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On the Nature of Entropy and Complexity in Psychology

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Declaration

I certify that the thesis I have presented for examination for the MPhil/PhD degree of the London School of Economics and Political Science is solely my own work other than where I have clearly indicated that it is the work of others (in which case the extent of any work carried out jointly by me and any other person is clearly identified in it).

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Abstract

The link between entropy and complexity is the cornerstone of all complex systems. Despite their significance and previous research indicating that the principles of entropy and complexity can be applied to psychological systems, a theoretically and methodologically comprehensive examination of their link has remained largely unexplored in psychology. To address this, the present research investigated the link between entropy and complexity in psychological systems. Drawing on the theoretical and methodological approaches of complexity science, this research examined the link across three distinct yet interrelated lines of investigation that consisted of nine online studies (N = 665) and used a combination of linear and nonlinear analysis techniques. In Part I, the link was examined in relation to *patterns*, with the evaluation of the stimulus being the focus of the investigation. In Parts II and III, the link was examined in relation to *processes*, with the response to the stimulus being the focus of the investigation. More specifically, Part II focused on processes at the macro-level, after which Part III extended the focus to both the macro- and micro-levels. On the whole, the present research established and empirically validated an integrative perspective on how entropy and complexity – two fundamental concepts that are essential for understanding complex systems in nature – impact the dynamics of psychological systems.

Keywords: entropy, negentropy, complexity, complexity science, sample entropy, recurrence quantification analysis

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Introduction

Life, this anti-entropy, ceaselessly reloaded with energy, is a climbing force, toward order amidst chaos, toward light, among the darkness of the indefinite, toward the mystic dream of Love, between the fire which devours itself and the silence of the Cold. Such a Nature does not accept abdication, nor skepticism.

No doubt, man will continue to weigh and to measure, watch himself grow, and his Universe around him and with him, according to the ever growing powers of his tools. For the resolving powers of our scientific instruments decide, at a given moment, of the size and the vision of our Universe, and of the image we then make of ourselves. Once Ptolemy and Plato, yesterday Newton, today Einstein, and tomorrow new faiths, new beliefs, and new dimensions.

– Albert Claude, *Nobel Lecture*, *1974*

In school, you have been taught that what makes the world go round is energy. For instance, energy makes our engines run, plants grow, me write this thesis, and you read it. However, there is something that does not add up. According to the first law of thermodynamics, energy is conserved (i.e., it cannot be created or destroyed) (Carnot, 1824; Clausius, 1865), as you have also been told in school. Therefore, if energy is conserved, why cannot we keep on using the same energy, and why do we have to resupply it constantly?

To answer this question, we need to turn to the second law of thermodynamics, which refers to *entropy*. More exactly, if energy is conserved, it can only be transferred by performing work (i.e., energy is converted from one form to another). Nevertheless, none of these transfers are entirely efficient, which means that a certain amount of energy is converted into a form that is unusable to perform work. This unusable amount of energy has been the initial definition of entropy and forms the basis of the second law of thermodynamics (Carnot, 1824; Clausius, 1865).

Entropy is often simply defined as the amount of disorder in a system due to the fact that entropy is related to heat through the second law, and heat is defined as a state of molecular disorder (Boltzmann, 1877). More precisely, the second law states that the energy of a system transforms itself into thermal energy (i.e., heat), and this heat passes only from hot to cold bodies, and this process is irreversible (Carnot, 1824; Clausius, 1865). In simple terms, the second law states that the entropy of an isolated system increases with time.

Thus, although the total energy in the universe remains the same, consistent with the first law, every energy transfer leads to an increase in entropy and a reduced amount of usable energy, and it is this that cannot be turned back since the second law demands it. This means that the entropy of an isolated system increases until it reaches its maximum level, at which point no more usable energy is available. In other words, the system grows towards a state of increasing disorder until it reaches a final state of "heat death" (Helmholtz, 1854/1995). Subsequently, what drives the world is not energy but low entropy. If so, how do we get low entropy?

As previously stated, the second law applies to isolated systems, which are systems that cannot decrease their entropy by themselves in isolation without an external energy exchange with their surroundings. Now imagine the universe as an isolated system where entropy continues to grow, making more energy unusable, consistent with the second law. Nevertheless, most systems in the universe are open and can exchange energy with their surroundings (Janson, 2010), which allows them to reduce their entropy by dissipating it into their environment (Prigogine & Stengers, 1997). By reducing their internal entropy, open systems increase the external entropy of their environment, thus keeping the total energy in the universe the same, consistent with the first law of energy conservation. In other words, open systems engage in processes against entropy, leading Schrödinger (1944) to coin them as negative entropy or, shortly, *negentropy*. Therefore, entropy refers to processes leading a system towards disorder, whereas negentropy refers to processes leading a system towards order.

Entropy and negentropy also represent the most fundamental processes that guide all open systems because their survival depends on these processes (Schrödinger, 1944; Prigogine & Stengers, 1997). More precisely, without energy dissipation, any system would grow towards a state of maximum entropy, where it would not have any more usable energy to perform work, therefore ultimately being destroyed in a Darwinian style (Helmholtz, 1854/1995). In this respect, it has been suggested that the capacity of a system to reduce entropy constitutes the most important criterion for natural selection and evolution (Kauffman, 1993). In line with this, a large body of neuroscientific research has argued that the fundamental objective of any psychological system is to minimise entropy and that this is achieved via negentropic processes (Friston et al., 2006; Friston, 2009, 2010). But how exactly do these processes of entropy management manifest in systems?

The answer to this question is *complexity*. More specifically, complex systems are systems that are composed of many constituent parts, which in turn can themselves be composed of other sub-systems (Bar-Yam, 1997; Baranger, 2000; Richardson & Chemero, 2014; Richardson et al., 2014). The constituent parts of the system are interdependent, which implies that the micro-level interactions among the constituent parts modulate and, simultaneously, are being modulated by the macro-level organisation of the system (Bar-Yam, 1997; Richardson & Chemero, 2014; Richardson et al., 2014). These interactions among the constituent parts of the system happen in a nonlinear dynamical way, which entails that, over time, the degree of change at the micro-level will not be proportional to the degree of change at the macro-level of the system (Richardson & Chemero, 2014; Richardson et al., 2014).

On the whole, these properties allow complex systems to engage in their hallmark processes of self-organisation and emergence, which entail the creation of new structures that allow for internal entropy reduction. These processes are therefore negentropic, consistent with Schrödinger (1944). Moreover, the far-from-equilibrium state is typical for complex systems, as in this state their entropy is minimal, which implies that the system best uses its energy, thus increasing its chances for survival (Helmholtz, 1854/1995; Kauffman, 1993). The link between entropy and complexity is therefore the cornerstone of all complex systems, including psychological ones.

Beyond their importance, entropy and complexity are deeply linked through their histories. Entropy was first developed by thermodynamics (Carnot, 1824; Clausius, 1865; Boltzmann, 1877; Gibbs, 1878) and then applied in information theory (Shannon, 1948). Building on this work, negentropy was later advanced by cybernetics (Ashby, 1947, 1962; Wiener, 1948), advancements that ultimately paved the way towards complexity. Thus, not surprisingly, the concepts are currently studied theoretically and methodologically under the umbrella of complexity science.

At the most fundamental level, complexity science investigates complex systems, which include most systems in the universe. For example, the human body, the Earth, and ultimately the entire universe are all considered complex systems. Accordingly, complexity science has been hailed as the “Science of all Sciences” (Johnson, 2009, p. 18) and the science that “includes the entire spectrum […] – it’s a theory of everything” (Lewin et al., 1998, p. 85), and its theoretical and methodological approaches have been applied successfully in many distinct branches of science, including: formal sciences – mathematics (e.g., Chaitin, 1994); natural sciences – physics (e.g., Gleick, 1988), chemistry (e.g., Whitesides & Ismagilov, 1999), and biology (e.g., Salthe, 1993); and social sciences – economics (e.g., Arthur, 2013) and psychology (e.g., Kelso, 1995).

As the principles of entropy and complexity can be applied to any complex system, it might not be surprising that they have also been applied to examine psychological systems (e.g., Vallacher & Nowak, 1994, 1997; Nowak & Vallacher, 1998; Vallacher et al., 2002, 2015; Van Orden & Holden, 2002; Van Orden et al., 2003, 2005, 2010, 2012; Holden, 2005; Riley & Van Orden, 2005; Friston et al., 2006; Friston, 2009, 2010; Holden et al., 2009, 2011; Stephen et al., 2009; Hirsh et al., 2012; Riley & Holden, 2012; Van Orden & Stephen, 2012; Richardson & Chemero, 2014; Richardson et al., 2014; Dalege et al., 2018; Wallot & Stephen, 2018; Amon & Holden, 2019; Annand & Holden, 2023).

In spite of their importance and the existing body of research showing that the principles of entropy and complexity can be extended to psychological systems, a theoretically and methodologically comprehensive investigation of their link has been limited in psychology. Therefore, the purpose of the present research was to investigate the link between entropy and complexity in psychological systems.

To achieve this objective, the present research adopted the theoretical and methodological approaches of complexity science. The motivation for choosing a complexity science approach was fourfold. First, since the concepts of entropy and complexity belong to the complexity family and are essential to the study of complex systems (e.g., Gell-Mann, 1995; Mitchell, 2009; Lineweaver et al., 2013; Zurek, 2018;

Davies, 2019), a complexity science approach is therefore the most suitable for the investigation of these concepts. Second, as psychological systems have indicated intrinsic complexity (e.g., Vallacher & Nowak, 1994, 1997; Nowak & Vallacher, 1998; Vallacher et al., 2002, 2015), this entails that they can be examined using the theoretical and methodological approaches of complexity science. Third, a complexity science approach provides new theoretical insights that mainstream approaches would not be able to since they rarely acknowledge the complexity of psychological systems (e.g., Riley & Holden, 2012; Van Orden et al., 2012; Van Orden & Stephen, 2012; Richardson & Chemero, 2014; Richardson et al., 2014; Wallot & Stephen, 2018; Amon & Holden, 2019). Last, complexity science tools capture the dynamics of psychological systems more precisely than traditional methods, therefore allowing the investigation of these new theoretical insights more convincingly than previously available methods (e.g., Holden, 2005; Riley & Van Orden, 2005; Riley & Holden, 2012; Van Orden et al., 2012; Van Orden & Stephen, 2012; Richardson & Chemero, 2014; Richardson et al., 2014; Wallot & Stephen, 2018; Amon & Holden, 2019).

On the whole, the theoretical and methodological approaches of complexity science are the most suitable for studying psychological phenomena in general and the link between entropy and complexity in psychological systems in particular. Furthermore, drawing on the multidisciplinary literature in which the concepts of entropy and complexity are important and integrating them with existing psychological theory provides a more precise understanding of the examined link and places it within a broader multidisciplinary context.

The remainder of this thesis is summarised as follows. First, a theoretical review will be conducted, which consists of four sections. The first section reviews the concept of entropy, from its origins in thermodynamics to its application in information theory. The second section reviews the concept of negentropy, from its origins in physics to its application in cybernetics, and discusses how this work has paved the path towards complexity. The third section reviews the concept of complexity, from its generally accepted properties to its application in algorithmic information theory. The fourth and final section discusses the link between entropy and complexity in psychological systems as an integrated theoretical framework. Due to the extensive scope and intricate nature of each concept, the theoretical review is not exhaustive and must necessarily be selective, in the sense that it focuses on the most important aspects while still providing sufficient information for the purpose of the present research. Following the theoretical review, the methods and results are presented. Last, the findings are discussed, along with the contributions and limitations of the present research.

Theoretical Review

Entropy

In this section, the concept of entropy is reviewed, from its origins in thermodynamics to its application in information theory. Before delving into entropy, the notions of system, surroundings, and boundary are introduced, as they are central to the discussion.

System, Surroundings, and Boundary

"What is a system? As any poet knows, a system is a way of looking at the world" (Weinberg, 1975, p. 52). In general, a system is a theoretical construct that represents the object of investigation (Ward, 2002; Rickles et al., 2007). In particular, in thermodynamics, a system is the part of the universe that represents the object of investigation. The remaining part of the universe that is not included in the system is the surroundings. As a general principle, the system and its surroundings form the entire universe.

The system and its surroundings are separated by a boundary (factual or notional) that acts as an interface through which matter and/or energy are exchanged. Matter is anything that has mass and takes up space. In contrast, energy has neither mass nor takes up space and represents the ability of a system to perform work (i.e., transfer energy by converting it from one form to another) (Carnot, 1824; Clausius, 1865).

The types of systems are categorised based on whether matter and/or energy are exchanged during the interaction between the system and its surroundings. More precisely, there exist three types of systems: 1) open, which exchange both energy and matter; 2) closed, which exchange only energy but not matter; and 3) isolated, which exchange neither energy nor matter with their surroundings (Janson, 2010). All biological systems, including human beings, are open systems (Janson, 2010).

Physical Entropy

Entropy originated in classical thermodynamics, a branch of physics that investigates the exchanges of matter and/or energy between the system and its surroundings at the macroscopic level (i.e., the large scale of observation), as governed by the four laws of thermodynamics. These are numbered from the zeroth to the third law, but this ranking is neither based on their discovery nor their importance. The focus of the discussion will be on the first and second laws of thermodynamics, as they are of interest to this thesis (for further reading on the thermodynamical laws, see Clausius, 1865; Schrödinger, 1989).

The first law of thermodynamics states that the total amount of energy in the universe is conserved, so it never changes (i.e., it cannot be created or destroyed) (Carnot, 1824; Clausius, 1865). In other words, energy can only be transferred by performing work (i.e., energy is converted from one form to another). Nevertheless, none of these transfers are entirely efficient, which means that a certain amount of energy is converted into a form that is unusable to perform work. This is because useful work always depends on the movement of energy from one area to another.

This unusable amount of energy has been the initial definition of entropy (*S*), as designated by Rudolf J. E. Clausius (1865), and forms the basis of the second law of thermodynamics. More exactly, the second law states that the entropy of an isolated system increases or remains constant but never decreases with time (Clausius, 1865):

$$\Delta S \geq 0$$

where ΔS represents the change in entropy. In other words, the amount of unusable energy in an isolated system increases until or stays the same once it reaches thermodynamic equilibrium but never becomes usable again, so the process is irreversible. The level of entropy in a system therefore increases until it reaches a maximum level that constitutes thermodynamic equilibrium, which implies that the energy is dispersed equally throughout the system and no more useful work can be performed.

Entropy is often simply defined as the amount of disorder in a system due to the fact that entropy is related to heat through the second law, and heat is defined as a state of molecular disorder (Boltzmann, 1877). More precisely, the second law states that the energy of a system transforms itself into thermal energy (i.e., heat), and this heat passes only from hot to cold bodies, and this process is irreversible (Clausius, 1865). This implies that the system grows towards a state of increasing disorder until it reaches a final state of “heat death” (Helmholtz, 1854/1995).

This definition of entropy came from statistical mechanics, which emerged as a new branch of physics using statistics and probability theory to investigate the exchanges of matter and/or energy between the system and its surroundings at the microscopic level (i.e., the small scale of observation) in order to provide an explanation for the phenomena observed at the macroscopic level (i.e., the large scale of observation). In statistical mechanics, macroscopic level properties (e.g., pressure, temperature, volume, etc.) are described by a macrostate, whereas microscopic level properties (i.e., the position and momentum of particles) are described by a microstate.

Building on the classical thermodynamic approach of Clausius (1865) by applying statistical mechanics, Ludwig E. Boltzmann (1877) defined the entropy of a macrostate as a function of the number of microstates:

$$S = k_{\mathrm{B}} \ln \Omega$$

where S is the entropy, k_{B} is the Boltzmann constant, and Ω is the number of microstates. This implies that the entropy of an isolated system is higher if there are more possible configurations of microstates for a given macrostate. This higher entropy indicates a higher level of disorder in the system. In contrast, the entropy of an isolated system is lower if there are fewer possible configurations of microstates for a given macrostate, indicating a higher level of order in the system.

As Boltzmann’s (1877) entropy applies only to systems in thermodynamic equilibrium, his definition was extended to systems in thermodynamic non-equilibrium by J. Willard Gibbs (1878), who defined the entropy of a macrostate as a function of the probabilities of the microstates:

$$S = -\, k_{\mathrm{B}} \sum_{i=1}^{\Omega} p_i \ln p_i$$

where S is the entropy, k_{B} is the Boltzmann constant, Ω is the number of microstates, $\sum$ is the sum of the possible microstates, and p_i is the probability of microstate i. In simple terms, Gibbs’ (1878) entropy is the generalised form of Boltzmann’s (1877) entropy. This is because all microstates are equiprobable in thermodynamic equilibrium, which means that each microstate has a probability p of $\frac{1}{\Omega}$, where Ω is the number of microstates. Therefore, if we apply this to Gibbs’ (1878) equation, we get Boltzmann’s (1877) equation.

In summary, the first law of thermodynamics refers to the conservation of total energy in the universe, whereas the second law of thermodynamics refers to entropy. These laws have been explained both at the macroscopic level by classical thermodynamics, through the work of Clausius (1865), and at the microscopic level by statistical mechanics, through the works of Boltzmann (1877) and Gibbs (1878). In this respect, the importance and impact of thermodynamics were perfectly stated by Albert Einstein (as cited in Rajeev, 2008):

A theory is the more impressive the greater the simplicity of its premises, the more different kinds of things it relates, and the more extended its area of applicability. Therefore the deep impression that classical thermodynamics made upon me. It is the only physical theory of universal content which I am convinced will never be overthrown, within the framework of applicability of its basic concepts. (pp. 768-769)

Information Entropy

So far, the concept of entropy has been reviewed from a physical perspective in classical thermodynamics and statistical mechanics. Beyond thermodynamics, the concept of entropy has also been applied in information theory in mathematics, therefore extending its application from thermodynamic systems to information systems (Jaynes, 1957a, 1957b; Pierce, 1980).

The most important application comes from Claude E. Shannon (1948), who defined entropy as the expected amount of information (also called surprisal or randomness) of an event, taken over all possible outcomes of the event:

$$H = -\sum_{i=1}^{n} p_i \log_b p_i$$

where H is the entropy of the event, $\sum$ is the sum of the possible outcomes of the event, b is the base of the logarithm used, and p_i is the probability of the outcome i of the event. Depending on the choice of b, the units of entropy will be called bits or shannons ($b = 2$), nats ($b = e$), or bans ($b = 10$). Most commonly, b is set to 2. The negative sign in the formula is to assure that the result is always positive or zero. The minimum entropy is registered for the probability p = {0, 1} because the event is known, and the entropy is therefore zero. For other probabilities, entropy will be in the range of zero to one.

The fundamental idea behind Shannon’s (1948) formula (i.e., quantifying the amount of information in an event) is to measure how much surprise or randomness there is in an event. More precisely, the entropy of an event is lower (i.e., the event is very low in information) when there is a high probability of the event happening. This is because, if the event is common, there is no surprise (i.e., no randomness) when the event happens as expected, so the occurrence of the event carries very little new information. In contrast, a low probability event has higher entropy (i.e., the event is very high in information). This is because rare events are more surprising (i.e., more random), so their occurrence is more informative than in the case of common events. For instance, it is more informative to know that a given number will be the winning number for the lottery (i.e., a low probability event) than to know that the same number will not be the winning number since the number will certainly not win (i.e., a high probability event).

The information entropy derived in information theory was later mathematically connected to the physical entropy derived in statistical mechanics by E. T. Jaynes (1957a, 1957b), leading to a deeper understanding of the relationship between information and physical processes (Bawden & Robinson, 2015a). More precisely, Jaynes (1957a, 1957b) recognised the similarity between the expressions for Gibbs’ (1878) thermodynamic entropy and Shannon's (1948) information entropy and demonstrated that a mathematical connection exists between them, showing that many results in statistical mechanics can be interpreted as applications of Shannon's information entropy to physical systems.

Conclusion. In this section, the concept of entropy has been reviewed**,** from its origins in thermodynamics to its application in information theory. Next, the concept of negentropy is reviewed.

Negentropy

In this section, the concept of negentropy is reviewed, from its origins in physics to its application in cybernetics, and a discussion is made about how this work has paved the path towards complexity.

Physical Negentropy

As previously mentioned, the second law of thermodynamics states that the entropy of an isolated system increases or remains constant but never decreases with time, eventually leading the system towards a state of maximum entropy where it reaches thermodynamic equilibrium and no more useful work can be performed (Carnot, 1824; Clausius, 1865).

However, the second law holds for isolated systems but not for open systems. This is because open systems do not exist in isolation and constantly exchange matter and energy with their surroundings (Janson, 2010). This exchange of matter and energy allows open systems to decrease their entropy by dissipating it into their environment, for which they are also called dissipative (Prigogine & Stengers, 1997).

This is in line with the second law, which states that a system cannot decrease its entropy by itself in isolation without the help of an external exchange with its surroundings (Carnot, 1824; Clausius, 1865). Moreover, by reducing their internal entropy, open systems increase the external entropy of their environment, therefore keeping the total energy in the universe the same, consistent with the first law of energy conservation[1] (Carnot, 1824; Clausius, 1865).

According to Erwin Schrödinger (1944), this principle of entropy management – reducing internal entropy while increasing that of the surroundings – is fundamental for all open and dissipative systems because their survival depends on it. In other words, a system needs to dissipate its entropy into its surroundings in order to survive. This is due to the fact that, without entropy dissipation, the system would reach a state of maximum entropy and would be destroyed by "heat death" (Helmholtz, 1854/1995; Kauffman, 1993).

Schrödinger (1944) coined this process of entropy management "negative entropy," which was later shortened to "negentropy" by Leon Brillouin (1953), the latter of which remained the term used until nowadays.

Beyond physics, the concept of negentropy has been applied in cybernetics, most notably by its founder, Norbert Wiener (1948), and by another famous cybernetician, W. Ross Ashby (1947, 1962), whose work paved the path towards complexity.

In this respect, Ashby (1947, 1962) derived the original principle of self-organisation, which is now widely acknowledged as a defining characteristic of complex systems. According to Ashby (1947, 1962), self-organisation involves the breaking and reforming of constraints among the constituent parts of the system, allowing for the emergence of a new structure. The existence of constraints implies that there is a form of interdependence between the parts of the system, which can be understood in terms of entropy. More precisely, in a high entropy state, the system would be more disordered, which would imply that the constituent parts are interacting loosely without much constraint. In contrast, in a low entropy state, which is characterised by less disorder (i.e., more order), the interactions among the constituent parts would be more constrained.

Furthermore, self-organised structures emerge when the system is far-from-equilibrium, which denotes a state where the constraints among the constituent parts of the system disappear, allowing previously chained parts to interact and therefore the system to organise itself into a new structure (Prigogine & Stengers, 1997). This new emergent structure implies that the system has reached a low entropy state, which is better for entropy dissipation (Ashby, 1947, 1962). As self-organisation and emergence entail the creation of new structures that allow for internal entropy reduction, these processes are negentropic, consistent with Schrödinger (1944). Moreover, the far-from-equilibrium state is typical for open and

[1] The first law of thermodynamics states that the total amount of energy in the universe is conserved, so it never changes (i.e., it cannot be created or destroyed) (Carnot, 1824; Clausius, 1865).

dissipative systems, as in this state their entropy is minimal, which implies that the system best uses its energy, therefore increasing its chances for survival (Helmholtz, 1854/1995; Kauffman, 1993).

In summary, the second law of thermodynamics holds for isolated systems but not for open systems. This is because open systems constantly exchange matter and energy with their surroundings, which allows them to reduce their internal entropy by dissipating it into the environment. This principle of entropy management is known as negentropy. Entropy therefore refers to processes leading a system towards disorder, whereas negentropy refers to processes leading a system towards order. In open and dissipative systems, negentropic processes manifest through self-organisation and emergence, the hallmark properties of complexity.

Information Negentropy

The other advancement in cybernetics was made by Wiener (1948), who derived a cybernetic perspective of entropy that viewed information as negentropic, consistent with Schrödinger's (1944) principle of entropy management[2]. More exactly, Wiener (1948) argued that as entropy tends to increase, information tends to decrease (i.e., lose its informational value) because the system continuously interacts with its surroundings. Nevertheless, the scope of communication is to assure that information is properly transmitted, and that depends on information being structured and not random. Information is thus negentropic because it is always fighting the tendency for entropy to increase (i.e., destroying the structure) and instead relying on the formation of structures. In other words, Wiener (1948) defined entropy as a measure of disorder (i.e., randomness) and information as a measure of order (i.e., non-randomness). Simply put, information is essentially the negative of its entropy (i.e., negentropy): the more common the information, the less value it provides.

To illustrate Wiener's (1948) perspective, for a piece of information to provide new knowledge, it has to unveil something significantly different from the existent stock of knowledge in the community. For example, clichés are less informative than great novels. This is because the public has become acquainted with their contents, so the information has become very common, hence the prevalence of clichés. Nonetheless, even great novels have lost their informative value to a great extent since their contents are well known to the public. In order to continue to draw informational value, new layers of meaning need to be unveiled, and this is only possible if the novels are being studied at a level that is deeper than the currently held level of knowledge.

