated with their Distinctions. These forms encompass 44 unrelated Actions and 26 unrelated Reactions. This highlights that a vast majority (approximately 75%) of the Distinctions are ‘passive’ distinctions.

The dominance of formulations of passive distinctions in the responses of the study is striking. Our interactive world is dynamic, with experiences shaped by complex interplays among constituents. The interconnected parts form wholes that in turn interact with the environment and with other entities. It is obvious that this characteristic of reality is not reflected in the participants' responses.

Of course, we must question the influence of our methodology on the occurrence of the Relations pattern in the responses. One the one hand, we must question whether the question “Describe what you think!” facing an image on a computer screen encourages a response involving action-reaction loops? On the other hand, we ought to question the impact of the online form on shaping the response in a passive way. However, if the absence of linguistic elements linked to relational dynamics reflects a generalized cognitive deficit, this could be questioned, and lead to a reflection on the link between this deficit and the phenomenon of resistance to change so present in each of us, in social groups or in society in general. Since a world that is not dynamic in our mental models is a world that does not change in subjective reality. In the context of the multiple crises facing humanity in the 21st century and the need to change the trajectory of humanity, we need to ask ourselves whether strengthening relational thinking - i.e. the Relations cognitive function of the DSRP model - could potentially reduce resistance to change and help improve the adaptability of individuals and social groups?

## Considerations about the Lack of Critical Thinking

The second point we want to discuss in more details is the notably low occurrence of Perspectives pattern-related language elements in participant responses. In systems thinking, Perspectives (Pϸv) are based on the interaction between a view and the associated viewpoint. This critical thought forms the core of the issue of the subjectivity of our cognitive functions. It reflects the awareness that every representation of reality 'is' a subjective view that emerges from the interaction between an object in reality and a particular subject observing it.

The instruction "Describe what you think!" invites participants to describe the mental representation that forms in their mind in the context of the experiment. This formulation therefore represents a point of view, whether it is recognized or not. To articulate a perspective, however, the author must make the existence of a perspective clear in their words. To do this, it is necessary to include a 'Point' in the text, or to make the acknowledgment of its 'View' explicit. To make the 'Point' of the perspective explicit, the subject must, in his formulation, stage his own existence or the role of subjective observer in the interaction. He must say "I", "me", or any other form of reference to himself, or formulate another who "thinks". A 'View' is explicit in a text when it relates to a 'Point' or, possibly, in the absence of a formulated point of view, when the text incorporates alternative 'Views' or views qualified by uncertainty or relativisation.

It is worth remembering that the DSRP theory emphasizes that all components of a system can be considered as a ‘Point’ of a perspective. It reflects the fact that this component interacts with other component in the system and, somehow, is a point with a view on the system it interacts with [5,9,10]. When describing something we observe, we can therefore describe many different points of view, in addition to our own, including conceptual viewpoints from non-human objects. As we demonstrated in the Discussion section, formulating a perspective increases systems thinking efficacy, and significantly reduces the biases of systems thinking (Section 5.4). Making explicit, and diversifying perspectives greatly enriches, and balances the formulation of the mental model we describe or communicate about.

Undoubtedly, what emerges from our study, reinforced by other larger-scale studies and anecdotal observations, is that the 'Perspectives' pattern of systems thinking is very little used in general. Among the 54 responses, only 13 included a reference to the author themselves, expressing the need to explicitly formulate that the response is a subjective view and not reality itself. Notably, only 1 response referred to a viewpoint distinct from that of the author and only 9 responses include the formulation of an explicit alternative view.

Perspectives are the least represented patterns in our study. At this stage of our analysis, it is difficult to determine what this is linked to. As with the Relations pattern, we must question the influence of the study's design. We intentionally formulated the question of our study very openly. But perhaps the instruction “Describe what you think!” does not encourage a response beginning with “I…”. On the other hand, we must question the impact of the online form on the shape of the response. Participants are relatively isolated when they respond. This may perhaps favor an anonymous formulation. But the context was similar for all participants. Yet, one third of the cohort formulated one or more elements of perspectives showing that the process was not completely hindered by the study methodology. Overall, none of the elements of the DSRP patterns are entirely absent showing that activations of these patterns and elements were possible, which speaks in favor of the reliability of our study findings.

The most important point is to have highlighted the extent to which the formulation of one perspective has a significant effect on the other components of systems thinking. This is an argument that is qualitatively well known and defended in many fields of science. However, for the first time we are able to quantify the effect of critical thinking on the parallelism and efficacy of systems thinking.

# 6. Conclusions

## 5.1 Validation of the Study Hypotheses

In conclusion, our study has either fully or partially confirmed two out of the three hypotheses we formulated:

Firstly, we predicted specific imbalances in DSRP element usage, expecting a greater occurrence of Identity over Other, Part over Whole, Action over Reaction, and View over Point (refer back to Section 2.1). This hypothesis is largely confirmed, except for the anticipated bias between Action (Ra) and Reaction (Rr). Despite averages supporting our hypothesis, the distinction between these two variables was not statistically significant.

Our second hypothesis was an expected DSRP pattern bias. We anticipated a predominance of Distinctions over Systems, followed by Relations and Perspectives (refer back to Section 2.1). This hypothesis is confirmed, except for the expected bias between Relations and Perspectives.

Finally, we hypothesized that DSRP training would reduce biases between DSRP patterns and elements among individuals trained in the DSRP model. Contrary to our expectations, this hypothesis was not confirmed. Instead, our study revealed a general increase in the occurrence of almost all DSRP elements in the 'Trained' group ($I_T$), but with more pronounced biases compared to the 'Untrained' group ($I_U$).