On the whole, Shannon (1948) and Wiener (1948) had distinct views on the relationship between information and entropy. More specifically, Shannon (1948) viewed information as entropy and associated it with randomness. In contrast, Wiener (1948) viewed information as negative entropy (i.e., negentropy) and associated it with order (i.e., non-randomness).

Despite Wiener's (1948) negentropy not being as widely used or accepted as Shannon's (1948) entropy, it is still recognised as an important contribution because it shifted the mainstream perspective, which was focused on entropy and the eventual heat death of the universe, bringing into question phenomena that are now described as complex. This is perfectly stated by Hayles (1999):

…can be seen as a crucial crossing point, for this allowed entropy to be reconceptualized as the thermodynamic motor driving systems to self-organization rather than as the heat engine driving the world to universal heat death…chaos went from being associated with dissipation in the Victorian sense of dissolute living and reckless waste to being associated with dissipation in a newly positive sense of increasing complexity and new life. (pp. 102-103)

Conclusion. In this section, the concept of negentropy has been reviewed, from its origins in physics to its application in cybernetics, and a discussion has been made about how this work has paved the path towards complexity, which is reviewed next.

[2] Wiener's (1948) perspective on entropy was the reason why Brillouin (1953) shortened Schrödinger's (1944) "negative entropy" into "negentropy".

Complexity

In this section, the concept of complexity is reviewed. As complexity does not have a precise definition, with some scientists even stating that "complexity, by its very nature is an impossible term to define… complex systems defy definition" (Batty et al., 2014, p. 364), the focus of this review is on the definitions that are most generally accepted, especially in terms of their subsequent application in psychology.

Physical Complexity

Despite lacking a precise definition, the meaning of complexity can be conveyed through its properties, for which there is a general agreement among scientists (for a discussion, see Gallagher & Appenzeller, 1999; Baranger, 2000). To facilitate the understanding of these properties, the human body – one of the most well-known complex systems – will be used as an example throughout the entire description.

First, complex systems are highly composite (Bar-Yam, 1997; Baranger, 2000; Richardson & Chemero, 2014; Richardson et al., 2014). This entails that these systems are composed of many constituent parts, which in turn can themselves be composed of other sub-systems. For instance, the human body is formed of 11 systems (e.g., circulatory, nervous, and muscular), which in turn are themselves formed of other sub-systems (e.g., the circulatory system consists of the heart, blood, arteries, and so forth).

Second, the constituent parts of the system are interdependent (Bar-Yam, 1997; Richardson & Chemero, 2014; Richardson et al., 2014). This implies that the micro-level interactions among the constituent parts modulate and, simultaneously, are being modulated by the macro-level organisation of the system. For example, the circulatory system (micro-level) modulates the behavioural order of the human body (macro-level), and the order of the human body in turn alters the behaviour of the circulatory system within it.

Third, the interactions among the constituent parts of the system happen in a nonlinear dynamical way (Rickles et al., 2007; Gros, 2010; Richardson & Chemero, 2014; Richardson et al., 2014). Dynamic entails that the state[3] of the system changes over time (Beer, 2000; Gros, 2010). For instance, the human body exhibits dynamic behaviour through processes such as cell renewal and muscle growth because they imply an evolution of the body and its sub-systems over time. Nonlinearity implies a multiplicative rather than additive effect, therefore mathematically disobeying the superposition principle, which states that input changes are proportional to output changes and the output can be represented as the weighted sum of input changes (Lewontin, 1974). For complex systems, nonlinearity implies that the degree of change at the micro-level will not be proportional to the degree of change at the macro-level of the system (Richardson & Chemero, 2014; Richardson et al., 2014). In the case of the human body, for example, changes in the heart will have a different magnitude in the circulatory system than in the other systems or the body as a whole.

On the whole, these properties allow complex systems to engage in their hallmark processes of self-organisation and emergence (Bar-Yam, 1997; Baranger, 2000; Richardson & Chemero, 2014; Richardson et al., 2014). Emergence entails that the macro-level order of the system results from the interactions among micro-level constituent parts and cannot be reduced to these individual parts, thus reflecting the non-decomposability of the system (Richardson & Chemero, 2014; Richardson et al., 2014). In other words, the system cannot be understood by studying its constituent parts in isolation but only through their interactions. For instance, we cannot understand walking if we study only a leg or only the trunk, as walking reflects the emergent behaviour of many components of the human body.

Self-organisation is a process by which the interactions among the micro-level constituent parts result in changes in the macro-level order of the system, and this organisation happens in an independent manner in the absence of an invisible hand (Johnson, 2009; Richardson & Chemero, 2014; Richardson et al., 2014). In other words, the macro-level structure arises solely from the interactions of the micro-level parts of the system, without the help of a central executive authority or isolated causal structures.

[3] A state is the current value of the variable(s) that is used to capture the system, and this is represented by a point in the state space (i.e., the set of all the possible values of the variable(s)). The path that is traced by the evolving state of the system over time is called a trajectory (Rickles et al., 2007; Gros, 2010).

Self-organisation therefore determines the emergent order of the system, as the emergent macro-level structure results from the interaction among micro-level parts. In the case of the human body, the interaction among the many distinct systems and their sub-systems leads to the emergence of the body as a whole. For example, atoms make up different types of cells, cells create various organs, and groups of organs function within the 11 larger systems, which in turn compose the human body as one.

In summary, despite lacking a precise definition, the meaning of complexity can be conveyed through generally agreed-upon properties. More precisely, a complex system is one that is composed of many interdependent parts that interact in a nonlinear dynamical way and that exhibits self-organised and emergent behaviour.

Information Complexity

The relationship between information and complexity has mostly been explored through the concept of entropy. As previously mentioned, Shannon (1948) equated information with entropy, linking it with randomness. In contrast, Wiener (1948) equated information with negentropy, linking it with order (i.e., non-randomness). In this respect, most information approaches to complexity have adopted Shannon's (1948) perspective by default.

The most important of these approaches is the concept of algorithmic information content (AIC) – first introduced by Ray Solomonoff (1964) and then independently derived by Andrey Kolmogorov (1965) and Gregory Chaitin (1966) – who proposed quantifying the complexity of a string by determining the length of the shortest programme that can describe the string. More specifically, the shorter the programme, the less complex the string is considered to be.

These definitions have played an important role in understanding and measuring complexity in terms of compressibility, which refers to the ability to describe a string in a concise manner using a shorter programme. If a string is compressible, it signifies the existence of order (i.e., non-randomness). In contrast, if a string is incompressible, it signifies the existence of randomness. In other words, if the programme describing the string is concise, the string is considered simple (i.e., has a low AIC). In contrast, if the programme is lengthy, the string is considered complex (i.e., has a high AIC).

To illustrate, let’s take the following two strings:

String A: 0101010101010101010101

String B: 0110100011011110001011

String A can be described using a short programme (i.e., Print 01 eleven times), which indicates that this string has a low AIC. In contrast, string B can only be described using a longer programme (i.e., Print 0110100011011110001011), which indicates that this string has a high AIC. In simple terms, string A is compressible, but string B is not, therefore indicating that string B is more complex (i.e., it contains more algorithmic information).

The principle behind AIC is that strings higher in randomness require more information to be described, and therefore they are considered to be more complex as they are less compressible. In this respect, AIC attributes higher information content to random strings than to those that would be commonly perceived as complex. Thus, AIC challenges the intuitive perception of complexity (Bawden & Robinson, 2015a, 2015b), according to which "the most complex entities are not the most ordered or random ones but somewhere in between" (Mitchell, 2009, p. 98).

Despite not being a perfect measure of complexity, AIC has had a profound impact on multiple disciplines, including psychology, by allowing scientists to assess the information content of strings and therefore gain a deeper understanding of complex systems (e.g., Ben-Mizrachi et al., 1984; Grassberger & Procaccia, 1983; Eckmann & Ruelle, 1985; Grassberger, 1988; Grassberger et al., 1991; Pincus, 1991, 1995; Richman & Moorman, 2000; Richman et al., 2004).

Conclusion. In this section, the concept of complexity has been reviewed, from its generally accepted properties to its application in algorithmic information theory. Next, the link between entropy and complexity in psychology is discussed.

Entropy and Complexity in Psychology

Until now, the concepts of entropy and complexity have been reviewed, from their original to subsequent applications, therefore tracing their link not only through their historical evolution but also through their theoretical and methodological developments. In this section, the link between entropy and complexity in psychological systems is discussed as an integrated theoretical framework.

Objective

Since the principles of entropy and complexity are applicable to all complex systems, it might not be surprising that they have also been used to examine psychological systems (e.g., Vallacher & Nowak, 1994, 1997; Nowak & Vallacher, 1998; Vallacher et al., 2002, 2015; Van Orden & Holden, 2002; Van Orden et al., 2003, 2005, 2010, 2012; Holden, 2005; Riley & Van Orden, 2005; Friston et al., 2006; Friston, 2009, 2010; Holden et al., 2009, 2011; Stephen et al., 2009; Hirsh et al., 2012; Riley & Holden, 2012; Van Orden & Stephen, 2012; Richardson & Chemero, 2014; Richardson et al., 2014; Dalege et al., 2018; Wallot & Stephen, 2018; Amon & Holden, 2019; Annand & Holden, 2023).

Despite their significance and previous research indicating that the principles of entropy and complexity can be applied to psychological systems, a theoretically and methodologically comprehensive examination of their link has remained largely unexplored in psychology. Therefore, the purpose of the present research was to investigate the link between entropy and complexity in psychological systems. More precisely, this research examined how the link between entropy and complexity manifests in the processes of the brain and body of an individual during task performance.

Approach

To achieve this objective, the present research adopted the theoretical and methodological approaches of complexity science.

At the most fundamental level, complexity science investigates complex systems, which include most systems in the universe. For example, the human body, the Earth, and ultimately the entire universe are all considered complex systems. Accordingly, complexity science has been hailed as the "Science of all Sciences" (Johnson, 2009, p. 18) and the science that "includes the entire spectrum […] – it's a theory of everything" (Lewin et al., 1998, p. 85), and its theoretical and methodological approaches have been applied successfully in many distinct branches of science, including: formal sciences – mathematics (e.g., Chaitin, 1994); natural sciences – physics (e.g., Gleick, 1988), chemistry (e.g., Whitesides & Ismagilov, 1999), and biology (e.g., Salthe, 1993); and social sciences – economics (e.g., Arthur, 2013) and psychology (e.g., Kelso, 1995).

As an interdisciplinary science, the theoretical and methodological approaches of complexity science have been shaped by the various disciplines in which they have been applied, often leading to confusion and inconsistencies in terminology. In this respect, complexity science has come under many names, including complex systems theory (Gilden et al., 1995; Gros, 2010), complex dynamical systems (Abraham, 1984; Richardson et al., 2014), and the sciences of complexity (Pagels, 1988; Kauffman, 1990), among others.

In psychology, the terminology of complexity science has often been used equivalently with the terminologies from dynamical systems in general, the latter of which have also come under many names, including dynamical systems perspective (Beer, 1995; Krpan, 2017), dynamical systems theory (Vallacher & Novak, 1997), and nonlinear dynamics (Stephen et al., 2009; Janson, 2010), among others. The conflation of terminology occurs because dynamical systems as a whole refer both to simple and complex systems, and the theoretical and methodological tools used in simple systems are a pre-requisite for understanding and can also be applied to complex systems (Ward, 2000; Gros, 2010; Butner et al., 2015; Krpan, 2017). In other words, the approaches used in simple systems provide a necessary basis for studying complex systems, for which the latter can also be considered an extension of the former. The decision to conflate terminologies is therefore not necessarily mistaken, although it does add to the existing confusion and terminological inconsistency.

Taking all of the above into consideration, in this thesis, complexity science is used as an all-encompassing term that refers to the conceptual and computational tools that investigate strictly complex systems while acknowledging that their investigation requires an understanding of simple systems.

The motivation for choosing a complexity science approach was fourfold. First, as the concepts of entropy and complexity pertain to the complexity family and are central to the study of complex systems (e.g., Gell-Mann, 1995; Mitchell, 2009; Lineweaver et al., 2013; Zurek, 2018; Davies, 2019), a complexity science approach is thus the most suitable for the investigation of these concepts. Second, since psychological systems have been shown to be inherently complex (e.g., Vallacher & Nowak, 1994, 1997; Nowak & Vallacher, 1998; Vallacher et al., 2002, 2015), this implies that they can be examined using the theoretical and methodological approaches of complexity science. This argument is supported by a large body of research in psychology, where the tools have already been applied to examine affect (e.g., Thagard & Nerb, 2002; Lewis, 2005; Witherington & Crichton, 2007; Kuppens et al., 2010), personality (e.g., Mischel & Shoda, 1995; Shoda et al., 2002), and perception-action (e.g., Kelso & Kay, 1987; Turvey & Carello, 1995; Engström et al., 1996), among many others. Third, a complexity science approach offers new theoretical insights that traditional approaches would not allow, as they rarely acknowledge the complex nature of psychological systems (e.g., Riley & Holden, 2012; Van Orden et al., 2012; Van Orden & Stephen, 2012; Richardson & Chemero, 2014; Richardson et al., 2014; Wallot & Stephen, 2018; Amon & Holden, 2019). Last, complexity science allows for the examination of these new theoretical insights more convincingly than previously available methods since complexity science tools capture the dynamics of psychological systems more precisely than mainstream methods (e.g., Holden, 2005; Riley & Van Orden, 2005; Riley & Holden, 2012; Van Orden et al., 2012; Van Orden & Stephen, 2012; Richardson & Chemero, 2014; Richardson et al., 2014; Wallot & Stephen, 2018; Amon & Holden, 2019).

On the whole, the theoretical and methodological approaches of complexity science are the most suitable for studying psychological phenomena in general and the link between entropy and complexity in psychological systems in particular. Furthermore, drawing on the multidisciplinary literature in which the concepts of entropy and complexity are important and integrating them with existing psychological theory provides a more precise understanding of the examined link and places it within a broader multidisciplinary context.

Integrated Theoretical Framework

Since adopting a complexity science approach implies conceptualising psychological systems as complex – likewise other complex systems, psychological systems are expected to exhibit interaction dominant dynamics as opposed to component dominant dynamics (e.g., Van Orden & Holden, 2002; Van Orden et al., 2003, 2005, 2010; Holden et al., 2009, 2011). These perspectives have a clear connection with the properties of complex systems previously reviewed (see Complexity section), as will be discussed further.

To start with, component dominant dynamics argues that the observed dynamics of a psychological system reflect the highly delineated and independent contribution of its components, each having a specific and predetermined function in shaping the dynamics of the system (Van Orden & Holden, 2002; Van Orden et al., 2003, 2005, 2010; Holden et al., 2009, 2011). In other words, an individual's cognitive and behavioural patterns in performing a task would be the result of the independent, loosely coupled processes of the brain and body (Simon, 1973). Moreover, component dominant dynamics supports linearity (Lewontin, 1974), which entails that psychological and behavioural phenomena can be measured by measuring the effects of the processes of the brain and body separately. Take, for example, the activity of reading this thesis, which we can attribute to components such as perception, memory, and attention, among many others. In line with the component dominant dynamics perspective, reading would reflect these components working independently of each other, following predefined functions. Thus, reading would reflect the sum of all their separate effects.

In contrast, interaction dominant dynamics asserts that the components of a psychological system are not independent but highly interdependent, therefore the observed dynamics of the system are the result of the interdependent interactions among its components rather than the components themselves (Van Orden & Holden, 2002; Van Orden et al., 2003, 2005, 2010; Holden et al., 2009, 2011). This implies that the micro-level interactions among the components modulate and, simultaneously, are being modulated by the macro-level organisation of the system (Bar-Yam, 1997; Richardson & Chemero, 2014; Richardson et al., 2014). This has two important implications.

First, interaction dominant dynamics entails that the observed dynamics of a psychological system cannot be understood by studying its constituent parts in isolation but only through their interactions (Van Orden & Paap, 1997; Van Orden et al., 1997, 1999, 2001, 2003, 2005, 2010; Van Orden & Holden, 2002; Holden et al., 2009, 2011).

This is based on the inherent nonlinear character of complex systems, which implies that the degree of change at the micro-level will not be proportional to the degree of change at the macro-level of the system (Richardson & Chemero, 2014; Richardson et al., 2014). Therefore, the dynamics of the system cannot be reduced to a set of components that interact in a linear manner (Rickles et al., 2007; Gros, 2010; Richardson & Chemero, 2014; Richardson et al., 2014). Furthermore, this is reflected in the emergence property of complex systems, which entails that the macro-level order of the system results from the interactions among micro-level components and cannot be reduced to these individual parts, thus reflecting the non-decomposability of the system (Richardson & Chemero, 2014; Richardson et al., 2014). In psychology, an individual's cognitive and behavioural patterns in performing a task are therefore the result of interdependent rather than separate processes of the brain and body, and this interdependence allows the behaviour of each process to reflect something about the behaviour of the system as a whole. Following the same example, consistent with the interaction dominant dynamics perspective, reading this thesis would imply that the components attributed to performing this activity are interacting interdependently. Thus, reading would reflect the outcome of their interactions rather than their separate effects.

Second, interaction dominant dynamics entails that the emergent behaviour of the system as a whole is bound to its surroundings (Van Orden et al., 1999, 2003, 2005, 2010; Van Orden & Holden, 2002; Holden et al., 2009, 2011). In other words, an individual's cognitive and behavioural patterns in performing a task are an emergent feature of the brain and body's interdependently interacting processes, given the context in which the individual has to perform that task.

To achieve this contextual adaptation reflected in a new emerging structure, the processes of the brain and body organise themselves to match the changing conditions of a specific context (Van Orden et al., 1999, 2003, 2005, 2010; Van Orden & Holden, 2002; Holden et al., 2009, 2011). The self-organised and emergent cognitive and behavioural patterns are therefore in response to ongoing changes in information flow (Kelso, 1995). More exactly, the nervous system is presented with an array of perceptual and behavioural affordances that allow the system to identify the possible actions that can be implemented to perform the task successfully (Gibson, 1966, 1975, 1979). These affordances represent incoming sensory information from the task environment, combined with the cognitive and behavioural possibilities of the system. The nervous system must thus organise its neural structures in order to adapt to the ongoing changes in environmental information that arise during task performance by integrating the appropriate perception-action frames with the incoming sensory information (Hirsh et al., 2012).

As previously discussed, self-organised and emergent behaviour results from the interdependent interaction between the parts of the system (Ashby, 1947, 1962). This interdependence implies the existence of constraints, which can be understood in terms of entropy. Therefore, psychologically, entropy emerges as a function of the degree of constraint that is placed upon the interpretation of competing perceptual and behavioural affordances during task performance.

More precisely, a low entropy state entails that the degree of constraint is higher, and this will be reflected in a tighter coupling of the processes of the brain and body. This tighter coupling of the processes means that there are strong neural inputs for a single affordance and weak neural competition for other possible alternatives. Thus, it is easier for the nervous system to interpret the situation and select the appropriate course of action to suit the demands of the task at hand (Hirsh et al., 2012). Furthermore, as low entropy states are less random (i.e., more familiar) (Shannon, 1948), the nervous system is able to match the incoming sensory information from the environment with the existing perception-action patterns already familiar to the system. In this way, the system is able to maintain cognitive consistency, which is required in order to sustain a low entropy state (Friston et al., 2006; Friston, 2009, 2010; Dalege et al., 2018). The link between entropy reduction and cognitive consistency is also supported by existing research, which shows that people inherently prefer states of cognitive consistency (Festinger, 1957; Monroe & Read, 2008; Gawronski & Strack, 2012). Due to the high cognitive consistency, the search for a course of action becomes a more organised process, implying lower levels of entropy as more energy is saved in looking for a suitable course of action.

Therefore, during these low entropy situations, the nervous system is more efficient and can settle faster into a perceptual-behavioural frame (i.e., select a course of action).

In contrast, a high entropy situation implies that the degree of constraint is lower, as reflected in a looser coupling of the processes of the brain and body. This looser coupling of the processes entails that there is a strong neural competition for possible affordances and a lack of dominant inputs for a single one. Thus, it is more difficult for the nervous system to interpret the situation and choose among courses of action (Hirsh et al., 2012). Moreover, as high entropy states are more random (i.e., less familiar) (Shannon, 1948), the nervous system cannot match the incoming sensory information with the existing perception-action patterns, leading to cognitive inconsistency (Friston et al., 2006; Friston, 2009, 2010; Dalege et al., 2018). Because of the high cognitive inconsistency, the search for a course of action becomes a more disorganised process, entailing higher levels of entropy since more energy is wasted in looking for a suitable course of action. Thus, the brain's operation during these high entropy situations is inefficient and settles harder into a particular perceptual-behavioural frame.

These high entropy situations eventually poise the processes of the brain and body in a far-from-equilibrium state, which denotes a state where the constraints among the components of the system disappear, allowing previously chained parts to interact and therefore the system to organise itself into a new structure (Prigogine & Stengers, 1997). This new emergent structure implies that the system has reached a low entropy state, which is better for entropy dissipation (Ashby, 1947, 1962). In other words, the low entropy state suggests that the system has settled into a perceptual-behavioural frame where a course of action has been chosen. As self-organisation and emergence entail the creation of new structures that allow for internal entropy reduction, these processes are negentropic, consistent with Schrödinger (1944). Moreover, the far-from-equilibrium state is typical for open and dissipative systems, as in this state their entropy is minimal, which implies that the system best uses its energy, therefore increasing its chances for survival (Helmholtz, 1854/1995; Kauffman, 1993).

On the whole, the integrated theoretical framework indicates that the link between entropy and complexity in psychological systems manifests through interaction rather than component dominant dynamics in the processes of the brain and body during task performance. More specifically, it is expected that task performance will reflect interdependent rather than separate interacting processes, and that this performance will be context-dependent, therefore showing higher entropy when embedded in a high randomness context as opposed to a low randomness context.

Hypothesis 1: Task performance will reflect interdependent as opposed to separate interacting processes.

Hypothesis 2: Task performance will reflect contextual dependency (i.e., task performance will show higher entropy when embedded in a high randomness context as opposed to a low randomness context).

Conclusion. In this section, the link between entropy and complexity in psychological systems has been discussed as an integrated theoretical framework. Next, the overview of the present research will be discussed.

Overview of the Present Research

In this section, the overview of the present research is discussed, including key terminology, lines of investigation, studies, data collection, and data analysis.

Terminology

The purpose of the present research was to investigate the link between entropy and complexity in psychological systems. More precisely, this research examined how the link between entropy and complexity manifests in the processes of the brain and body of an individual during task performance.

In this context, *psychological system* refers to the processes of the brain and body of the participant, *surroundings* refers to the task environment the participant is embedded in, and *task performance* refers to the pattern of reaction times in the participant's responses.

Lines of Investigation

The purpose of the present research was achieved across three distinct yet interrelated lines of investigation.

Part I examined the link in relation to *patterns*, with the evaluation of the stimulus being the focus of the investigation. Parts II and III examined the link in relation to *processes*, with the response to the stimulus being the focus of the investigation. More specifically, Part II focused on processes at the macro-level, after which Part III extended the focus to both the macro- and micro-levels. Therefore, from Part I to Parts II and III, the focus shifted from the stimulus itself to the processes in response to the stimulus.

As the focus was on patterns, Part I does not directly address the research objective, and it was conducted as a test of the surroundings of the psychological system, since the system-surroundings unit of analysis is important for achieving theoretical and methodological comprehensiveness. In contrast, as the focus was on processes, Parts II and III directly address the research objective. On the whole, the three lines of investigation in relation to patterns and processes (macro- and micro-levels) allowed for a comprehensive examination of the link between entropy and complexity in psychological systems.

Studies

The studies of the present research can be categorised as follows, each having a specific purpose in addressing the research objective.

Part I: Patterns

Part I consisted of one large-scale study (Study 1). The purpose of this study was to examine (a) the relationship between entropy and complexity in relation to patterns by testing binary stimuli, with entropy expressed as a continuum between randomness and non-randomness as its endpoints and complexity expressed as a continuum between complexity and simplicity as its endpoints, and (b) if the ratio of white vs. black squares in the binary stimuli affected the examined relationship.

In Part I, the study adopted a data-driven approach (i.e., no hypotheses) (e.g., Rand, 1990; Locke, 2007; Hayes et al., 2010; Woo et al., 2017; Hayes & Heit, 2018; Jack et al., 2018; Janiszewski & van Osselaer, 2022).

Part II: Processes (Macro-Level)

Part II consisted of a combination of two small-scale and three large-scale studies (Studies 2A-4).

In relation to the small-scale studies (Studies 2A and 3A), the purpose of these studies was to (a) create a set of stimuli, (b) examine their subjective and objective randomness, and (c) use these measures to allocate the stimuli between conditions for the subsequent large-scale studies (Studies 2B, 3B, and 4).

In relation to the large-scale studies, the purpose of Study 2B was to (a) collect preliminary data to examine the relationship between entropy and complexity in relation to processes at the macro-level by testing Hypotheses 1 and 2, and (b) develop, assess, and refine the feasibility of the main research components to be used in the subsequent studies. The purpose of Study 3B was to examine the relationship between entropy and complexity in relation to processes at the macro-level by testing Hypotheses 1 and 2, subject to the development, assessment, and refinement of the feasibility of the main research components based on Study 2B. The purpose of Study 4 was to examine (a) the relationship between entropy and complexity in relation to processes at the macro-level by testing Hypotheses 1 and 2, and (b) if difficulty confounded the examined relationship.

In Part II, all large-scale studies adopted a theory-driven approach (i.e., by testing Hypotheses 1 and 2) (e.g., Popper, 2005; Lakatos, 2014; Janiszewski & van Osselaer, 2022).

Part III: Processes (Macro- and Micro-Levels)

Part III consisted of a combination of one small-scale study and two large-scale studies (Studies 5A-6).

In relation to the small-scale study (Study 5A), as in Part II, the purpose of this study was to (a) create a set of stimuli, (b) examine their subjective and objective randomness, and (c) use these measures to allocate the stimuli between conditions for the subsequent large-scale studies (Studies 5B and 6).

In relation to the large-scale studies, the purpose of Study 5B was to examine (a) the relationship between entropy and complexity in relation to processes at the macro- and micro-levels, and (b) if the ranking of the micro-levels affected the examined relationship. The purpose of Study 6 was to examine (a) the relationship between entropy and complexity in relation to processes at the macro- and micro-levels, and (b) if the range of the micro-levels affected the examined relationship.

In Part III, all large-scale studies adopted a theory-driven approach at the macro-level (i.e., by testing Hypotheses 1 and 2), as in Part II, and a data-driven approach at the micro-level (i.e., no hypotheses).

Data Collection

The data were collected across nine online studies (N = 665), using a combination of scoring tasks (for Studies 1, 2A, 3A, and 5A) and reaction time (RT) tasks (i.e., simple and choice RT tasks; for Studies 2B, 3B, 4, 5B, and 6). In relation to the latter, RT studies record participants' reaction times during the performance of a task, where a reaction time represents the time elapsed between a signal-to-respond and an actual response (Van Orden et al., 2003, 2005, 2010; Holden, 2005; Holden et al., 2009, 2011).

The motivation for choosing RT tasks was twofold. First, they are the standard in this area of research as they have been very successful in measuring human performance (e.g., Van Orden et al., 2003, 2005, 2010; Holden, 2005; Holden et al., 2009, 2011). Second, RT tasks capture cognitive dynamics through the dynamics of the body as they are based on the theory of embodied cognition, which states that the mind is grounded in the body (e.g., Chiel & Beer, 1997; Beer, 1995, 2000; Clark, 1998, 1999, 2017; Clark & Chalmers, 1998; Scheier & Pfeifer, 1999; Wilson, 2002; Anderson, 2003; Anderson et al., 2012; Chemero, 2013; Baggs & Chemero, 2021). This is very important because cognitive dynamics cannot be measured via mainstream methods (e.g., self-reports) since individuals are unaware of the real reasons behind their actions (Nisbett & Wilson, 1977).

Data Analysis

The data were analysed using a combination of linear (i.e., Pearson correlations, t-tests, and ANOVAs) and nonlinear (i.e., recurrence quantification analysis and sample entropy) analysis techniques (Zbilut & Webber, 1992; Webber & Zbilut, 1994; Richman & Moorman, 2000; Marwan et al., 2002; Richman et al., 2004; Maydeu-Olivares & Millsap, 2009; Field, 2013; Little, 2013a, 2013b).

The full overview of sample sizes and demographics for the studies can be seen in Table 1.

Table 1

Overview of Sample Sizes and Demographics (Studies 1 - 6)

Study	Sample Size	*M*	*SD*	Gender		
				Female	Male	Other*
			Participants – Before Exclusion			
1	300	35.517	6.387	196	100	4
2A	30	35.533	6.837	18	12	0
2B	73	33.606	6.426	42	29	2
3A	30	34.833	5.760	20	10	0
3B	80	36.316	5.631	38	41	1
4	79	37.769	5.689	43	36	0
5A	30	37.200	5.810	22	8	0
5B	70	38.072	6.436	40	28	2
6	80	34.125	5.909	44	36	0
			Participants – After Exclusion			
1	300	35.517	6.387	196	100	4
2A	30	35.533	6.837	18	12	0
2B	11	33.727	6.035	4	7	0
3A	30	34.833	5.760	20	10	0
3B	71	36.829	5.376	33	37	1
4	58	37.526	5.584	32	26	0
5A	30	37.200	5.810	22	8	0
5B	65	37.641	6.388	36	27	2
6	70	34.529	5.855	35	35	0

Note. * = includes participants who selected the option “Prefer not to say” or whose data were missing for Gender.

Part I: Study 1

The purpose of this large-scale study was to examine (a) the relationship between entropy and complexity in relation to patterns by testing binary stimuli, with entropy expressed as a continuum between randomness and non-randomness as its endpoints and complexity expressed as a continuum between complexity and simplicity as its endpoints, and (b) if the ratio of white vs. black squares in the binary stimuli affected the examined relationship.

Method

Participants

In total, we recruited 300 individuals (Female = 196, Male = 100, Other[4] = 4; Age range: 22 – 46 years; M_{Age} = 35.517; SD_{Age} = 6.387), and all remained after the exclusion criterion was applied (see Procedure section).

All participants were recruited[5] online via Prolific in exchange for a monetary reward of £3.0 (£7.2/h). Prolific was chosen for: 1) highest data quality overall, including in attention, comprehension, honesty, and reliability of participant responses (e.g., compared to MTurk, Qualtrics); 2) large active participant pool, as Prolific shows both active user numbers and total pool size (e.g., unlike MTurk); 3) flexible and free audience filtering; 4) easiness of retargeting participants (for exclusion in future studies); and 5) high ethical standards, including clear guidelines about approvals, rejections, and returns (Palan & Schitter, 2018; Peer et al., 2017, 2021).

Sample Size

Sample size was determined via power analysis using G*Power (Faul et al., 2007), where an a priori power calculation was performed for a mixed ANOVA with the following input parameters: effect size f = 0.25, significance level α = 0.05, power (1 - β) = 0.95, number of groups = 4, and number of measurements = 8.

For this study, power analysis indicated a minimum number of 160. We recruited 88% in excess of this estimate until 300 participants to account for any participants who would not pass the exclusion criterion.

Design

The study had a 4 x 2 mixed design, with quality (four levels: randomness vs. non-randomness vs. complexity vs. simplicity) as a between-subjects factor and ratio (two levels: low, high) as a within-subjects factor.

The study involved two experimental tasks, one for each level of ratio as a within-subjects factor (each 180 trials), which totalled 360 trials.

Each participant was randomly allocated to one of the four levels of quality as a between-subjects factor, and the order in which participants completed the two experimental tasks was also randomised. Each stimulus appeared only once, and the order in which they were presented was randomised for each participant and task.

[4] Includes participants who selected the option "Prefer not to say" (*n* = 2) or whose data were missing for Gender (*n* = 2).
[5] The following pre-screening criteria were applied: 1) age: 22 – 45 years; 2) location: UK, USA; 3) nationality: American, British; 4) vision: normal or corrected-to-normal; 5) minimum approval rate on Prolific: 99%; 6) minimum number of previous submissions on Prolific: 300; and 7) a custom blocklist containing the Prolific IDs of the participants from the previous studies to prevent them from taking part in the present one.

Stimuli
The stimuli consisted of a matrix with 9 x 9 white and black squares, with a white square representing "0" and a black square representing "1"[6].

The motivation for choosing the binary representation was twofold. First, it is the most fundamental representation of information, both visually and mathematically, as it provides a straightforward, simple, and precise way of expressing and examining information and its change. In this respect, as Vitz (1968) points out, the binary representation "presumably exposes the process of perceptual organization more clearly than other patterns" (p. 275). Second, the binary representation is context-free, as it can be examined without a metric that might change depending on the context and therefore add extra layers of information that do not pertain to the representation of information, visually and mathematically, in the stimulus.

A three-step strategy was used to create the stimuli. To start with, a literature review was conducted on 2-dimensional binary stimuli research in general and that investigated the same qualities in particular (e.g., Chipman, 1977; Falk & Konold, 1997; Van Geert & Wagemans, 2020, 2021; Krpan & van Tilburg, 2022). Then, the descriptions of the qualities and samples of stimuli uncovered from the literature review were used as inspiration. Last, the qualities were created by changing the spatial distribution of the squares while keeping constant the surface area of the matrix, the surface area of each individual square, and the white/black ratio.

In total, 360 stimuli were created, 180 for each level of ratio (two levels: low, high) as a within-subjects factor. The stimuli had a 25 white/56 black squares ratio for the low level and a 56 white/25 black squares ratio for the high level of the ratio factor. The white and black colours were also inverted between the two levels of the within-subjects factor, with the white squares becoming black and the black squares becoming white, to exclude colour as a confounding variable.

Examples of stimuli can be seen in Figure 1, and the full set of stimuli can be seen in Appendix A.

Procedure
Participants read and approved the informed consent form, after which they were presented with the description and instructions of the scoring task.

Each trial began with the stimulus being presented in the centre of the screen until a response was registered. Depending on the level of the between-subjects factor participants were assigned to, they had to score the stimuli on one of the following qualities[7]:

1. randomness, which referred to how random they found the stimulus (i.e., to what extent it lacked any underlying order);
2. non-randomness, which referred to how ordered they found it;
3. complexity, which referred to how complex they found it; or
4. simplicity, which referred to how simple they found it.

For each trial, a slider[8] with values ranging from 0 to 100 was displayed, and participants had to adjust the slider to correspond to how they perceived the stimulus, with 0 meaning very low and 100 meaning very high on the given quality. Each stimulus was scored only once, and after an evaluation had been

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[6] In mathematics, this type of number system is called the base-2 or binary numeral system because every number is mathematically expressed in a base (or radix) of 2, namely by using only two symbols: "0" and "1".
[7] The motivation for choosing the descriptions was twofold. On the one hand, the descriptions were kept in line with previous research on stimuli perception (Van Geert & Wagemans, 2020, 2021; Krpan & van Tilburg, 2022). On the other hand, the descriptions were kept as simple as possible to avoid (a) confusing participants with advanced definitions that are unfamiliar to a non-specialised audience and (b) priming the participants as to the definition of the qualities and therefore influencing their responses.
[8] The two most commonly used rating procedures in the literature are the scoring method (i.e., where participants assign a number) and the slider method (i.e., where participants adjust a slider to a certain number, as in this study). Although previous research has shown that the rating procedure does not confound rating scores (Chipman, 1977; Krpan & van Tilburg, 2022), the slider method was chosen because it would yield the same results as the scoring method but would be faster and easier for participants, therefore also reducing the possibility of them dropping out of the study.

made, participants could not go back to change their answers. After each stimulus was scored, participants had to press "Next" to proceed to the next trial. If participants tried to proceed without answering, a message (i.e., "You must give a response to all items") was displayed on the screen reminding them to answer.

Participants were first shown some examples to get a general idea of the stimuli they were about to score. Then, participants moved on to the experimental tasks, and they were reminded of the instructions before the start of each task. There were short breaks during the study.

After the experimental tasks, participants were given a seriousness check (Aust et al., 2013).

At the end, participants were debriefed and thanked for their participation. In total, the study lasted approximately 25 minutes.

Platform and Participant Setup

The study was created and administered using Gorilla (www.gorilla.sc), a cloud-based research platform and experiment builder that provides a full interface for designing and administering experiments quickly and easily (Anwyl-Irvine et al., 2020, 2021), and that has been shown to perform consistently overall across all operating systems and device types compared to other platforms (e.g., Lab.js, PsychoJS, jsPsych) (Anwyl-Irvine et al., 2020).

In Gorilla, all the elements of a task are first positioned within the *stage*, the largest 4:3 area that can be fit on the screen, and then the positions and sizes of the elements are defined as a proportion of the stage dimensions rather than pixels. This allows Gorilla to treat all screens as if they had the same aspect ratio, and all the elements on a screen will be scaled with it. The layout of the task will therefore stay consistent, and all participants will have a similar experience, irrespective of their screen sizes. For images in particular, Gorilla also offers the option to define them in absolute pixels, which means that the images will always be shown at the same size.

In the present research, the stimuli were defined as a proportion of the stage dimensions rather than absolute pixels. The motivation was twofold. First, previous research has shown that the size of stimuli did not confound stimuli perception (Chipman, 1977; Krpan & van Tilburg, 2022). Second, to ensure that the results are generalisable beyond a specific size of the stimuli (Westfall et al., 2015; Yarkoni, 2022).

The stimuli were first designed to a standard size of 500 (width) x 500 (height) pixels (each square 55.56 (width) x 55.56 (height) pixels), in line with the latest research (Krpan & van Tilburg, 2022). Then, the stimuli were defined as 60% of the stage dimensions, which implies that the original size of the stimuli would scale to that percentage, irrespective of participants' screen sizes. All stimuli were presented on a white background. Examples of task display can be seen in Figure 2.

It is also important to mention that previous research has shown that there are no differences in data quality between the online and laboratory settings (Hilbig, 2016; Semmelmann & Weigelt, 2017), and that mode of presentation (i.e., digital vs. printed) does not confound stimuli perception (Chipman, 1977; Krpan & van Tilburg, 2022).

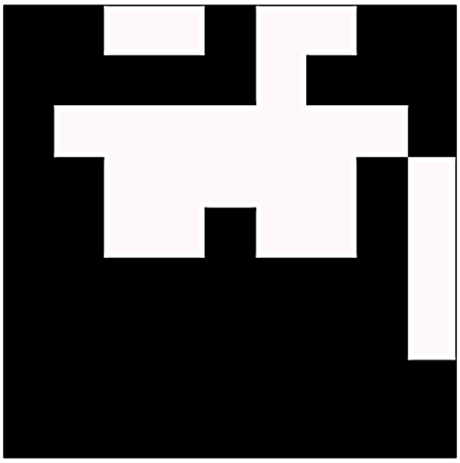
Participants were allowed to take part in the study only using computers (i.e., desktops and laptops).

Figure 1

Example of Stimulus and Stimulus Code for the Low and High Levels of the Ratio Factor (Study 1)

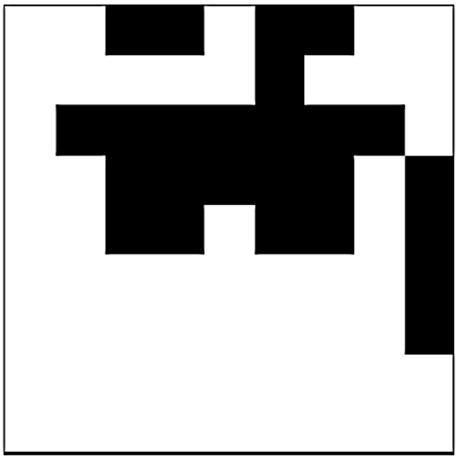
Ratio	Stimulus	Stimulus Code

Low



1	1	0	0	1	0	0	1	1
1	1	1	1	1	0	1	1	1
1	0	0	0	0	0	0	0	1
1	1	0	0	0	0	0	1	0
1	1	0	0	1	0	0	1	0
1	1	1	1	1	1	1	1	0
1	1	1	1	1	1	1	1	0
1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1

High



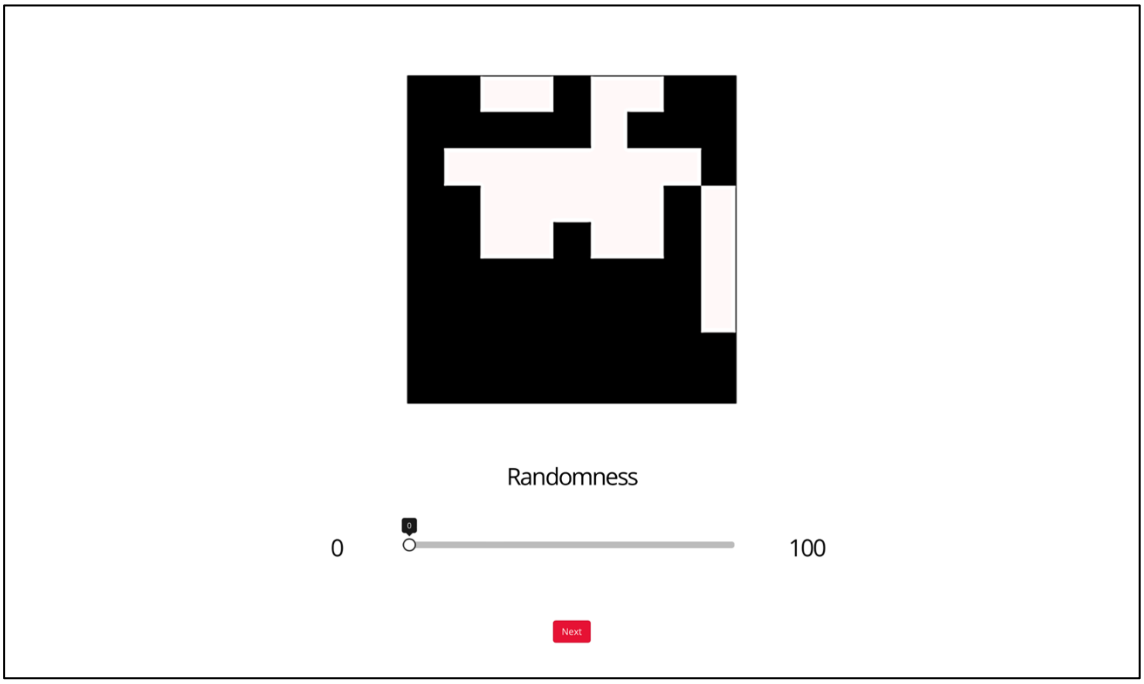
0	0	1	1	0	1	1	0	0
0	0	0	0	0	1	0	0	0
0	1	1	1	1	1	1	1	0
0	0	1	1	1	1	1	0	1
0	0	1	1	0	1	1	0	1
0	0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0

Note. The full set of stimuli can be seen in Appendix A.

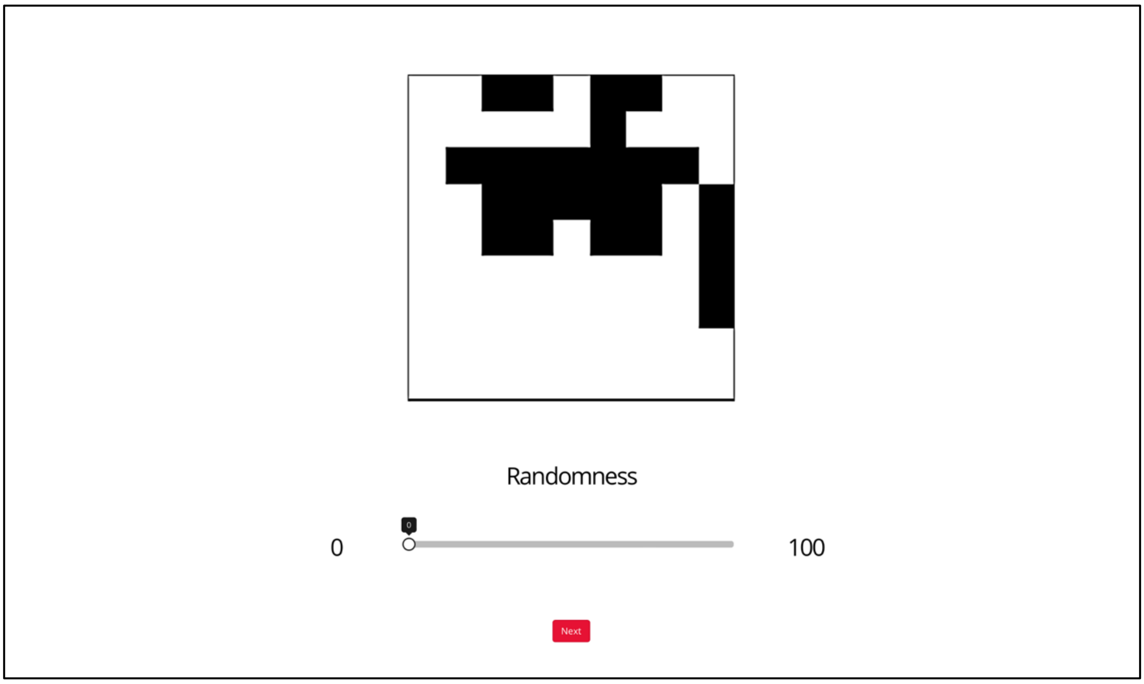
Figure 2

Examples of Task Display for the Low and High Levels of the Ratio Factor at the Randomness Level of the Quality Factor (Study 1)

Low Ratio



High Ratio



Results

Correlations

Participants' average scores for each stimulus were calculated, after which a Pearson correlation test was performed to determine the relationships between all levels of the quality factor (Table 2).

Findings showed strongly positive and statistically significant correlations between *Randomness* and *Complexity*, $r(178) = .765$, $p < .001$, and *Non-Randomness* and *Simplicity*, $r(178) = .943$, $p < .001$, and strongly negative and statistically significant correlations between all remaining levels of the quality factor, rs(178) ≥ -.692, ps < .001.

Table 2
Correlations Between All Levels of the Quality Factor (Study 1)

Variable	Randomness	Non-Randomness	Complexity
Non-Randomness	-.986**		
Complexity	.765**	-.692**	
Simplicity	-.968**	.943**	-.870**

Note. ** = Correlation is significant at the $p < .01$ level and $N = 180$.

To also confirm that the same relationships between all levels of the quality factor happen at the low and high levels of the ratio factor, a Pearson correlation test was performed (Table 3).

Results indicated strongly positive and statistically significant correlations between *Randomness* and *Complexity*, rs(178) ≥ .762, ps < .001, and *Non-Randomness* and *Simplicity*, rs(178) ≥ .939, ps < .001, and strongly negative and statistically significant correlations between all remaining levels of the quality factor, rs(178) ≥ -.689, ps < .001, at the low and high levels of the ratio factor, consistent with Table 2.

Table 3
Correlations Between All Levels of the Quality Factor at the Low and High Levels of the Ratio Factor (Study 1)

Variable	R – L	NR – L	C – L	S – L	R – H	NR – H	C – H
NR – L	-.984**						
C – L	.762**	-.689**					
S – L	-.963**	.940**	-.866**				
R – H	.995**	-.985**	.754**	-.961**			
NR – H	-.981**	.993**	-.678**	.932**	-.984**		
C – H	.769**	.-699**	.990**	-.872**	.764**	-.688**	
S – H	.968**	.945**	.856**	.990**	-.965**	.939**	-.865**

Note. R = Randomness, NR = Non-Randomness, C = Complexity, S = Simplicity, L = Low, and H = High. ** = Correlation is significant at the $p < .01$ level and $N = 180$.

After the initial analysis, additional Pearson correlation tests were performed to determine the relationships between the low and high levels of the ratio factor in general and at each level of the quality factor in particular. Findings showed a strongly positive and statistically significant correlation between the low and high levels of the ratio factor, $r(718) = .992$, $p < .01$, and strongly positive and statistically significant correlations between the low and high levels of the ratio factor at each level of the quality factor, rs(178) ≥ .990, ps < .001.

Differences
Two sets of tests were performed, in the following order:

1. One overall ANOVA: Participants' average scores for each stimulus were subjected to a two-way mixed ANOVA, with quality (four levels: randomness vs. non-randomness vs. complexity vs. simplicity) as a between-subjects factor and ratio (two levels: low, high) as a within-subjects factor (see Tables 4 and 5).
2. One hundred eighty individual ANOVAs: The scores for each stimulus were subjected to two-way mixed ANOVAs, with quality (four levels: randomness vs. non-randomness vs. complexity vs. simplicity) as a between-subjects factor and ratio (two levels: low, high) as a within-subjects factor (see Appendix B).

First, in the overall ANOVA, there was a small and statistically significant main effect of quality, $F(3, 716) = 10.424$, $p < .001$, partial $\eta^2 = .042$, with pairwise comparisons showing statistically significant mean differences between all levels of the quality factor, $M_{Differences} \geq 3.949$, ps < .05, except between *Non-Randomness* and *Simplicity*, $M_{Difference} = 2.126$, $p = .280$. The same effects were observed in the individual ANOVA tests.

Second, there was a small and statistically significant main effect of ratio, $F(1, 716) = 9.990$, $p = .002$, partial $\eta^2 = .014$, such that scores were greater in the low ratio condition than in the high ratio condition, $M_{Difference} = 0.267$. However, the same effects were not observed in the individual ANOVA tests, where the main effect of ratio was significant for only 13 out of the 180 stimuli (7.22%). Therefore, as the main effect of ratio occurred only for a small stimulus sample and did not generalise to the stimulus category in question, it can be concluded that the effect cannot be considered valid since it would not replicate beyond those few stimuli (Westfall et al., 2015).