In summary, our study results confirm that biases in systems thinking are common. Two of three hypotheses were confirmed with few secondary exceptions, and the last hypothesis was contradicted by study evidence:

- DSRP elements present a significant bias between elementary partners. An anecdotal bias was also observed between Action (Ra) and Reaction (Rr) but it could not be confirmed as statistically significant. The element's bias-ratios (ratio between the highest and lowest value of a theoretically even distribution of variables) range from 1.7 (Ra/Rr) to 6.8 (Di/Do).
- DSRP patterns present a significant bias among the four of them making the DSRP model, with the marginal exception of Relations versus Perspectives which scarce data populations overlap statistically. A complete split of pattern distributions was observed in DSRP trained individuals. Overall, the patterns bias-ratios range from 1.6 (Rtot/Pϸv) to 6.5 (Dio/Pϸv).
- DSRP training did not confirm to attenuate biases. On the contrary, biases in the 'Trained' group were reinforced, while they appear attenuated in the 'Untrained' group.

This study reveals that biases in systems thinking, particularly in the differential use of DSRP elements and patterns, are not only common but also influential in shaping our cognitive processes. These biases tend to favor certain elements and patterns over others, potentially leading to skewed perceptions and analyses in systemic approaches. Apparently, general systems thinking training does not attenuate these biases. Figure 11 provides a summary of our study key results.

Hence, we shall formulate the two following statements about common biases in thoughts' formulation, analyzed through the lens of the systems perspective:

1. The use of DSRP Elements in systems thinking is generally biased such that $B_{\mathbb{E}} = (i>o;\ p>w;\ a\equiv r;\ ϸ<v)$.
2. The use of DSRP Pattern in systems thinking is generally biased such that $B_{\mathbb{P}} = (D > S > R \equiv P)$.

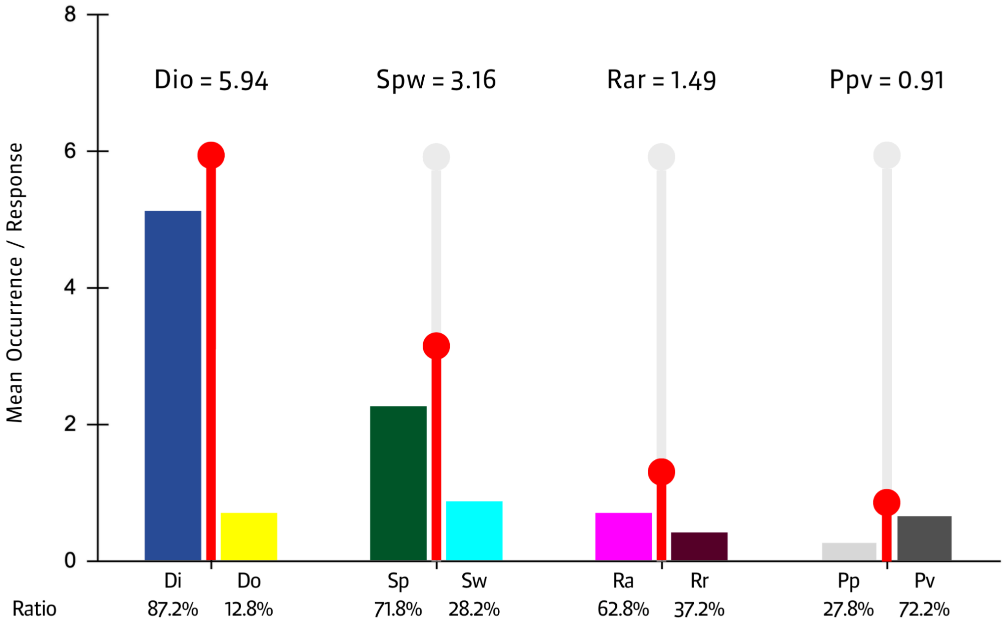


Figure 11: Summary of key results

## 5.2 Implications for Training and Future Research

Our study also uncovered the significant impact of critical thinking – evidenced by the manifestation of the Ppv pattern – on other systemic cognitive functions. Without Perspectives, Systems and Relations patterns almost vanish, leaving only Distinctions. In contrast, the inclusion of perspectives, even just nuances of perspectives, leads to a substantial increase in Systems and Relations patterns.

The findings from this study, though based on a limited sample, highlight several avenues for future research in this field. Specifically:

- The concept of DSRP-Scoring of texts, which seeks language elements linked to specific systemic cognitive functions, shows promise. It allows for the determination of an individual's systems thinking profile and identification of its strengths and weaknesses, offering significant academic and applied potential.
- The DSRP-Scoring protocol, informed by this study, can be refined for future research applications.
- Our results indicate that DSRP model training does not necessarily reduce occurrence biases in different patterns. This suggests a need for targeted training that emphasizes balancing elementary cognitive functions and DSRP patterns, with particular focus on the DSRP Perspectives and Relations patterns.

In conclusion, this study substantiates the prevalence of biases in systems thinking, highlighting the challenges in practicing systems thinking appropriately. It shed new light on addressing the thinking algorithms that govern our thinking and shape our mental models. The results emphasize the importance of systematically integrating principles that counteract biases in systems thinking into systemic approaches. This involves more systematic incorporation of ST-Bias analysis in various domains, such as systemic interventions, systems thinking training, and interpersonal relationship development methods.

We trust that our study lays the groundwork for a new path in deeper analysis of systems thinking. It introduces an innovative method applied to language analysis. This method, currently applied to written language, holds potential for broader application in other forms of communication, enabling measurement of systems thinking in individual behaviors.

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