Last, there was a large and statistically significant quality x ratio interaction effect, $F(3, 716) = 47.685$, $p < .001$, partial $\eta^2 = .167$. Therefore, simple main effects were run. The simple main effect of quality showed that the relationships between all levels of the quality factor are the same at each level of the ratio factor, except between *Randomness* and *Complexity*, and *Randomness* and *Simplicity*, respectively, whose relationships changed between ratios. More exactly, for the low level, there were no significant mean differences observed in either relationship, $M_{Difference} = 2.986$, $p = .132$, and $M_{Difference} = -3.755$, $p = .058$, respectively. For the high level, the opposite effect was observed, as there were significant mean differences observed in both relationships, $M_{Difference} = 5.189$, $p = .008$, and $M_{Difference} = -3.143$, $p = .035$, respectively. Nevertheless, the same effects were not observed in the individual ANOVA tests, where the interaction effect was significant for only 17 out of the 180 stimuli (9.44%). Therefore, it can be concluded that the interaction effect cannot be considered valid since it would not replicate beyond those few stimuli, in line with Westfall et al. (2015).

Table 4
Descriptive Statistics for Study Variables (Study 1)

Within-Subjects Factor (IV)	Between-Subjects Factor (IV)	*n*	Score (DV)	
			M	*SD*
Low Ratio	Randomness	180	42.452	22.346
	Non-Randomness	180	49.067	21.902
	Complexity	180	39.465	14.051
	Simplicity	180	46.206	15.256
	Total	720	44.297	19.083
High Ratio	Randomness	180	42.909	22.301
	Non-Randomness	180	48.443	21.651
	Complexity	180	37.719	14.213
	Simplicity	180	47.052	14.634
	Total	720	44.031	19.015

Table 5
Two-Way Mixed ANOVA (Study 1)

Test	$M_{Difference}$	*SE*	*F*	*p*	η_p^2
Main Effect of Quality			10.424	< .001	.042
Pairwise Comparisons of Quality					
Randomness – Non-Randomness	-6.075	1.965		.002	
Randomness – Complexity	4.088	1.965		.038	
Randomness – Simplicity	-3.949	1.965		.045	
Non-Randomness – Complexity	10.163	1.965		< .001	
Non-Randomness – Simplicity	2.126	1.965		.280	
Complexity – Simplicity	-8.037	1.965		< .001	
Main Effect of Ratio	0.267		9.990	.002	.014
Interaction Effect of Quality x Ratio			47.685	< .001	.167
Simple Main Effects of Quality (Low Ratio)					
Randomness – Non-Randomness	-6.615	1.979		< .001	
Randomness – Complexity	2.986	1.979		.132	
Randomness – Simplicity	-3.755	1.979		.058	
Non-Randomness – Complexity	9.602	1.979		< .001	
Non-Randomness – Simplicity	2.861	1.979		.149	
Complexity – Simplicity	-6.741	1.979		< .001	
Simple Main Effects of Quality (High Ratio)					
Randomness – Non-Randomness	-5.534	1.959		.005	
Randomness – Complexity	5.189	1.959		.008	
Randomness – Simplicity	-4.143	1.959		.035	
Non-Randomness – Complexity	10.724	1.959		< .001	
Non-Randomness – Simplicity	1.391	1.959		.478	
Complexity – Simplicity	-9.332	1.959		< .001	

Discussion

For correlations, findings showed (a) strongly positive/negative and statistically significant relationships between all levels of the quality factor and (b) that the same relationships were observed at the low and high levels of the ratio factor. Two important observations arise when we consider the strength of a *very large* effect size (i.e., $r \geq 0.4$, Funder & Ozer, 2019), which is rarely seen in psychological research (e.g., Bosco et al., 2015; Funder & Ozer, 2019), in relation to the direction of these correlations. First, the strongly positive direction of the correlations between the pairs *Randomness* and *Complexity*, and *Non-Randomness* and *Simplicity* indicated that in each of these pairs, the levels of the quality factor represented the same end of the same construct. Second, the strongly negative direction of the correlations between the pairs *Randomness* and *Non-Randomness*, and *Complexity* and *Simplicity* showed that in each of these pairs, the levels of the quality factor represented two ends of the same construct (i.e., the degree of randomness in a stimulus that can range from random to non-random and the degree of complexity in a stimulus that can range from complex to simple) (e.g., Cohen & Swerdlik, 2005; Piedmont, 2014).

For differences, results indicated (a) a statistically significant main effect of quality, with pairwise comparisons showing statistically significant mean differences between all levels of the quality factor, except between *Non-Randomness* and *Simplicity*, while (b) the main effect of ratio and (c) the interaction effect were not considered valid as they would not generalise beyond a small stimulus sample. It is also important to mention that the observed signs of the mean differences between all levels of the quality factor might be due to a phenomenon frequently seen in psychometric research. More precisely, variables that are opposites of each other or that are reverse worded (e.g., random, non-random) can yield responses that are not fully consistent, as participants might adopt a different frame of reference when rating these variables (e.g., starting from random to non-random vs. from non-random to random) and therefore also have different rating scales in mind when answering (Wong et al., 2003; Carlson et al., 2011; Ebesutani et al., 2012; Weijters & Baumgartner, 2012; Zhang & Savalei, 2016).

On the whole, despite the observed mean differences between the levels of the quality factor, the very large effect sizes of the correlations showed that the levels of the quality factor represented either the same or opposite aspects of the same construct, and that these effects were sustained at the low and high levels of the ratio factor. This implies that whether the stimulus contains more or less white vs. black squares does not influence the perception of the quality of that stimulus. Therefore, what matters is not the number of white vs. black squares in the stimulus but their structure (i.e., how they are arranged). In a simple analogy, it is *quality* over *quantity*.

Part II: Study 2A

The purpose of this small-scale study was to (a) create a set of stimuli, (b) examine their subjective and objective randomness, and (c) use these measures to allocate the stimuli between conditions for the subsequent large-scale study (see Study 2B).

Method

Participants

In total, we recruited 30 individuals (Female = 18, Male = 12; Age range: 25 – 45 years; M_{Age} = 35.533, SD_{Age} = 6.837), and all remained after the exclusion criterion was applied (see Procedure section).

All participants were recruited[9] online via Prolific in exchange for a monetary reward of £1.11 (£8.32/h).

Sample Size

Sample size was determined using a *flat* rule of thumb, where a fixed number is recommended for every situation, irrespective of the subsequent large-scale study (Machin et al., 2018). This is due to the fact that sample sizes for small-scale studies cannot be precisely determined via power analysis because they are not intended for hypothesis testing, as in the case of large-scale studies (Cohen, 1988; Faul et al., 2007).

In general, previous research has recommended sample sizes ranging from 10 to 30 participants, including: 10 – 30 (Isaac & Michael, 1995; Hill, 1998), 12 (van Belle, 2002), 20 (Birket & Day, 1994), 24 (Julious, 2005), and 30 (Browne, 1995). Therefore, the minimum sample size recommended was 10 participants.

For this study, we recruited 200% in excess of this estimate until 30 participants to account for any participants who would not pass the exclusion criterion.

Design

The study involved one experimental task (100 trials). Each stimulus appeared only once, and the order in which they were presented was randomised for each participant.

Stimuli

The stimuli consisted of a matrix with 9 x 9 white and black squares.

For each stimulus, randomness was created by changing the spatial distribution of the squares while keeping constant the surface area of the matrix and the surface area of each individual square.

In total, 105[10] stimuli were created: 5 for the practice task and 100 for the experimental tasks, 50 for each level of randomness (two levels: low, high) as a within-subjects factor (see Design section in Study 2B).

Examples of stimuli can be seen in Figure 3, and the full set of stimuli can be seen in Appendix C.

Procedure

Participants read and approved the informed consent form, after which they were presented with the description and instructions of the scoring task.

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[9] The following pre-screening criteria were applied: 1) age: 25 – 45 years; 2) location: UK, USA; 3) nationality: American, British; 4) minimum approval rate on Prolific: 99%; 5) minimum number of previous submissions on Prolific: 300; and 6) a custom blocklist containing the Prolific IDs of the participants from the previous studies to prevent them from taking part in the present one.

[10] Only the 100 stimuli for the experimental tasks were tested in this study, as the remaining 5 stimuli for the practice task were not of interest.

Each trial began with the stimulus being presented in the centre of the screen until a response was registered. Participants had to score the stimuli on the following quality: randomness, which referred to how random they found the stimulus (i.e., to what extent it lacked any underlying order).

For each trial, a slider with values ranging from 0 to 100 was displayed, and participants had to adjust the slider to correspond to how they perceived the stimulus, with 0 meaning very low and 100 meaning very high randomness. Each stimulus was scored only once, and after an evaluation had been made, participants could not go back to change their answers. After each stimulus was scored, participants had to press "Next" to proceed to the next trial. If participants tried to proceed without answering, a message (i.e., "You must give a response to all items") was displayed on the screen reminding them to answer.

Participants were first shown some examples to get a general idea of the stimuli they were about to score. Then, participants moved on to the experimental task, and they were reminded of the instructions before the start of the task. There was a short break during the study.

After the experimental task, participants were given a seriousness check (Aust et al., 2013), which was the same as in the previous study.

At the end, participants were debriefed and thanked for their participation. In total, the study lasted approximately 8 minutes.

Platform and Participant Setup

The platform and participant setup were the same as in the previous study.

Examples of task display can be seen in Figure 4.

Results

For subjective randomness, participants' average scores for each stimulus were calculated, after which they were transformed into ranks (duplicate scores were assigned an average rank), with higher ranks indicating higher subjective randomness. These ranks were then used to allocate the stimuli between conditions (see Design section in Study 2B).

To confirm the allocation, a paired-samples t-test was performed to determine if there was a statistically significant mean difference in subjective randomness between conditions. Findings showed that subjective randomness was greater in the high randomness condition (M = 66.763, SD = 3.860) than in the low randomness condition (M = 9.320, SD = 2.069), a statistically significant mean difference, $M_{Difference}$ = 57.443, $t(49) = 93.865$, $p < .001$.

To also confirm the allocation of the same stimuli between conditions for objective randomness, Fourier randomness (for details, see Krpan & van Tilburg, 2022) was used. Objective randomness for each stimulus was computed, after which a paired-samples t-test was conducted to determine whether there was a statistically significant mean difference in objective randomness between conditions. Results indicated that objective randomness was greater in the high randomness condition (M = 71.000, SD = 5.018) as opposed to the low randomness condition (M = 42.080, SD = 25.420), a statistically significant mean difference, $M_{Difference}$ = 28.920, $t(49) = 7.786$, $p < .001$.

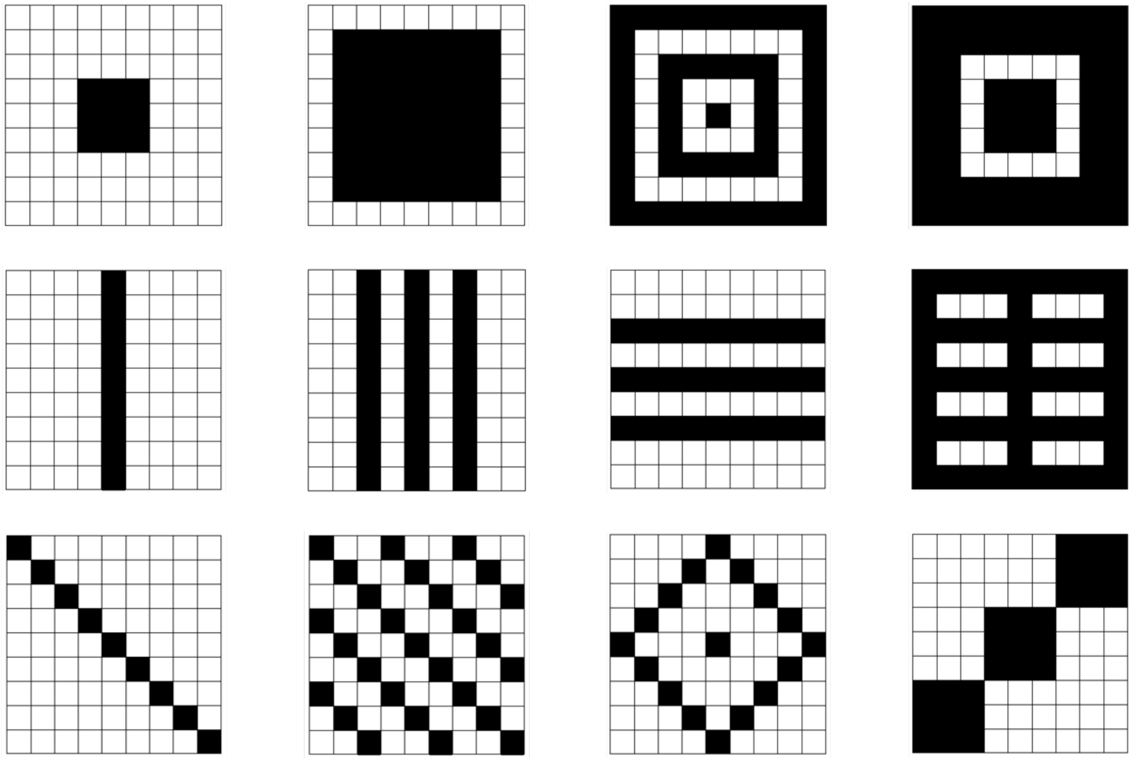
Discussion

On the whole, this study successfully created, examined, and allocated the set of stimuli between the low randomness and high randomness conditions for the next study (see Study 2B), using both subjective (i.e., participants' scores) and objective (i.e., Fourier randomness, Krpan & van Tilburg, 2022) randomness measures.

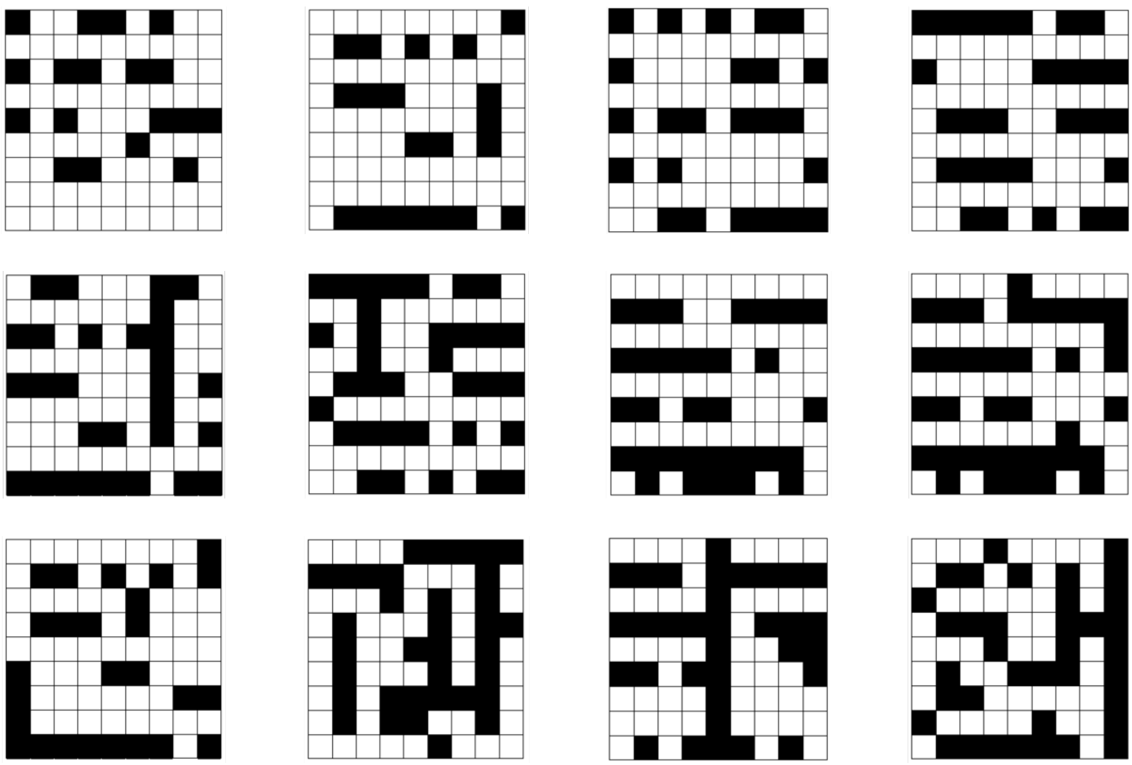
Figure 3

Examples of Stimuli for the Low and High Levels of the Randomness Factor (Study 2A)

Low Randomness



High Randomness

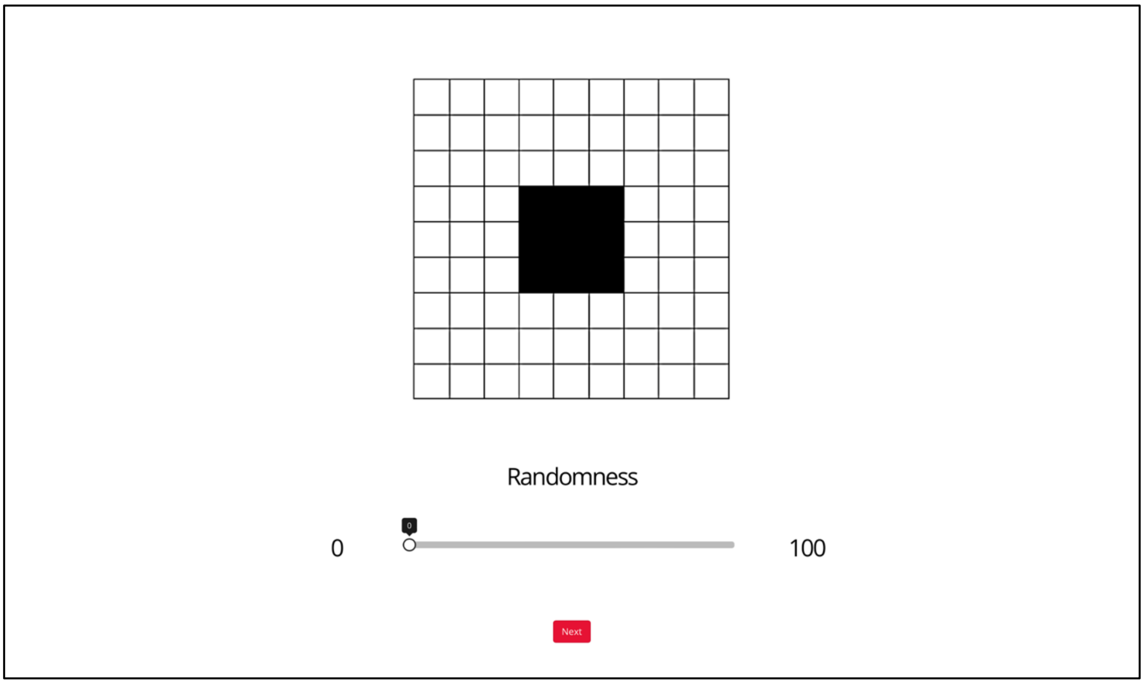


Note. The full set of stimuli can be seen in Appendix C.

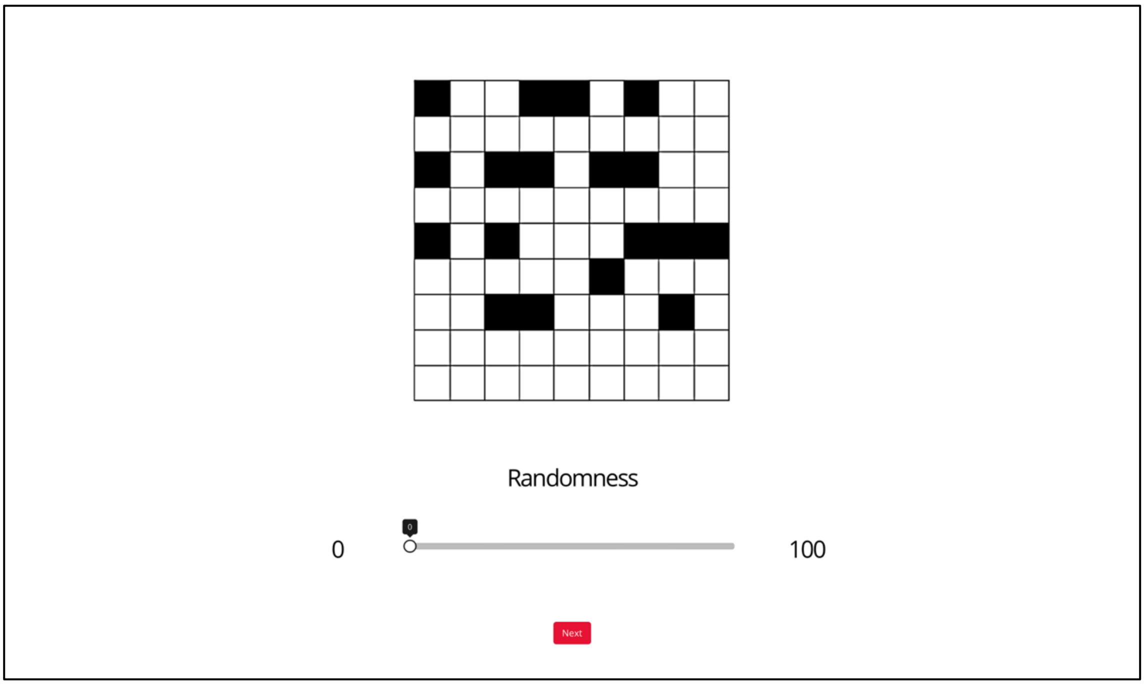
Figure 4

Examples of Task Display for the Low and High Levels of the Randomness Factor (Study 2A)

Low Randomness



High Randomness



Part II: Study 2B

The purpose of this large-scale study was to (a) collect preliminary data to examine the relationship between entropy and complexity in relation to processes at the macro-level by testing Hypotheses 1 and 2, and (b) develop, assess, and refine the feasibility of the main research components to be used in the subsequent studies.

Method

Participants

In total, we recruited 73 individuals (Female = 42, Male = 29, Other[11] = 2; Age range: 21 – 47 years; M_{Age} = 33.606, SD_{Age} = 6.426), and 11 individuals (Female = 4, Male = 7; Age range: 23 – 45 years; M_{Age} = 33.727, SD_{Age} = 6.035) remained after the exclusion criteria were applied (see Procedure section).

All participants were recruited[12] online via Prolific in exchange for a monetary reward of £7.5 (£10/h).

Sample Size

Sample size was determined via power analysis using G*Power (Faul et al., 2007), where an a priori power calculation was performed for a paired-samples t-test with the following input parameters: effect size dz[13] = 0.5, significance level α = 0.05, and power (1 - β) = 0.95.

For this study, power analysis indicated a minimum number of 54. We recruited 35% in excess of this estimate until 73 participants to account for any participants who would not pass the exclusion criteria.

Design

The study had a within-subjects design, with randomness (two levels: low, high) as a within-subjects factor.

The study involved a practice task (45 trials) and two experimental tasks, one for each level of randomness as a within-subjects factor (each 1100[14] trials), which totalled 2245 trials.

After the practice task, the order in which participants completed the two experimental tasks was randomised. Each stimulus appeared equally often, and the order in which they were presented was randomised for each participant and task.

Stimuli

The stimuli were the same as in Study 2A.

Procedure

Participants read and approved the informed consent form, after which they were presented with the description and instructions of the simple RT task.

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[11] Includes participants whose data were missing for Gender.

[12] The following pre-screening criteria were applied: 1) age: 21 – 48 years; 2) nationality: American, British, German, and Irish; 3) minimum approval rate on Prolific: 97%; and 4) minimum number of previous submissions on Prolific: 150.

[13] Cohen's *d* for matched pairs.

[14] For the experimental tasks, 1100 trials were chosen so that the number of trials was an integer of power 2 in length (in this case, 2^{10} = 1024), and 1100 trials are enough to be left with a healthy 76-trial "buffer" to reach the necessary 1024 trials after any exclusion criteria were applied. The motivation was twofold. First, using a standard metric to calculate the trial length provides mathematical precision and elegance while ensuring consistency across participants and conditions. Second, the standard metric helps with data validity, as previous research has shown that the number of trials influences test-retest reliability (James et al., 2007).

Each trial began with the stimulus being presented in the centre of the screen until a response was registered. Participants had to press the 'Space' key as soon as the stimuli appeared, and they had to do this multiple times for as long as the stimuli kept appearing on the screen. Between each response and the next set of stimuli, there was a fixed[15] 500[16] ms inter-trial interval during which the computer monitor was blank. RT was measured as the interval between when the stimulus was presented and when the participant pressed the key.

Participants were instructed to press only when the stimuli appeared on the screen and not before to prevent anticipatory responding (e.g., Woodworth & Schlosberg, 1954; Snodgrass et al., 1967; Luce, 1986; Wagenmakers et al., 2004; Whelan, 2008). Moreover, participants were instructed to keep their index finger on the response key at all times to enable rapid response and minimise noise due to motor processes (Wagenmakers et al., 2004).

Participants first completed a practice task to get accustomed to the upcoming experimental tasks during which they received feedback for 2 s following each response. The feedback consisted of a "Too Fast" for very fast responses (i.e., RT ≤ 100 ms; Wagenmakers et al., 2004), displayed at the bottom of the screen. Then, participants moved on to the experimental tasks during which no feedback was provided, and they were reminded of the instructions before the start of each task. There was a short break between the experimental tasks.

After the experimental tasks, participants were given an attention check (Meade & Craig, 2012; Thomas & Clifford, 2017; Kung et al., 2018) and a seriousness check (Aust et al., 2013). The attention check was non-specific to the study and consisted of a subset of 10 out of 61, 5-point (1 = *Very Untrue*, 5 = *Very True*) items from the Zimbardo Time Perspective Inventory (ZTPI; Zimbardo & Boyd, 2015). Participants had to choose a specific response to one of the items[17]. The seriousness check was the same as in the previous studies.

At the end, participants were debriefed and thanked for their participation. In total, the study lasted approximately 45 minutes.

Platform and Participant Setup

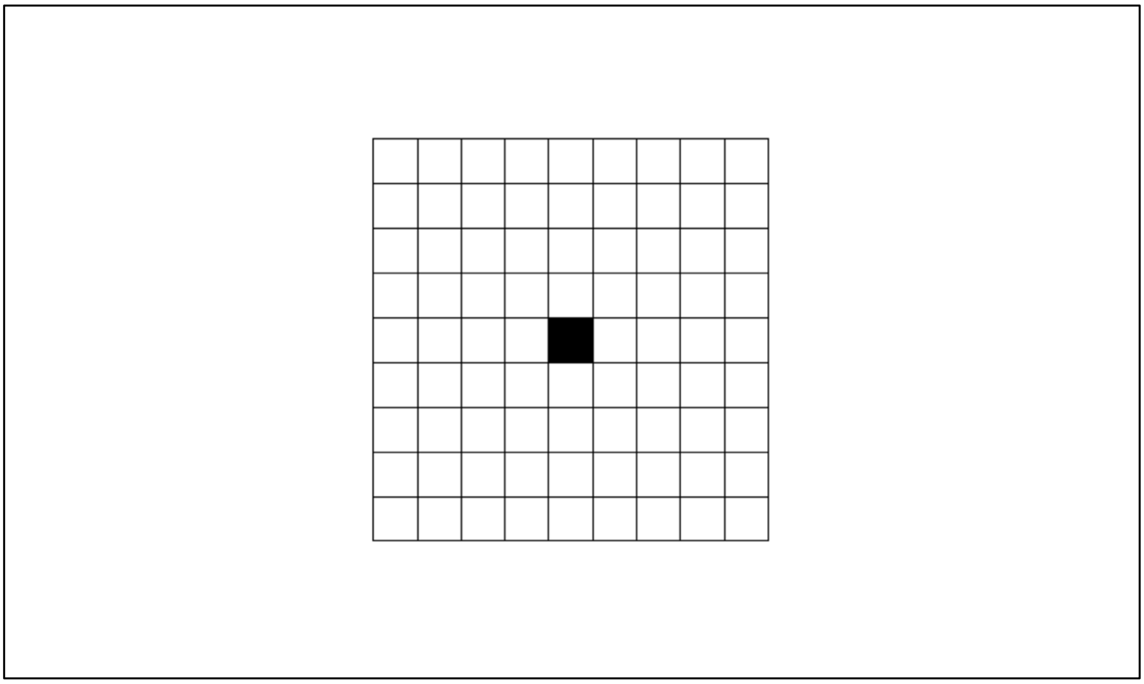
The platform and participant setup were the same as in the previous studies.

Examples of task display can be seen in Figure 5.

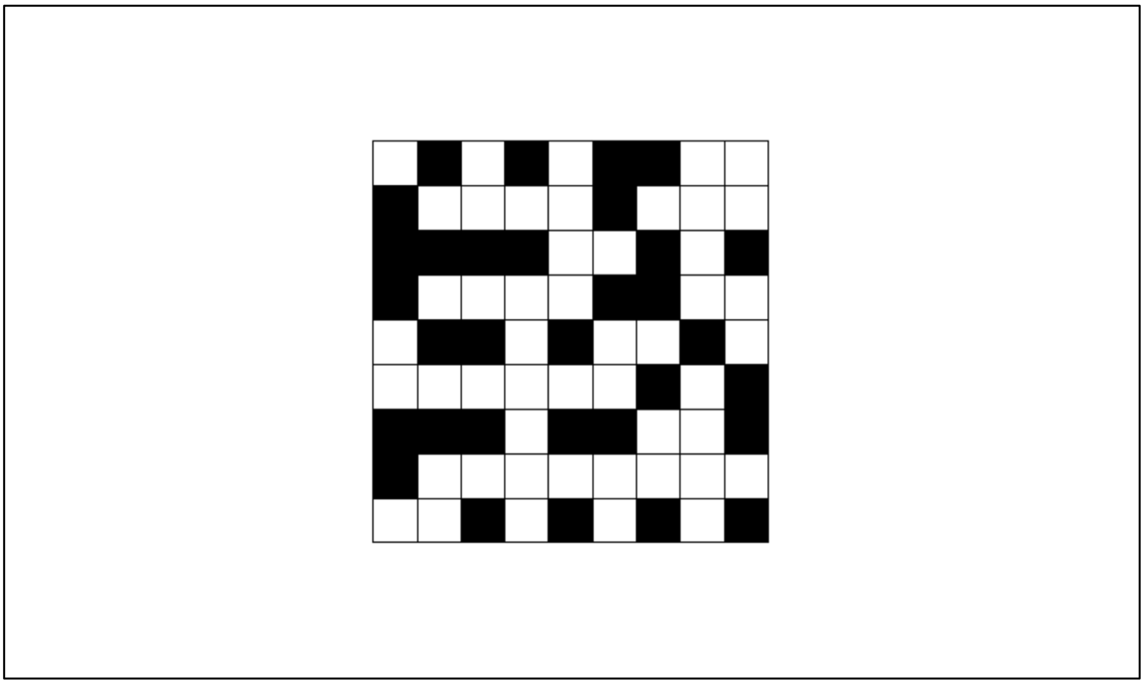
[15] Fixed intervals were chosen because they reduce the extent to which the measurements disrupt the pattern of sequential correlations in the time series (Van Orden et al., 2003, 2005).
[16] The decision to set the inter-trial interval at 500 ms was based on previous research (e.g., Van Orden et al., 2003, 2005; Wagenmakers et al., 2004).
[17] "Q7: Fate determines much in my life. Please select 'Very True'."

Figure 5
Examples of Task Display for the Low and High Levels of the Randomness Factor (Study 2B)

Low Randomness



High Randomness



Results

Data Preparation

Participants were excluded from the data analyses based on two categories of pre-existing exclusion criteria, in the following order: 1) exclusion based on the attention and seriousness checks; and 2) exclusion based on the RT data, if the number of remaining trials was less than 1024 after specific RT responses were removed from the data. This procedure was done in three steps by eliminating: 1) missing RT responses, defined as RT where participants failed to press the key; 2) anticipatory RT responses, defined as RT ≤ 100 ms ("irreducible minimum", Woodworth & Schlosberg, 1954; Snodgrass et al., 1967; Luce, 1986; Wagenmakers et al., 2004; Whelan, 2008); and 3) RT responses that fell beyond ± 3 standard deviations from the time series mean (Ratcliff, 1993; Ulrich & Miller, 1994; Whelan, 2008).

The motivation for the exclusion procedures based on the RT data was threefold. First, they are standard procedures for RT tasks in psychophysics research (e.g., Van Orden & Holden, 2002; Van Orden et al., 2003, 2005; Wagenmakers et al., 2004; Holden, 2005; Holden et al., 2009, 2011; Kello et al., 2007, 2010; Ihlen & Vereijken, 2010). Second, regarding anticipatory responses, previous research has shown that real RT (i.e., those that relate to the process of interest) have a minimum value of 100 ms from the onset of a stimulus to allow for the perception and generation of a response to it. RT responses less than that value are likely to be anticipations (i.e., the initiation of a response before the onset of the stimulus) and thus do not relate to the process of interest (Woodworth & Schlosberg, 1954; Snodgrass et al., 1967; Luce, 1986; Wagenmakers et al., 2004; Whelan, 2008). Last, time series regularly have extreme RT responses that, irrespective of their origin, are likely to distort the results of data analyses. Therefore, removing extreme RT responses is based more on result accuracy than measurement accuracy, as observations might certainly be legitimate measurements (Ratcliff, 1993; Ulrich & Miller, 1994; Van Orden & Holden, 2002; Holden, 2005; Whelan, 2008).

Based on the attention and seriousness checks, one participant was excluded (one for the non-specific attention check and none for the seriousness check). For the remaining participants, missing and anticipatory RT responses were removed, after which the mean and standard deviation of each participant's time series were calculated, and RT responses that fell beyond ± 3 standard deviations from the mean were removed. In total, 61 participants were further excluded based on having less than 1024 trials in one of their tasks.

Data Analyses

In total, 11 out of 73 participants remained after the exclusion criteria were applied. For the excluded participants (n = 62), their elimination was almost entirely based on the RT data, as the attention and seriousness checks resulted in the elimination of only one participant. More specifically, these respondents had a very high number of missing (M = 54.660, SD = 82.758, Min = 1, Max = 565) and anticipatory (M = 141.635, SD = 153.847, Min = 1, Max = 755) RT responses in one or both of their tasks. As the remaining sample size would not have produced enough statistical power for hypothesis testing, no data analyses were performed.

Discussion

With regard to the observed effects, they could be explained by a number of factors. First, participants might not have thoroughly read the task description and instructions; thus, they might not have fully understood the importance of not skipping trials or pressing in anticipation and how this would affect their data. Nevertheless, the issue was with the participants rather than the design, as the task description and instructions explicitly stated in capitalised bold text to press only when the stimuli appeared on the screen and not before. Furthermore, participants first completed a practice task to get accustomed to the upcoming experimental tasks during which they received feedback (designed expressly to discourage anticipatory responding), and they were reminded of the instructions before the start of each task.

Second, respondents may have experienced fatigue both cognitively and physically from having to pay attention to the stimuli and press the Space key over a long trial length (i.e., 2245 trials) and period (i.e., approximately 45 min). In this regard, previous research has indicated that fatigue from prolonged task performance is very common, such that individuals frequently struggle to maintain adequate task performance once exhausted (Boksem et al., 2006). Respondents may have also experienced the sunk cost fallacy, choosing to continue rather than drop out of the study despite their exhaustion, given the time and energy they had already invested. Although respondent fatigue usually results in dropouts (Ben-Nun, 2008), here fatigue may have manifested as missing and anticipatory RT responses.

Last, the observed effects could be attributed to the online setting. In this respect, even if participants took part in the study seriously (as shown by all passing the seriousness check), they might have wanted to finish it as soon as possible so that they could move on to the next available one. This is because online studies are an avenue of income, especially for the highest-ranked participants with a high approval rate and number of previous submissions on Prolific, as in this case.

Taking into consideration the observed effects, several changes were made for the next study. First, the study switched from a simple to a choice RT task. A choice task requires participants to press more than one key on the keyboard, preventing them from pressing almost incessantly because they know that more stimuli will be displayed and forcing them to focus on the actual stimuli rather than just their appearance. In addition, the choice task was designed to involve matching stimuli to ensure that respondents had no alternative but to actively look at the patterns displayed in the stimuli, therefore avoiding mindless choosing and pressing in anticipation. Second, the switch in task type allowed the implementation of another attention check designed specifically for the task to provide extra rigour in participant selection. Last, the trial length per task was cut in half (i.e., from 1100 to 550 trials) to avoid respondent fatigue and, as a result, dropout in general and large numbers of missing and anticipatory RT responses in particular.

On the whole, this study was unsuccessful in collecting preliminary data to examine the relationship between entropy and complexity in relation to processes at the macro-level by testing Hypotheses 1 and 2, but successful in developing, assessing, and refining the feasibility of the main research components to be used in the subsequent RT studies.

Part II: Study 3A

The purpose of this small-scale study was to (a) create a set of stimuli, (b) examine their subjective and objective randomness, and (c) use these measures to allocate the stimuli between conditions for the subsequent large-scale study (see Study 3B).

Method

Participants

In total, we recruited 30 individuals (Female = 20, Male = 10; Age range: 25 – 45 years; M_{Age} = 34.833, SD_{Age} = 5.760), and all remained after the exclusion criterion was applied (see Procedure section).

All participants were recruited[18] online via Prolific in exchange for a monetary reward of £1.2 (£9/h).

Sample Size

Sample size was determined using a *flat* rule of thumb, where a fixed number is recommended for every situation, irrespective of the subsequent large-scale study (Machin et al., 2018). This is due to the fact that sample sizes for small-scale studies cannot be precisely determined via power analysis because they are not intended for hypothesis testing, as in the case of large-scale studies (Cohen, 1988; Faul et al., 2007).

In general, previous research has recommended sample sizes ranging from 10 to 30 participants, including: 10 – 30 (Isaac & Michael, 1995; Hill, 1998), 12 (van Belle, 2002), 20 (Birket & Day, 1994), 24 (Julious, 2005), and 30 (Browne, 1995). Therefore, the minimum sample size recommended was 10 participants.

For this study, we recruited 200% in excess of this estimate until 30 participants to account for any participants who would not pass the exclusion criterion.

Design

The study involved one experimental task (110 trials). Each stimulus appeared only once, and the order in which they were presented was randomised for each participant.

Stimuli

The stimuli consisted of a matrix with 9 x 9 white and black squares.

For each stimulus[19], randomness was created by changing the spatial distribution of the squares while keeping constant the surface area of the matrix, the surface area of each individual square, and the white/black ratio (56 white/25 black squares).

In total, 115[20] stimuli were created: 5 for the practice task and 110 for the experimental tasks, 55 for each level of randomness (two levels: low, high) as a within-subjects factor (see Design section in Study 3B).

Examples of stimuli can be seen in Figure 6, and the full set of stimuli can be seen in Appendix C.

[18] The following pre-screening criteria were applied: 1) age: 25 – 45 years; 2) location: UK, USA; 3) nationality: American, British; 4) minimum approval rate on Prolific: 99%; 5) minimum number of previous submissions on Prolific: 300; and 6) a custom blocklist containing the Prolific IDs of the participants from the previous studies to prevent them from taking part in the present one.

[19] In contrast to Studies 2A and 2B, two changes were made to the stimuli: 1) design-wise, the inside lines were removed so that participants could focus on the visual rather than the underlying mathematical expression of the stimulus; and 2) code-wise, the ratio was changed from a variable to a fixed one to exclude the ratio as a confounding variable.

[20] Only the 110 stimuli for the experimental tasks were tested in this study, as the remaining 5 stimuli for the practice task were not of interest.

Procedure
Participants read and approved the informed consent form, after which they were presented with the description and instructions of the scoring task.

Each trial began with the stimulus being presented in the centre of the screen until a response was registered. Participants had to score the stimuli on the following quality: randomness, which referred to how random they found the stimulus (i.e., to what extent it lacked any underlying order).

For each trial, a slider with values ranging from 0 to 100 was displayed, and participants had to adjust the slider to correspond to how they perceived the stimulus, with 0 meaning very low and 100 meaning very high randomness. Each stimulus was scored only once, and after an evaluation had been made, participants could not go back to change their answers. After each stimulus was scored, participants had to press "Next" to proceed to the next trial. If participants tried to proceed without answering, a message (i.e., "You must give a response to all items") was displayed on the screen reminding them to answer.

Participants were first shown some examples to get a general idea of the stimuli they were about to score. Then, participants moved on to the experimental task, and they were reminded of the instructions before the start of the task. There was a short break during the study.

After the experimental tasks, participants were given a seriousness check (Aust et al., 2013), which was the same as in the previous studies.

At the end, participants were debriefed and thanked for their participation. In total, the study lasted approximately 8 minutes.

Platform and Participant Setup
The platform and participant setup were the same as in the previous studies.

Examples of task display can be seen in Figure 7.

Results

For subjective randomness, participants' average scores for each stimulus were calculated, after which they were transformed into ranks (duplicate scores were assigned an average rank), with higher ranks indicating higher subjective randomness. These ranks were then used to allocate the stimuli between conditions (see Design section in Study 3B).

To confirm the allocation, a paired-samples t-test was performed to determine if there was a statistically significant mean difference in subjective randomness between conditions. Findings showed that subjective randomness was greater in the high randomness condition (M = 60.313, SD = 5.375) than in the low randomness condition (M = 12.407, SD = 8.087), a statistically significant mean difference, $M_{Difference}$ = 47.906, $t(54)$ = 83.721, p < .001.

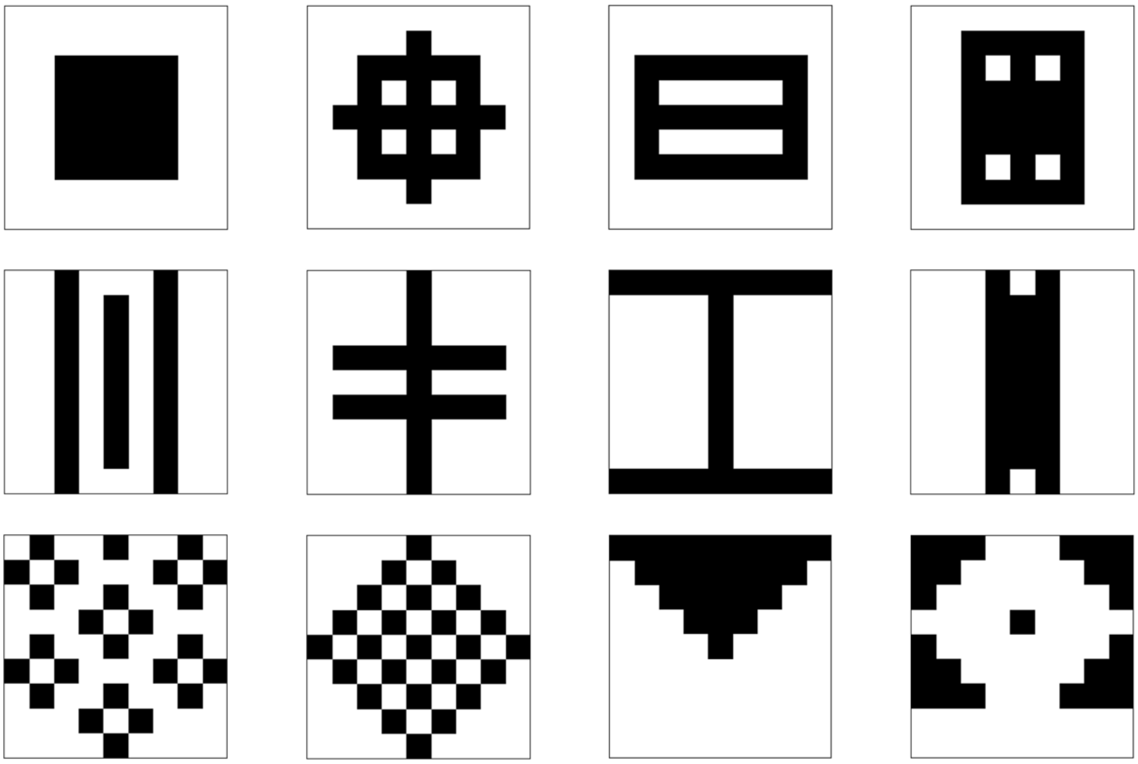
To also confirm the allocation of the same stimuli between conditions for objective randomness, Fourier randomness (for details, see Krpan & van Tilburg, 2022) was used. Objective randomness for each stimulus was computed, after which a paired-samples t-test was conducted to determine whether there was a statistically significant mean difference in objective randomness between conditions. Results indicated that objective randomness was greater in the high randomness condition (M = 63.891, SD = 7.338) as opposed to the low randomness condition (M = 43.164, SD = 17.349), a statistically significant mean difference, $M_{Difference}$ = 20.727, $t(54)$ = 8.079, p < .001.

Discussion

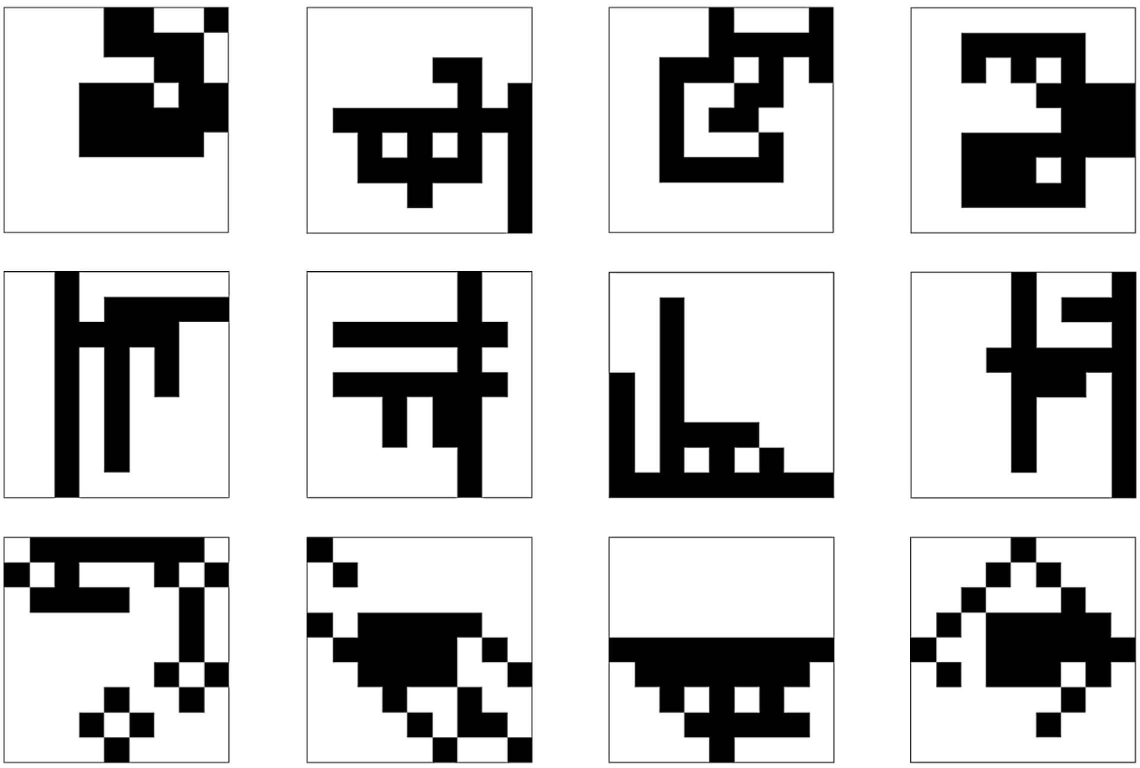
On the whole, this study successfully created, examined, and allocated the set of stimuli between the low randomness and high randomness conditions for the next study (see Study 3B), using both subjective (i.e., participants' scores) and objective (i.e., Fourier randomness, Krpan & van Tilburg, 2022) randomness measures.

Figure 6
Examples of Stimuli for the Low and High Levels of the Randomness Factor (Study 3A)

Low Randomness



High Randomness

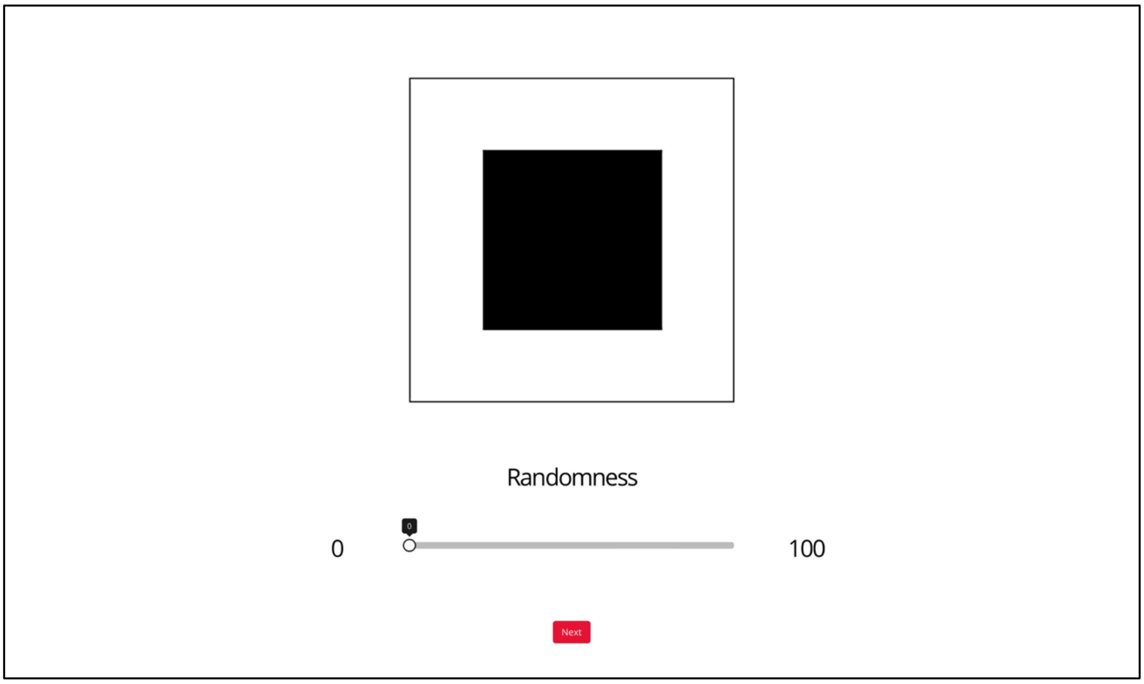


Note. The full set of stimuli can be seen in Appendix C.

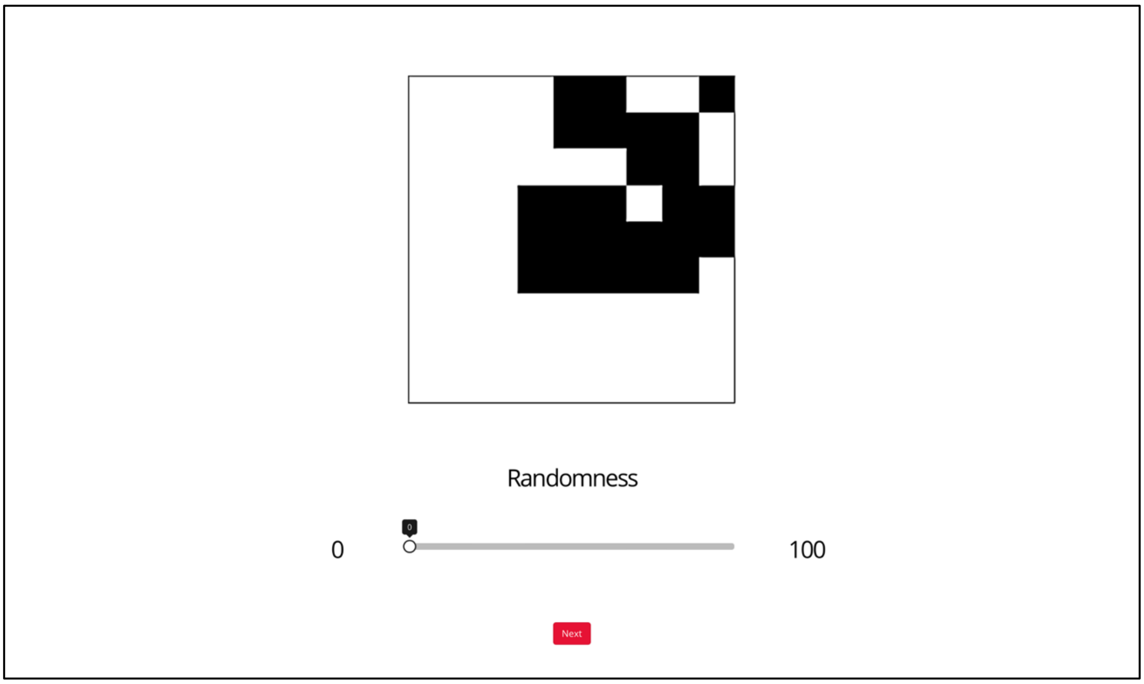
Figure 7

Examples of Task Display for the Low and High Levels of the Randomness Factor (Study 3A)

Low Randomness



High Randomness



Part II: Study 3B

The purpose of this large-scale study was to examine the relationship between entropy and complexity in relation to processes at the macro-level by testing Hypotheses 1 and 2, subject to the development, assessment, and refinement of the feasibility of the main research components based on Study 2B.

Method

Participants

In total, we recruited 80 individuals (Female = 38, Male = 41, Other[21] = 1; Age range: 27 – 48 years; M_{Age} = 36.316, SD_{Age} = 5.631), and 71 individuals (Female = 33, Male = 37, Other = 1; Age range: 27 – 48 years; M_{Age} = 36.829, SD_{Age} = 5.376) remained after the exclusion criteria were applied (see Procedure section).

All participants were recruited[22] online via Prolific in exchange for a monetary reward of £3.5 (£7/h).

Sample Size

Sample size was determined via power analysis using G*Power (Faul et al., 2007), where an a priori power calculation was performed for a paired-samples t-test with the following input parameters: effect size dz = 0.5, significance level α = 0.05, and power (1 - β) = 0.95.

For this study, power analysis indicated a minimum number of 54. We recruited 48% in excess of this estimate until 80 participants to account for any participants who would not pass the exclusion criteria.

Design

The study had a within-subjects design, with randomness (two levels: low, high) as a within-subjects factor.

The study involved a practice task (25 trials) and two experimental tasks, one for each level of randomness as a within-subjects factor (each 550[23] trials), which totalled 1125 trials.

After the practice task, the order in which participants completed the two experimental tasks was randomised. Each stimulus appeared equally often, and the order in which they were presented was randomised for each participant and task.

Stimuli

The stimuli were the same as in Study 3A.

Procedure

Participants read and approved the informed consent form, after which they were presented with the description and instructions of the choice RT task.

Each trial began with a set of three stimuli being presented on the screen at the same time: one in the centre, one in the top left, and one in the top right, until a response was registered. As soon as the stimuli appeared on the screen, participants had to correctly match the stimulus in the centre to either the stimulus in the top right or the stimulus in the top left. Participants had to press the ‘X’ key if the stimulus in the centre matched the one in the top left and the ‘M’ key if the stimulus in the centre matched the one in the top right. They had to do this multiple times for as long as the stimuli kept appearing on

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[21] Includes a participant whose data was missing for Gender.
[22] The following pre-screening criteria were applied: 1) age: 28 – 48 years; 2) nationality: American, British; 3) minimum approval rate on Prolific: 99%; 4) minimum number of previous submissions on Prolific: 300; and 5) a custom blocklist containing the Prolific IDs of the participants from the previous studies to prevent them from taking part in the present one.
[23] For the experimental tasks, 550 trials were chosen so that the number of trials was an integer of power 2 in length (in this case, 2^9 = 512), and 550 trials are enough to be left with a healthy 38-trial “buffer” to reach the necessary 512 trials after any exclusion criteria were applied.

the screen. If no response was recorded, trials timed out after 5 s. Between each response and the next set of stimuli, there was a fixed 500 ms inter-trial interval during which the computer monitor was blank. RT was measured as the interval between when the stimulus was presented and when the participant pressed one of the keys.

Participants were instructed to match the stimuli as quickly as they could while making as few mistakes as possible. Moreover, participants were instructed to keep their index fingers on both response keys at all times to enable rapid response and minimise noise due to motor processes (Wagenmakers et al., 2004).

Participants first completed a practice task to get accustomed to the upcoming experimental tasks during which they received feedback for 2 s following each response. The feedback consisted of a '✔' for right and '✖' for wrong responses displayed at the bottom of the screen. Then, participants moved on to the experimental tasks during which no feedback was provided, and they were reminded of the instructions before the start of each task. There was a short break between the experimental tasks.

After the experimental tasks, participants were given two attention checks (Meade & Craig, 2012; Thomas & Clifford, 2017; Kung et al., 2018) and a seriousness check (Aust et al., 2013). The first attention check was non-specific to the study and consisted of a subset of 10 out of 61, 5-point (1 = *Very Untrue*, 5 = *Very True*) items from the ZTPI (Zimbardo & Boyd, 2015). Participants had to choose a specific response to one of the items[24]. The second attention check was specific to the study and involved responding correctly to the question: "Which key did you have to press when the image in the centre matched the one in the top left?", by choosing among several answer options (i.e., A, M, Space, X, T)[25]. The seriousness check was the same as in the previous studies.

At the end, participants were debriefed and thanked for their participation. In total, the study lasted approximately 30 minutes.

Platform and Participant Setup

The platform and participant setup were the same as in the previous studies.

Examples of task display can be seen in Figure 8.

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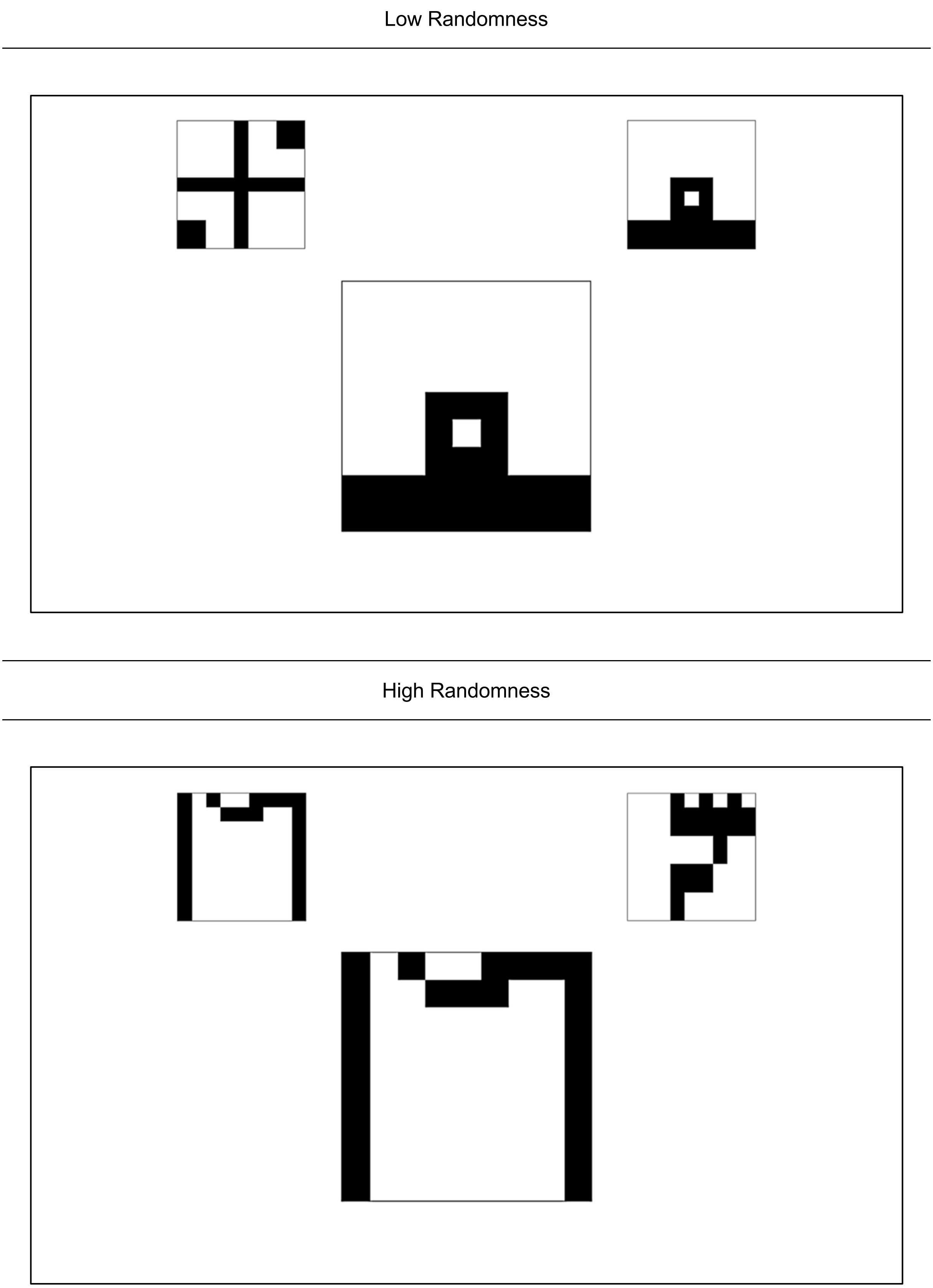
[24] "Q7: Fate determines much in my life. Please select 'Very True'."

[25] The correct answer was X.

Figure 8
Examples of Task Display for Low and High Levels of the Randomness Factor (Study 3B)



Results

Data Preparation

Participants were excluded from the data analyses based on two categories of pre-existing exclusion criteria[26], in the following order: 1) exclusion based on the attention and seriousness checks; and 2) exclusion based on the RT data, if the number of remaining trials was less than 512 after specific RT responses were removed from the data. This procedure was done in three steps by eliminating: 1) missing RT responses, defined as RT where participants failed to press the keys; 2) anticipatory RT responses, defined as RT ≤ 100 ms ("irreducible minimum", Woodworth & Schlosberg, 1954; Snodgrass et al., 1967; Luce, 1986; Wagenmakers et al., 2004; Whelan, 2008); and 3) RT responses that fell beyond ± 3 standard deviations from the time series mean (Ratcliff, 1993; Ulrich & Miller, 1994; Whelan, 2008).

Based on the attention and seriousness checks, seven participants were excluded (one for the non-specific attention check, six for the specific attention check, and none for the seriousness check). For the remaining participants, missing and anticipatory RT responses were removed, after which the mean and standard deviation of each participant's time series were calculated, and RT responses that fell beyond ± 3 standard deviations from the mean were removed. In total, two participants were further excluded based on having less than 512 trials in one of their tasks.

After the exclusion, the beginning of each time series was first truncated until 512 trials remained. Then, each time series was standardised or z-normalised (M = 0, SD = 1).

The motivation for the standardisation procedure was twofold. First, it is a standard procedure for the main analyses used in the present research (Richman & Moorman, 2000; Richman et al., 2004; Marwan et al., 2007; Marwan, 2011; Marwan & Webber, 2014; Wallot, 2017; Delgado-Bonal & Marshak, 2019). Second, by transforming raw RT responses into z-scores, standardisation allowed (a) the exclusion of differences in magnitude and variance between time series as a confound and (b) the direct comparison of findings across studies.

Data Analyses

Accuracy

For each participant and condition, the number of errors was calculated, after which a paired-samples t-test was performed to determine if there was a statistically significant mean difference in accuracy between conditions.

Findings showed that participants were less accurate in the high randomness condition (M = 26.282, SD = 18.238) than in the low randomness condition (M = 15.944, SD = 13.619), a statistically significant mean difference, $M_{Difference}$ = 10.338, $t(70) = 7.559$, $p < .001$.

Recurrence Quantification Analysis

Definition

Recurrence Quantification Analysis (RQA) is a nonlinear data analysis technique that determines if the states of a dynamical system recur over time and, if so, the extent to which these recurrences happen (Zbilut & Webber, 1992; Webber & Zbilut, 1994). In simple terms, RQA quantifies the nature and degree of deterministic structure of a dynamical system (Riley et al., 1999).

RQA is a fairly straightforward technique. The states of a dynamical system are first reconstructed into a two-dimensional plot called a recurrence plot (RP) – a *qualitative* technique introduced by Eckmann et al. (1995) – to visualise the patterns of recurrence in the states of the system: if data points are separated in time but are spatial neighbours in the reconstructed space, they are said to be recurrent

[26] The motivation for the exclusion procedures based on the RT data was the same as in Study 2B.

in time. Then, the RP is quantified using several variables, a process known as recurrence quantification analysis (RQA) – a *quantitative* technique initially developed by Zbilut and Webber (1992) and extended by Marwan et al. (2002).

Justification

The motivation for choosing RQA was threefold. First, RQA is one of the most robust and general-purpose nonlinear analysis techniques, as it can be applied to almost any type of data and has no a priori requirements regarding the statistical distribution, stationarity, or length of the data (Webber & Zbilut, 1994, 2005; Trulla et al., 1996; Riley et al., 1999; Orsucci et al., 2006; Coco & Dale, 2014). In relation to the length of the data, Webber and Zbilut (1994) also indicated that RQA can provide meaningful insights even if the phenomenon under study has a characteristic period that is longer than its observation period. Second, RQA provides a diverse yet comprehensive view of the characteristics of a dynamical system at both (a) its local and global levels and (b) qualitatively via the RP and quantitatively via the various variables that it uses (Zbilut & Webber, 1992; Webber & Zbilut, 1994, 1996, 2005; Riley et al., 1999; Marwan et al., 2002). Last, RQA is a well-established and versatile nonlinear data analysis technique that has been applied successfully across many distinct disciplines, including engineering (e.g., Syta & Litak, 2014; Zimatore & Cavagnaro, 2015), physiology (e.g., Webber & Zbilut, 1994; Marwan et al., 2002, 2007), and psychology (e.g., Shockley et al., 2003; Dale & Spivey, 2005; Richardson et al., 2008), among many others.

Recurrence Variables

The following RQA variables have been calculated[27]:

I. Percent Recurrence (%REC): quantifies the percentage of recurrence points in the RP and measures the degree of repetitiveness in the states of the system.
II. Percent Determinism (%DET): quantifies the percentage of recurrent points that form diagonal lines in the RP and measures the degree of deterministic structure of the system.
III. Entropy (ENTR): quantifies the Shannon entropy of the probability distribution of the diagonal line lengths and measures the degree of complexity of the deterministic structure of the system.
IV. Maximum Diagonal Line Length (LMAX): quantifies the length of the longest diagonal line in the RP (excluding the main diagonal) and measures the degree of dynamical stability of the system.
V. Percent Laminarity (%LAM): quantifies the percentage of recurrence points that form vertical lines in the RP and measures the occurrence of laminar states in the system.
VI. Maximum Vertical Line Length (VMAX): quantifies the length of the longest vertical line in the RP and measures the longest time the system stays in a specific state.
VII. Trapping Time (TT): quantifies the average length of the vertical lines in the RP and measures the average time the system stays in a specific state.

Parameter Selection[28]

RQA requires the a priori selection of three parameters:

I. τ = time delay, or the number of time steps that will be used to embed the time series in the m-dimensional space
II. m = embedding dimension, or the number of coordinates used in reconstructing the space
III. r = radius, or the maximum distance between two points in the time series to be considered recurrent

For this study, the input parameters were set to $\tau = 1$, $m = 5$, and $r = \{0.6, 0.7, 0.8\}$.

The τ and m parameters were estimated for each time series, after which their average (rounded to the nearest integer) was calculated. The delay and embedding dimension parameters were estimated by

[27] For a full description of the variables, see Zbilut and Webber (1992), Webber and Zbilut (1994, 2005), and Marwan et al. (2002).

[28] The delay and embedding dimension parameters were computed using the *mutual()* and *false.nearest()* functions, respectively, from the "tseriesChaos" package, while the radius parameter was computed using the *rqa()* function from the "nonlinearTseries" package in R.

performing the Average Mutual Information (AMI; Frazer & Swinney, 1986) and the False Nearest Neighbour (FNN; Kennel et al., 1992) functions, respectively, and finding their first local minimums.

In respect to the τ parameter, it is important to mention that (a) it is usually 1 for interevent data, as in the present research (Wallot, 2017), and (b) in contrast to the *m* and *r* parameters, previous research has shown that the τ parameter is non-critical, which implies that the quantitative features of the time series are robust against changes in this parameter (Grassberger et al., 1991; Webber & Zbilut, 2005).

The *r* parameter was estimated by performing RQA function and finding the %REC that yields at least 1%[29]. More specifically, the %REC values were estimated for each time series, after which their average (rounded to the nearest integer) was calculated. Moreover, as RQA has indicated sensitivity to the *r* parameter, previous research has recommended that data analyses should be performed using several values for this parameter (Riley et al., 1999). Overall, using several values for the *r* parameter (a) follows the standard procedures in the literature and (b) establishes if the results of this study are robust to the parameter selection.

Results[30]

To test Hypothesis 1, for all *r* parameters, the RQA values for each time series were calculated, after which the range of values was observed to determine if they were characteristic of deterministic systems in both conditions (see Table 6). This is because highly deterministic behaviour, which implies a sequential dependence in reaction times, reflects interdependent or tightly coupled processes. In contrast, if the processes operated independently or were loosely coupled, the observed dynamics would indicate highly stochastic behaviour with no underlying sequential dependence in reaction times.

For all RQA variables, findings showed that RQA values were moderate to high in the low randomness condition and the high randomness condition. Based on the wider literature, the observed range of RQA values was characteristic of deterministic systems (e.g., Zbilut & Webber, 1992; Webber & Zbilut, 1994, 2005; Riley et al., 1999; Pellecchia & Shockley, 2005), therefore supporting Hypothesis 1.

To test Hypothesis 2, for all *r* parameters, the RQA values for each time series were calculated, after which paired-samples t-tests were performed to determine if there were statistically significant mean differences in RQA values between conditions (see Table 6).

Findings showed that RQA values were greater in the low randomness condition than in the high randomness condition, a statistically significant mean difference, $M_{Differences} \geq 0.160$, ts$(70) \geq 2.765$, ps $\leq .007$, therefore supporting Hypothesis 2.

In practice, it is recommended that the results obtained using the original data are always compared with their surrogate versions, which represent randomly shuffled versions of the original data (Nichols & Murphy, 2016). Since randomly shuffling the data destroys any sequential correlation in the series, surrogates act as baseline measures with which the original data can be contrasted to determine whether the pattern of reaction times reflects a true property of the time series dynamics rather than a chance occurrence (Theiler et al., 1991, 1992, 1993; Schreiber & Schmitz, 2000; Nichols & Murphy, 2016). Subsequently, after the initial analyses, the RQA values of the original data were compared with their surrogate versions.

Surrogates were generated using the Fourier transform (FT) method[31] (for details, see Theiler et al., 1993), the most recommended and successfully applied technique for surrogate analysis (e.g., Nichols & Murphy, 2016). The FT method generates surrogates, which are random copies of the original time

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[29] In general, previous research has recommended *r* parameters yielding %REC between 1% and 20%: 1 – 2% (Riley et al., 1999), 1 – 5% (Webber & Zbilut, 2005), and 5 – 20% (Wallot et al., 2012). Therefore, the minimum recommended %REC was 1%.

[30] RQA was computed using the *rqa()* function from the "nonlinearTseries" package in R.

[31] Surrogates were generated using the *FFTsurrogate()* function from the “nonlinearTseries” package in R.

series with the same power spectrum and, thus, the same autocorrelation function[32] (i.e., the same serial correlations), but without any nonlinearity present in the original time series. The FT method therefore preserves the linear behaviour (i.e., the power spectrum/autocorrelation) while destroying any nonlinear behaviour of the original time series.

Surrogates were generated for each time series, after which RQA was applied to the surrogate data under the same input parameters as the original data. Paired-samples t-tests were then conducted to determine whether there were statistically significant mean differences in RQA values between the original time series and their respective surrogates. Results indicated that RQA values were greater for the original as opposed to the surrogate data, a statistically significant mean difference, $M_{Differences} \geq 0.191$, $ts(70) \geq 2.981$, $ps \leq .004$. These results indicate that the observed pattern of reaction times reflects an actual property of the time series dynamics rather than a chance occurrence, thus further supporting Hypotheses 1 and 2.

Table 6
Paired-Samples T-Tests (Study 3B)

Variable	*r*	Low Randomness		High Randomness		*t*(70)	*p*
		M	*SD*	*M*	*SD*		
%REC	0.6	2.673	1.740	1.311	0.723	6.653	< .001
	0.7	4.467	2.391	2.240	1.104	7.942	< .001
	0.8	6.838	3.034	3.532	1.502	9.298	< .001
%DET	0.6	75.562	4.422	71.503	3.460	6.246	< .001
	0.7	79.593	4.293	74.355	3.961	8.011	< .001
	0.8	83.358	3.873	77.742	3.820	9.233	< .001
ENTR	0.6	1.352	0.182	1.161	0.175	7.393	< .001
	0.7	1.514	0.176	1.311	0.172	7.854	< .001
	0.8	1.667	0.177	1.445	0.165	8.597	< .001
LMAX	0.6	11.817	3.567	9.338	4.011	4.180	< .001
	0.7	15.394	5.837	11.230	4.534	4.726	< .001
	0.8	18.92	6.542	13.55	4.690	5.972	< .001
%LAM	0.6	27.748	13.619	17.616	11.298	5.822	< .001
	0.7	36.848	13.956	24.822	12.311	6.531	< .001
	0.8	45.566	13.412	31.916	12.473	7.495	< .001
VMAX	0.6	9.51	4.385	7.113	4.716	3.275	.002
	0.7	12.803	9.222	9.394	5.706	2.765	.007
	0.8	15.52	9.315	11.35	6.123	3.424	.001
TT	0.6	2.596	0.343	2.436	0.275	3.283	.002
	0.7	2.760	0.415	2.559	0.328	3.612	< .001
	0.8	2.957	0.503	2.692	0.376	3.997	< .001

Sample Entropy

Definition

Sample Entropy (SampEn) is a statistical index that quantifies the degree of randomness of a time series “in terms of degrees of irregularity” (Pincus & Singer, 1996, p. 2083). A lower or higher value of the index indicates less or more irregularity in the time series (Richman & Moorman, 2000; Richman et al., 2004).

[32] Autocorrelation of the original time series can be preserved in the surrogate version by preserving the power spectrum, consistent with the Wiener–Khinchin theorem (Wiener, 1930; Nichols & Murphy, 2016).

Mathematically, SampEn has been defined as the negative natural logarithm of the conditional probability that given a time series of length *N*, if the sequence repeated itself within a tolerance *r* for a distance of *m* points, the same sequence would repeat itself at the next point, *m* + 1, while excluding self-matches (Richman & Moorman, 2000; Richman et al., 2004).

Justification

SampEn is an improved version of its predecessor, Approximate Entropy (ApEn; Pincus, 1991, 1995). Despite the fact that both indexes are widely used in practice, SampEn was chosen over ApEn for several reasons. First, SampEn is independent of data length, except for very short time series of length *N* < 100 (Richman & Moorman, 2000; Richman et al., 2004; Molina-Picó et al., 2011; Yentes et al., 2013). Second, unlike ApEn (Eckmann & Ruelle, 1985; Pincus & Goldberger, 1994; Pincus, 1995), SampEn does not count self-matches, therefore eliminating the bias towards regularity by showing more similarity than is actually present in the time series (Richman & Moorman, 2000; Richman et al., 2004). Furthermore, self-matches are discounted from SampEn as they imply comparing the data with itself, which is meaningless because entropy measures the rate at which new information is produced (Richman & Moorman, 2000; Richman et al., 2004). Last, SampEn demonstrates relative consistency: if one time series has a higher value than another for a set of input parameters, by changing the parameters, the same time series will still have a higher value than the other time series. In contrast, numerous studies have indicated that ApEn is relatively inconsistent (e.g., Richman & Moorman, 2000; Richman et al., 2004; Yentes et al., 2013).

Parameter Selection

SampEn requires the a priori selection of three parameters:

I. *N* = length of the time series
II. *m* = embedding dimension, or length of the sequence of points that will be compared
III. *r* = tolerance, or maximum distance for accepting similar patterns between two sequences

For this study, the input parameters were set to *N* = 512, *m* = {2, 3}, and *r* = {0.15, 0.2, 0.25}. Tolerance is standardly set as *r* x *SD*, the standard deviation of the respective time series. In this study, as each time series has been standardised to *M* = 0 and *SD* = 1, the *r* was therefore set to 0.15, 0.2, and 0.25, respectively.

The parameter selection was based on a number of factors. First, previous research has shown that SampEn is independent of data length, except for very short time series of length *N* < 100 (Richman & Moorman, 2000; Richman et al., 2004; Molina-Picó et al., 2011; Yentes et al., 2013). Therefore, the *N* parameter was not of concern in this study because each time series had 512 trials in length. Nevertheless, as SampEn has indicated sensitivity to the *m* and *r* parameters, previous research has recommended that data analyses should be performed using several values for the same parameter. In general, it is recommended to set the *m* parameter to 2 or 3 and the *r* parameter between 0.1 and 0.25 (e.g., Richman & Moorman, 2000; Lake et al., 2002; Richman et al., 2004; Ramdani et al., 2009; Molina-Picó et al., 2011; Yentes et al., 2013, 2018; Cone et al., 2017; Lee et al., 2017; Lubetzky et al., 2018; McCamley et al., 2018; Delgado-Bonal & Marshak, 2019), for time series of length ranging from 100 to 5,000 trials. Overall, using several values for the same parameter (a) follows the standard procedures in the literature and (b) establishes if the results of this study are robust to the parameter selection.

Results[33]

To test Hypothesis 2, for all *m* and *r* parameters, the SampEn values for each time series were calculated, after which paired-samples t-tests were performed to determine if there were statistically significant mean differences in SampEn values between conditions (see Table 7).

Findings showed that SampEn values were greater in the high randomness condition than in the low randomness condition, a statistically significant mean difference, $M_{Differences} \geq 0.181$, $ts(70) \geq 4.329$, $ps < .001$, therefore supporting Hypothesis 2.

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[33] SampEn was computed using the *SampEn()* function from the "TSEntropies" package in R.

After the initial analyses, the SampEn values of the original data were compared with their surrogate versions. Surrogates were generated for each time series using the Fourier transform (FT) method[34] (for details, see Theiler et al., 1993), after which SampEn was applied to the surrogate data under the same input parameters as the original data. Paired-samples t-tests were then conducted to determine whether there were statistically significant mean differences in SampEn values between the original time series and their respective surrogates. Results indicated that SampEn values were greater for the surrogate as opposed to the original data, a statistically significant mean difference, $M_{Differences} \geq 0.221$, ts(70) ≥ 3.657, ps < .001. These results indicate that the observed pattern of reaction times reflects an actual property of the time series dynamics rather than a chance occurrence, thus further supporting Hypothesis 2.

Table 7
Paired-Samples T-Tests (Study 3B)

m	*r*	Low Randomness		High Randomness		*t*(70)	*p*
		M	*SD*	*M*	*SD*		
2	0.15	2.033	0.175	2.221	0.168	7.906	< .001
	0.20	1.746	0.170	1.931	0.152	8.198	< .001
	0.25	1.533	0.163	1.714	0.143	8.621	< .001
3	0.15	2.006	0.231	2.221	0.391	4.329	< .001
	0.20	1.738	0.206	1.926	0.241	5.650	< .001
	0.25	1.518	0.182	1.698	0.182	6.751	< .001

Discussion

On the whole, this study successfully supported Hypotheses 1 and 2, which predicted that task performance will reflect interdependent as opposed to separate interacting processes, and that this performance is context-dependent, therefore showing higher entropy when embedded in a high randomness context as opposed to a low randomness context.

[34] Surrogates were generated using the *FFTsurrogate()* function from the “nonlinearTseries” package in R.

Part II: Study 4

The purpose of this large-scale study was to examine (a) the relationship between entropy and complexity in relation to processes at the macro-level by testing Hypotheses 1 and 2, and (b) if difficulty confounded the examined relationship.

Method

Participants

In total, we recruited 79 individuals (Female = 43, Male = 36; Age range: 29 – 47 years; M_{Age} = 37.769, SD_{Age} = 5.689), and 58 individuals (Female = 32, Male = 26; Age range: 29 – 47 years; M_{Age} = 37.526, SD_{Age} = 5.584) remained after the exclusion criteria were applied (see Procedure section).

All participants were recruited[35] online via Prolific in exchange for a monetary reward of £3.5 (£7/h).

Sample Size

Sample size was determined via power analysis using G*Power (Faul et al., 2007), where an a priori power calculation was performed for a repeated measures ANOVA with the following input parameters: effect size f = 0.25, significance level α = 0.05, power (1 - β) = 0.95, number of groups = 1, and number of measurements = 4.

For this study, power analysis indicated a minimum number of 36. We recruited 119% in excess of this estimate until 79 participants to account for any participants who would not pass the exclusion criteria.

Design

The study had a 2 x 2 within-subjects design, with randomness (two levels: low, high) and key (two levels: two keys, three keys) as within-subjects factors.

The study involved two practice tasks, one for two keys and one for three keys (each 12 trials), and four experimental tasks, one for each combination of levels of the within-subjects factors (each 276[36] trials), which totalled 1128 trials.

After the practice tasks, the order in which participants completed the four experimental tasks was randomised. Each stimulus appeared equally often, and the order in which they were presented was randomised for each participant and task.

Stimuli

The stimuli were the same as in Studies 3A and 3B.

Procedure

Participants read and approved the informed consent form, after which they were presented with the description and instructions of the choice RT task.

There were two versions of this task. In the first version, each trial began with a set of three stimuli being presented on the screen at the same time: a larger one in the center and two smaller ones, one in the top left and one in the top right, until a response was registered.

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[35] The following pre-screening criteria were applied: 1) age: 27 – 46 years; 2) nationality: American, British; 3) minimum approval rate on Prolific: 99%; 4) minimum number of previous submissions on Prolific: 300; and 5) a custom blocklist containing the Prolific IDs of the participants from the previous studies to prevent them from taking part in the present one.

[36] For the experimental tasks, 276 trials were chosen so that the number of trials was an integer of power 2 in length (in this case, 2^8 = 256), and 276 trials are enough to be left with a healthy 20-trial "buffer" to reach the necessary 256 trials after any exclusion criteria were applied.

In the second version, each trial began with a set of four stimuli being presented on the screen at the same time: a larger one in the centre and three smaller ones, one in the top left, one in the top centre, and one in the top right, until a response was registered.

As soon as the stimuli appeared on the screen, participants had to correctly match the stimulus in the centre to one of the smaller stimuli at the top. In the first version of the task, participants had to match the larger stimulus in the centre to one of the stimuli in the top right or top left. In the second version of the task, participants had to match the larger stimulus in the centre to one of the stimuli in the top right, top centre, or top left.

Participants had to press 'C' if the stimulus in the centre matched the one in the top left, 'B' if the stimulus in the centre matched the one in the top centre, and 'M' if the stimulus in the centre matched the one in the top right. They had to do this multiple times for as long as the stimuli kept appearing on the screen. If no response was recorded, trials timed out after 5 s. Between each response and the next set of stimuli, there was a fixed 500 ms inter-trial interval during which the computer monitor was blank. RT was measured as the interval between when the stimulus was presented and when the participant pressed one of the keys.

Participants were instructed to match the stimuli as quickly as they could while making as few mistakes as possible. Moreover, participants were instructed to keep their index fingers on the response keys at all times to enable rapid response and minimise noise due to motor processes (Wagenmakers et al., 2004).

Participants first completed a practice task to get accustomed to the upcoming experimental tasks during which they received feedback for 2 s following each response. The feedback consisted of a '✓' for right and '✗' for wrong responses displayed at the bottom of the screen. Then, participants moved on to the experimental tasks during which no feedback was provided, and they were reminded of the instructions before the start of each task. There were short breaks between the experimental tasks.

After the experimental tasks, participants were given two attention checks (Meade & Craig, 2012; Thomas & Clifford, 2017; Kung et al., 2018) and a seriousness check (Aust et al., 2013). The first attention check was non-specific to the study and consisted of a subset of 10 out of 61, 5-point (1 = *Very Untrue*, 5 = *Very True*) items from the ZTPI (Zimbardo & Boyd, 2015). Participants had to choose a specific response to one of the items[37]. The second attention check was specific to the study and involved responding correctly to the question: "Which key did you have to press when the image in the centre matched the one in the top right?", by choosing among several answer options (i.e., A, M, Space, B, C)[38]. The seriousness check was the same as in the previous studies.

At the end, participants were debriefed and thanked for their participation. In total, the study lasted approximately 30 minutes.

Platform and Participant Setup
The platform and participant setup were the same as in the previous studies.

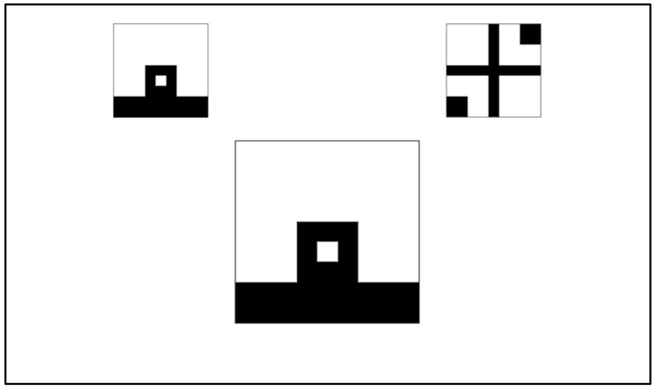
Examples of task display can be seen in Figure 9.

[37] "Q7: Fate determines much in my life. Please select 'Very True'."
[38] The correct answer was M.

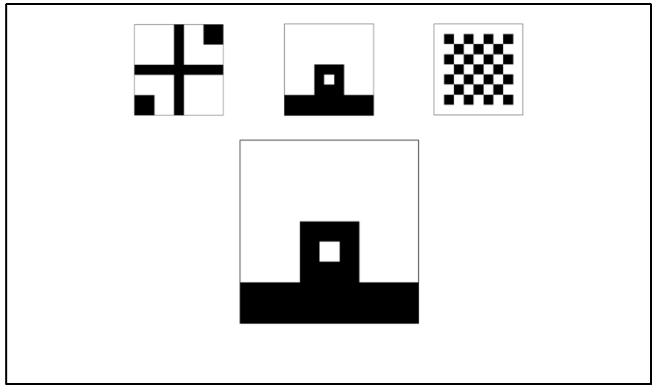
Figure 9

Examples of Task Display for the Low and High Levels of the Randomness Factor, and the Two and Three Keys Levels of the Key Factor (Study 4)

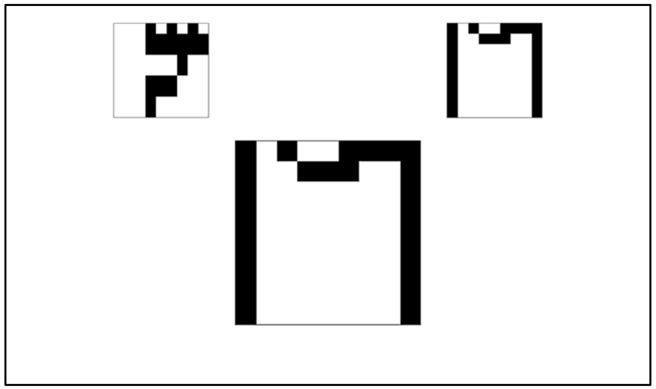
Low Randomness, Two Keys



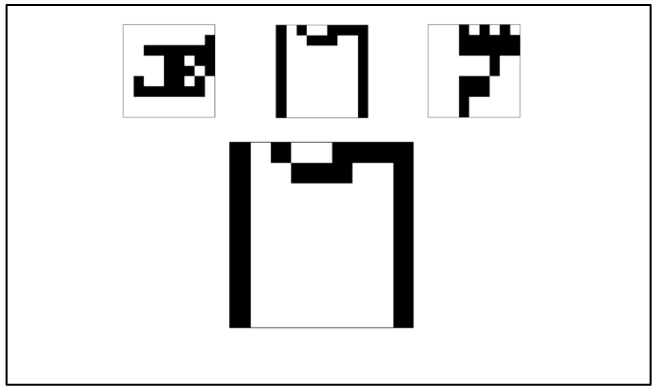
Low Randomness, Three Keys



High Randomness, Two Keys



High Randomness, Three Keys



Results

Data Preparation

Participants were excluded from the data analyses based on two categories of pre-existing exclusion criteria[39], in the following order: 1) exclusion based on the attention and seriousness checks; and 2) exclusion based on the RT data, if the number of remaining trials was less than 256 after specific RT responses were removed from the data. This procedure was done in three steps by eliminating: 1) missing RT responses, defined as RT where participants failed to press the keys; 2) anticipatory RT responses, defined as RT ≤ 100 ms ("irreducible minimum", Woodworth & Schlosberg, 1954; Snodgrass et al., 1967; Luce, 1986; Wagenmakers et al., 2004; Whelan, 2008); and 3) RT responses that fell beyond ± 3 standard deviations from the time series mean (Ratcliff, 1993; Ulrich & Miller, 1994; Whelan, 2008).

Based on the attention and seriousness checks, 14 participants were excluded (two for the non-specific attention check, 12 for the specific attention check, and none for the seriousness check). For the remaining participants, missing and anticipatory RT responses were removed, after which the mean and standard deviation of each participant's time series were calculated, and RT responses that fell beyond ± 3 standard deviations from the mean were removed. In total, seven participants were further excluded based on having less than 256 trials in one of their tasks.

After the exclusion, the beginning of each time series was first truncated until 256 trials remained. Then, each time series was standardised or z-normalised[40] ($M = 0$, $SD = 1$).

Data Analyses

Accuracy

For each participant and condition, the number of errors was calculated, after which they were subjected to a two-way repeated measures ANOVA test, with randomness (two levels: low, high) and key (two levels: two keys, three keys) as within-subjects factors.

First, there was a medium and statistically significant main effect of randomness, $F(1, 57) = 8.789$, $p = .004$, partial $\eta^2 = .134$, with participants being less accurate in the high randomness condition than in the low randomness condition, $M_{Difference} = 1.690$. Second, there was a large and statistically significant main effect of key, $F(1, 57) = 59002.233$, $p < .001$, partial $\eta^2 = .999$, such that participants made more errors when having to press three keys as opposed to two keys, $M_{Difference} = 163.241$. Last, there was a medium and statistically significant randomness x key interaction effect, $F(1, 57) = 7.359$, $p = .009$, partial $\eta^2 = .114$. Therefore, simple main effects were run. The simple main effect of randomness showed that participants were less accurate in the high randomness condition than in the low randomness condition for two keys, a statistically significant mean difference, $M_{Difference} = 2.948$, $F(1, 57) = 15.526$, $p < .001$, partial $\eta^2 = .214$. However, the same effect was not observed for three keys, $M_{Difference} = 0.431$, $F(1, 57) = 0.357$, $p = .553$, partial $\eta^2 = .006$.

Recurrence Quantification Analysis

Parameter Selection[41,42]

RQA requires the a priori selection of three parameters:

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[39] The motivation for the exclusion procedures based on the RT data was the same as in Studies 2B and 3B.
[40] The motivation for the standardisation procedure was the same as in Study 3B.
[41] The parameter selection was based on the same reasons as in Study 3B.
[42] The delay and embedding dimension parameters were computed using the *mutual()* and *false.nearest()* functions, respectively, from the "tseriesChaos" package, while the radius parameter was computed using the *rqa()* function from the "nonlinearTseries" package in R.

I. τ = time delay, or the number of time steps that will be used to embed the time series in the m-dimensional space
II. m = embedding dimension, or the number of coordinates used in reconstructing the space
III. r = radius, or the maximum distance between two points in the time series to be considered recurrent

For this study, the input parameters were set to $\tau = 1$, $m = 5$, and $r = \{0.7, 0.8, 0.9\}$.

***Results*[43]**

To test Hypothesis 1, for all *r* parameters, the RQA values for each time series were calculated, after which the range of values was observed to determine if they were characteristic of deterministic systems in both conditions (see Table 8). This is because highly deterministic behaviour, which implies a sequential dependence in reaction times, reflects interdependent or tightly coupled processes. In contrast, if the processes operated independently or were loosely coupled, the observed dynamics would indicate highly stochastic behaviour with no underlying sequential dependence in reaction times.

For all RQA variables, findings showed that RQA values were moderate to high in all conditions. Based on the wider literature, the observed range of RQA values was characteristic of deterministic systems (e.g., Zbilut & Webber, 1992; Webber & Zbilut, 1994, 2005; Riley et al., 1999; Pellecchia & Shockley, 2005), therefore supporting Hypothesis 1.

To test Hypothesis 2, for all *r* parameters, the RQA values for each time series were calculated, after which they were subjected to two-way repeated measures ANOVA tests, with randomness (two levels: low, high) and key (two levels: two keys, three keys) as within-subjects factors (see Tables 8 and 9).

First, there were large and statistically significant main effects of randomness, Fs(1, 57) ≥ 29.088, ps ≤ .001, partial η^2s ≥ .338, with RQA values being greater in the low randomness condition than in the high randomness condition, $M_{Differences}$ ≥ 0.224, therefore supporting Hypothesis 2. Second, there were large and statistically significant main effects of key, Fs(1, 57) ≥ 30.621, ps ≤ .001, partial η^2s ≥ .349, such that RQA values were greater in the two keys condition than in the three keys condition, $M_{Differences}$ ≥ 0.200. Last, there were no statistically significant randomness x key interaction effects, Fs(1, 57) ≥ .013, ps ≥ .161, partial η^2s ≥ .001, therefore showing that the effects predicted by Hypothesis 2 did not change depending on the levels of the key factor.

For %REC, there were medium and statistically significant randomness x key interaction effects, Fs(1, 57) ≥ 5.019, ps ≤ .029, partial η^2s ≥ .081. Therefore, simple main effects were run. The simple main effect of randomness showed that RQA values were greater in the low randomness condition than in the high randomness condition for two keys, a statistically significant mean difference, $M_{Differences}$ ≥ 2.750, Fs(1, 57) ≥ 37.525, ps ≤ .001, partial η^2s ≥ .397. The same effect was observed for three keys, $M_{Differences}$ ≥ 1.576, Fs(1, 57) ≥ 94.466, ps ≤ .001, partial η^2s ≥ .624. Therefore, despite the significant interaction effects, the effects predicted by Hypothesis 2 held at both levels of the key factor.

After the initial analyses, the RQA values of the original data were compared with their surrogate versions. Surrogates were generated for each time series using the Fourier transform (FT) method[44] (for details, see Theiler et al., 1993), after which RQA was applied to the surrogate data under the same input parameters as the original data. Paired-samples t-tests were then conducted to determine whether there were statistically significant mean differences in RQA values between the original time series and their respective surrogates. Results indicated that RQA values were greater for the original as opposed to the surrogate data, a statistically significant mean difference, $M_{Differences}$ ≥ 0.081, ts(57) ≥ 2.264, ps ≤ .027. These results indicate that the observed pattern of reaction times reflects an actual property of the time series dynamics rather than a chance occurrence, thus further supporting Hypotheses 1 and 2.

[43] RQA was computed using the *rqa()* function from the "nonlinearTseries" package in R.
[44] Surrogates were generated using the *FFTsurrogate()* function from the “nonlinearTseries” package in R.

Table 8
Descriptive Statistics for Study Variables (Study 4)

Variable	*r*	LR – Two Keys		HR – Two Keys		LR – Three Keys		HR – Three Keys	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
%REC	0.7	5.864	3.398	3.114	1.464	3.187	1.320	1.611	0.396
	0.8	8.590	4.200	4.775	2.109	4.844	1.852	2.490	0.612
	0.9	11.810	4.913	6.962	2.791	6.966	2.347	3.735	0.854
%DET	0.7	81.876	4.755	78.066	3.582	78.059	4.114	75.221	2.497
	0.8	84.949	4.580	80.691	4.126	80.711	4.133	76.065	2.606
	0.9	87.676	4.042	83.662	3.993	83.568	3.857	78.454	2.475
ENTR	0.7	1.559	0.239	1.355	0.162	1.379	0.160	1.136	0.148
	0.8	1.719	0.231	1.493	0.168	1.493	0.164	1.261	0.136
	0.9	1.861	0.230	1.634	0.173	1.624	0.163	1.389	0.125
LMAX	0.7	14.224	5.588	10.224	3.770	10.466	3.180	7.362	1.754
	0.8	16.035	5.864	12.035	4.163	12.328	3.384	8.724	2.007
	0.9	18.845	6.596	15.104	5.251	14.552	4.342	11.104	3.088
%LAM	0.7	40.724	15.647	27.378	12.472	26.868	12.471	13.532	7.482
	0.8	49.309	14.957	35.441	13.511	34.446	12.851	19.286	8.319
	0.9	56.599	14.269	42.910	13.560	41.733	12.512	25.153	9.428
VMAX	0.7	11.069	6.138	7.345	2.744	7.552	3.090	4.552	1.739
	0.8	13.586	6.816	9.621	4.503	9.724	4.204	5.776	1.855
	0.9	16.793	8.612	12.604	6.733	12.052	5.253	7.517	2.550
TT	0.7	2.949	0.728	2.601	0.299	2.620	0.323	2.347	0.243
	0.8	3.174	0.804	2.741	0.367	2.757	0.375	2.426	0.235
	0.9	3.450	0.906	2.899	0.427	2.905	0.420	2.534	0.245

Note. LR = Low Randomness and HR = High Randomness.

Table 9
Main Effects of Two-Way Repeated Measures ANOVA (Study 4)

Variable	Within-Subjects Factor	*r*	$M_{Difference}$	*SE*	*F*(1,57)	*p*	η_p^2
%REC	Randomness	0.7	2.163	0.252	73.946	< .001	.565
		0.8	3.084	0.321	92.192	< .001	.618
		0.9	4.039	0.386	109.254	< .001	.657
	Key	0.7	2.091	0.230	82.725	< .001	.592
		0.8	3.016	0.292	106.761	< .001	.652
		0.9	4.036	0.352	131.562	< .001	.698
%DET	Randomness	0.7	3.324	0.469	50.185	< .001	.468
		0.8	4.452	0.497	80.291	< .001	.585
		0.9	4.564	0.452	102.154	< .001	.642
	Key	0.7	3.331	0.465	51.398	< .001	.474
		0.8	4.432	0.453	95.884	< .001	.627
		0.9	4.658	0.414	126.802	< .001	.690
ENTR	Randomness	0.7	0.224	0.022	99.751	< .001	.636
		0.8	0.229	0.023	97.028	< .001	.630
		0.9	0.231	0.022	106.571	< .001	.652
	Key	0.7	0.200	0.023	78.184	< .001	.578
		0.8	0.229	0.022	105.456	< .001	.649
		0.9	0.241	0.022	120.140	< .001	.678
LMAX	Randomness	0.7	3.552	0.515	47.562	< .001	.455
		0.8	3.802	0.566	45.121	< .001	.442
		0.9	3.595	0.636	31.985	< .001	.359
	Key	0.7	3.310	0.474	48.765	< .001	.461
		0.8	3.509	0.507	47.979	< .001	.457
		0.9	4.147	0.593	48.876	< .001	.462
%LAM	Randomness	0.7	13.341	1.453	84.326	< .001	.597
		0.8	14.514	1.511	92.309	< .001	.618
		0.9	15.135	1.484	103.980	< .001	.646
	Key	0.7	13.851	1.396	98.404	< .001	.633
		0.8	15.510	1.419	119.408	< .001	.677
		0.9	16.312	1.368	142.278	< .001	.714
VMAX	Randomness	0.7	3.362	0.495	46.141	< .001	.447
		0.8	3.957	0.578	46.816	< .001	.451
		0.9	4.362	0.734	35.293	< .001	.382
	Key	0.7	3.155	0.472	44.711	< .001	.440
		0.8	3.853	0.610	39.863	< .001	.412
		0.9	4.914	0.795	38.238	< .001	.401
TT	Randomness	0.7	0.310	0.058	29.088	< .001	.338
		0.8	0.382	0.062	37.775	< .001	.399
		0.9	0.461	0.069	44.758	< .001	.440
	Key	0.7	0.292	0.053	30.621	< .001	.349
		0.8	0.366	0.061	36.466	< .001	.390
		0.9	0.455	0.070	42.796	< .001	.429

Sample Entropy

Parameter Selection[45]

SampEn requires the a priori selection of three parameters:

I. N = length of the time series
II. m = embedding dimension, or length of the sequence of points that will be compared
III. r = tolerance, or maximum distance for accepting similar patterns between two sequences

For this study, the input parameters were set to N = 256, m = {2, 3}, and r = {0.15, 0.2, 0.25}. Tolerance is standardly set as r x SD, the standard deviation of the respective time series. In this study, since each time series has been standardised to M = 0 and SD = 1, the r was therefore set to 0.15, 0.2, and 0.25, respectively.

Results[46]

To test Hypothesis 2, for all m and r parameters, the SampEn values for each time series were calculated, after which they were subjected to two-way repeated measures ANOVA tests, with randomness (two levels: low, high) and key (two levels: two keys, three keys) as within-subjects factors (see Tables 10 and 11).

First, there were large and statistically significant main effects of randomness, Fs(1, 57) ≥ 10.167, ps ≤ .001, partial η^2s ≥ .184, with SampEn values being greater in the high randomness condition than in the low randomness condition, $M_{Differences}$ ≥ 0.198, therefore supporting Hypothesis 2. Second, there were large and statistically significant main effects of key, Fs(1, 57) ≥ 10.249, ps ≤ .001, partial η^2s ≥ .186, such that SampEn values were greater in the three keys condition than in the two keys condition, $M_{Differences}$ ≥ 0.197. Last, there were no statistically significant randomness x key interaction effects, Fs(1, 57) ≥ 0.010, ps ≥ .298, partial η^2s ≥ .001, therefore showing that the effects predicted by Hypothesis 2 did not change depending on the levels of the key factor.

After the initial analyses, the SampEn values of the original data were compared with their surrogate versions. Surrogates were generated for each time series using the Fourier transform (FT) method[47] (for details, see Theiler et al., 1993), after which SampEn was applied to the surrogate data under the same input parameters as the original data. Paired-samples t-tests were then conducted to determine whether there were statistically significant mean differences in SampEn values between the original time series and their respective surrogates. Results indicated that SampEn values were greater for the surrogate as opposed to the original data, a statistically significant mean difference, $M_{Differences}$ ≥ 0.077, ts(57) ≥ 3.254, ps ≤ .002. These results indicate that the observed pattern of reaction times reflects an actual property of the time series dynamics rather than a chance occurrence, thus further supporting Hypothesis 2.

[45] The parameter selection was based on the same reasons as in Study 3B.
[46] SampEn was computed using the *SampEn()* function from the "TSEntropies" package in R.
[47] Surrogates were generated using the *FFTsurrogate()* function from the “nonlinearTseries” package in R.

Table 10
Descriptive Statistics for Study Variables (Study 4)

m	*r*	LR – Two Keys		HR – Two Keys		LR – Three Keys		HR – Three Keys	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
2	0.15	1.963	0.240	2.179	0.249	2.169	0.214	2.391	0.252
	0.20	1.683	0.217	1.879	0.173	1.879	0.165	2.085	0.161
	0.25	1.474	0.200	1.663	0.163	1.663	0.151	1.870	0.132
3	0.15	1.953	0.427	2.226	0.505	2.222	0.453	2.386	0.462
	0.20	1.680	0.274	1.893	0.338	1.919	0.313	2.148	0.417
	0.25	1.484	0.252	1.677	0.230	1.655	0.193	1.912	0.273

Note. LR = Low Randomness and HR = High Randomness.

Table 11
Main Effects of Two-Way Repeated Measures ANOVA (Study 4)

Within-Subjects Factor	*m*	*r*	$M_{Difference}$	*SE*	*F*(1,57)	*p*	η_p^2
Randomness	2	0.15	0.219	0.025	74.029	<.001	.565
		0.20	0.201	0.021	92.416	<.001	.619
		0.25	0.198	0.018	115.367	<.001	.669
	3	0.15	0.218	0.068	10.167	.003	.184
		0.20	0.221	0.041	29.226	<.001	.343
		0.25	0.225	0.026	71.946	<.001	.558
Key	2	0.15	0.208	0.030	48.757	<.001	.461
		0.20	0.201	0.023	79.005	<.001	.581
		0.25	0.197	0.020	97.224	<.001	.630
	3	0.15	0.215	0.067	10.249	.003	.186
		0.20	0.247	0.048	26.210	<.001	.319
		0.25	0.202	0.032	40.253	<.001	.414

Discussion

On the whole, this study successfully supported Hypotheses 1 and 2, which predicted that task performance will reflect interdependent as opposed to separate interacting processes, and that this performance is context-dependent, therefore showing higher entropy when embedded in a high randomness context as opposed to a low randomness context.

This study also successfully determined that the observed effects were due to the extent of randomness in the stimuli, as predicted, rather than difficulty (i.e., the more random stimuli in the high randomness condition being more difficult to match than those in the low randomness condition).

Part III: Study 5A

The purpose of this small-scale study was to (a) create a set of stimuli, (b) examine their subjective and objective randomness, and (c) use these measures to allocate the stimuli between conditions for the subsequent large-scale study (see Study 5B).

Method

Participants

In total, we recruited 30 individuals (Female = 22, Male = 8; Age range: 27 – 47 years; M_{Age} = 37.200; SD_{Age} = 5.810), and all remained after the exclusion criterion was applied (see Procedure section).

All participants were recruited[48] online via Prolific in exchange for a monetary reward of £1.8 (£7.2/h).

Sample Size

Sample size was determined using a *flat* rule of thumb, where a fixed number is recommended for every situation, irrespective of the subsequent large-scale study (Machin et al., 2018). This is due to the fact that sample sizes for small-scale studies cannot be precisely determined via power analysis because they are not intended for hypothesis testing, as in the case of large-scale studies (Cohen, 1988; Faul et al., 2007).

In general, previous research has recommended sample sizes ranging from 10 to 30 participants, including: 10 – 30 (Isaac & Michael, 1995; Hill, 1998), 12 (van Belle, 2002), 20 (Birket & Day, 1994), 24 (Julious, 2005), and 30 (Browne, 1995). Therefore, the minimum sample size recommended was 10 participants.

For this study, we recruited 200% in excess of this estimate until 30 participants to account for any participants who would not pass the exclusion criterion.

Design

The study involved one experimental task (180 trials). Each stimulus appeared only once, and the order in which they were presented was randomised for each participant.

Stimuli

The stimuli were the same as in Studies 3A, 3B, and 4, with an additional 70 stimuli created to accommodate the design of Study 5B.

In total, 180 stimuli were created, 45 for each level of randomness (four levels: low, medium, high, very high) as a within-subjects factor (see Design section in Study 5B).

Examples of stimuli can be seen in Figure 10, and the full set of stimuli can be seen in Appendix C.

Procedure

Participants read and approved the informed consent form, after which they were presented with the description and instructions of the scoring task.

Each trial began with the stimulus being presented in the centre of the screen until a response was registered. Participants had to score the stimuli on the following quality: randomness, which referred to how random they found the stimulus (i.e., to what extent it lacked any underlying order).

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[48] The following pre-screening criteria were applied: 1) age: 26 – 47 years; 2) location: UK, USA; 3) nationality: American, British; 4) vision: normal or corrected-to-normal; 5) minimum approval rate on Prolific: 99%; 6) minimum number of previous submissions on Prolific: 300; and 7) a custom blocklist containing the Prolific IDs of the participants from the previous studies to prevent them from taking part in the present one.

For each trial, a slider with values ranging from 0 to 100 was displayed, and participants had to adjust the slider to correspond to how they perceived the stimulus, with 0 meaning very low and 100 meaning very high randomness. Each stimulus was scored only once, and after an evaluation had been made, participants could not go back to change their answers. After each stimulus was scored, participants had to press "Next" to proceed to the next trial. If participants tried to proceed without answering, a message (i.e., "You must give a response to all items") was displayed on the screen reminding them to answer.

Participants were first shown some examples to get a general idea of the stimuli they were about to score. Then, participants moved on to the experimental task, and they were reminded of the instructions before the start of the task. There was a short break during the study.

After the experimental tasks, participants were given a seriousness check (Aust et al., 2013), which was the same as in the previous studies.

At the end, participants were debriefed and thanked for their participation. In total, the study lasted approximately 15 minutes.

Platform and Participant Setup

The platform and participant setup were the same as in the previous studies.

Examples of task display can be seen in Figure 11.

Results

For subjective randomness, participants' average scores for each stimulus were calculated, after which they were transformed into ranks (duplicate scores were assigned an average rank), with higher ranks indicating higher subjective randomness. These ranks were then used to allocate the stimuli between conditions (see Design section in Study 5B).

To confirm the allocation, subjective randomness scores were subjected to a one-way repeated measures ANOVA, with subjective randomness (four levels: low, medium, high, very high) as a within-subjects factor. Findings showed a very large and significant effect of subjective randomness, $F(3, 132) = 826.817$, $p < .001$, partial $\eta^2 = .949$, with subjective randomness increasing from the low ($M = 12.242$, $SD = 2.856$), to the medium ($M = 44.417$, $SD = 14.039$), to the high ($M = 62.838$, $SD = 1.843$), and to the very high ($M = 69.512$, $SD = 2.594$) level. Post hoc analysis further revealed statistically significant mean differences between all levels of the subjective randomness factor, $M_{Differences} \geq 6.674$, *p*s < .001.

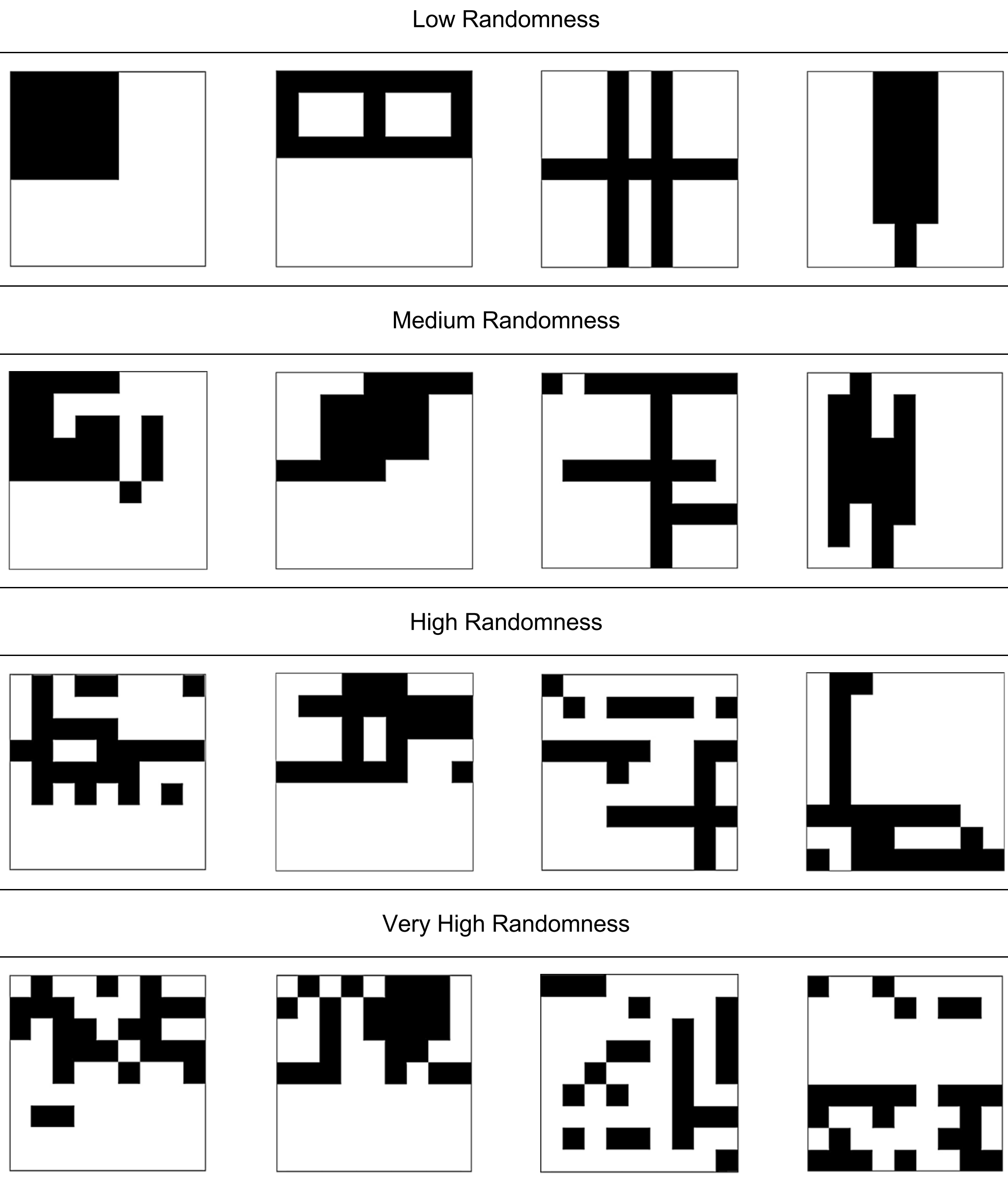
To also confirm the allocation of the same stimuli between conditions for objective randomness, Fourier randomness (for details, see Krpan & van Tilburg, 2022) was used. Objective randomness scores for each stimulus were computed, after which they were subjected to the same analysis as above. Results indicated a large and significant effect of objective randomness, $F(3, 132) = 38.795$, $p < .001$, partial $\eta^2 = .469$, such that objective randomness increased from the low ($M = 43.111$, $SD = 17.213$), to the medium ($M = 55.111$, $SD = 14.286$), to the high ($M = 64.889$, $SD = 7.142$), and to the very high ($M = 69.644$, $SD = 6.227$) level. Post hoc analysis further revealed statistically significant mean differences between all levels of the objective randomness factor, $M_{Differences} \geq 4.756$, *p*s ≤ .002.

Discussion

On the whole, this study successfully created, examined, and allocated the set of stimuli between the low, medium, high, and very high levels of the randomness factor for the next study (see Study 5B), using both subjective (i.e., participants' scores) and objective (i.e., Fourier randomness, Krpan & van Tilburg, 2022) randomness measures.

Figure 10

Examples of Stimuli for the Low, Medium, High, and Very High Levels of the Randomness Factor (Study 5A)

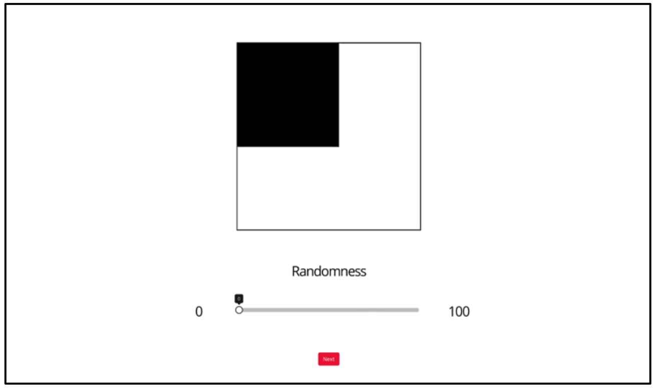


Note. The full set of stimuli can be seen in Appendix C.

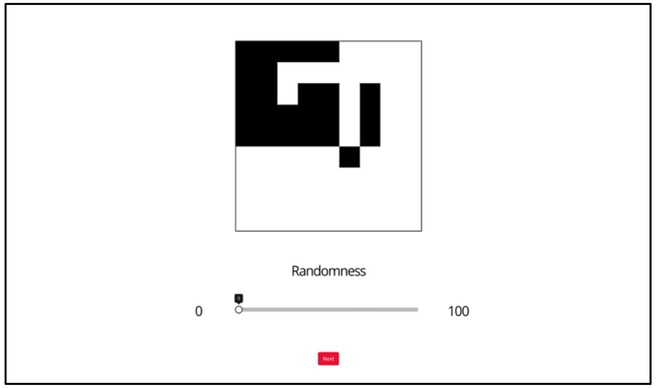
Figure 11

Examples of Task Display for the Low, Medium, High, and Very High Levels of the Randomness Factor (Study 5A)

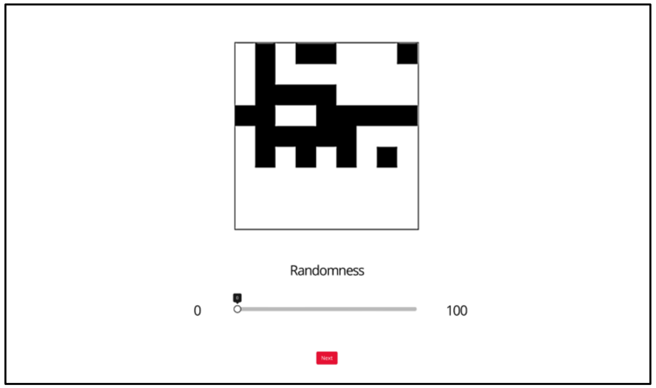
Low Randomness



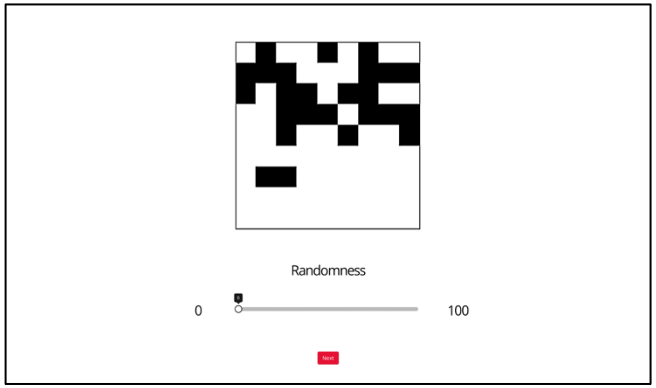
Medium Randomness



High Randomness



Very High Randomness



Part III: Study 5B

The purpose of this large-scale study was to examine (a) the relationship between entropy and complexity in relation to processes at the macro- and micro-levels, and (b) if the ranking of the micro-levels affected the examined relationship.

Method

Participants

In total, we recruited 70 individuals (Female = 40, Male = 28, Other[49] = 2; Age range: 26 – 48 years; M_{Age} = 38.072, SD_{Age} = 6.436), and 65 individuals (Female = 36, Male = 27, Other = 2; Age range: 26 – 48 years; M_{Age} = 37.641, SD_{Age} = 6.388) remained after the exclusion criteria were applied (see Procedure section).

All participants were recruited[50] online via Prolific in exchange for a monetary reward of £3 (£7.2/h).

Sample Size

Sample size was determined via power analysis using G*Power (Faul et al., 2007), where an a priori power calculation was performed for a repeated measures ANOVA with the following input parameters: effect size f = 0.25, significance level $\alpha = 0.05$, power $(1 - \beta) = 0.95$, number of groups = 1, and number of measurements = 8.

For this study, power analysis indicated a minimum number of 23. We recruited 204% in excess of this estimate until 70 participants to account for any participants who would not pass the exclusion criteria.

Design

The study had a 4 x 2 within-subjects design, with randomness (four levels: low, medium, high, very high) and rank (two levels: ascending, descending) as within-subjects factors.

The study involved a practice task (20 trials) and two experimental tasks, one for each level of rank as a within-subjects factor (each 540 trials), which totalled 1100 trials. Each experimental task was split into four parts, one for each level of randomness as a within-subjects factor (each 135 trials).

After the practice task, the order in which participants completed the two experimental tasks was randomised. Each stimulus appeared equally often, and the order in which they were presented depended on the within-subjects factors: the levels of the randomness factor were arranged in increasing/decreasing order for the ascending/descending levels of the rank factor, and at each level of the randomness factor, the stimuli were randomised for each participant and task.

Stimuli

The stimuli were the same as in Study 5A.

Procedure

Participants read and approved the informed consent form, after which they were presented with the description and instructions of the choice RT task.

Each trial began with a set of three stimuli being presented on the screen at the same time: one in the centre, one in the top left, and one in the top right, until a response was registered.

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[49] Includes participants who selected the option “Prefer not to say” (*n* = 1) or whose data were missing (*n* = 1) for Gender.

[50] The following pre-screening criteria were applied: 1) age: 26 – 47 years; 2) location: UK, USA; 3) nationality: American, British; 4) vision: normal or corrected-to-normal; 5) minimum approval rate on Prolific: 99%; 6) minimum number of previous submissions on Prolific: 300; and 7) a custom blocklist containing the Prolific IDs of the participants from the previous studies to prevent them from taking part in the present one.

As soon as the stimuli appeared on the screen, participants had to correctly match the stimulus in the centre to either the stimulus in the top right or the stimulus in the top left. Participants had to press the 'C' key if the stimulus in the centre matched the one in the top left and the 'M' key if the stimulus in the centre matched the one in the top right. They had to do this multiple times for as long as the stimuli kept appearing on the screen. If no response was recorded, trials timed out after 5s. Between each response and the next set of stimuli, there was a fixed 500 ms inter-trial interval during which the computer monitor was blank. RT was measured as the interval between when the stimulus was presented and when the participant pressed one of the keys.

Participants were instructed to match the stimuli as quickly as they could while making as few mistakes as possible. Moreover, participants were instructed to keep their index fingers on both response keys at all times to enable rapid response and minimise noise due to motor processes (Wagenmakers et al., 2004).

Participants first completed a practice task to get accustomed to the upcoming experimental tasks during which they received feedback for 2 s following each response. The feedback consisted of a '✔' for right and '✖' for wrong responses displayed at the bottom of the screen. Then, participants moved on to the experimental tasks during which no feedback was provided, and they were reminded of the instructions before the start of each task. There was a short break between the experimental tasks.

After the experimental tasks, participants were given two attention checks (Meade & Craig, 2012; Thomas & Clifford, 2017; Kung et al., 2018) and a seriousness check (Aust et al., 2013). The first attention check was non-specific to the study and consisted of a subset of 10 out of 61, 5-point (1 = *Very Untrue*, 5 = *Very True*) items from the ZTPI (Zimbardo & Boyd, 2015). Participants had to choose a specific response to one of the items[51]. The second attention check was specific to the study and involved responding correctly to the question: "Which key did you have to press when the image in the centre matched the one in the top right?", by choosing among several answer options (i.e., A, M, Space, B, C)[52]. The seriousness check was the same as in the previous studies.

At the end, participants were debriefed and thanked for their participation. In total, the study lasted approximately 25 minutes.

Platform and Participant Setup

The platform and participant setup were the same as in the previous studies.

Examples of task display can be seen in Figure 12.

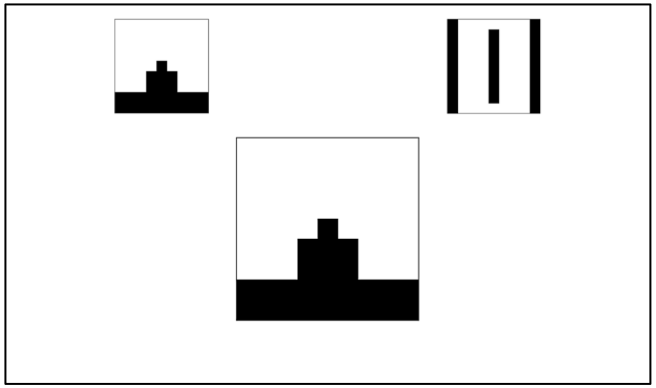
[51] "Q7: Fate determines much in my life. Please select 'Very True'."

[52] The correct answer was M.

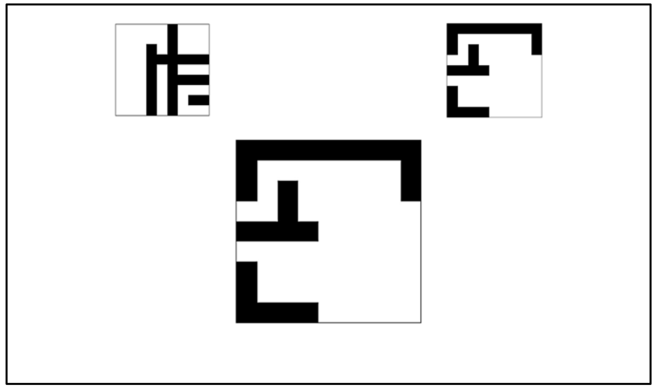
Figure 12

Examples of Task Display for the Low, Medium, High, and Very High Levels of the Randomness Factor (Study 5B)

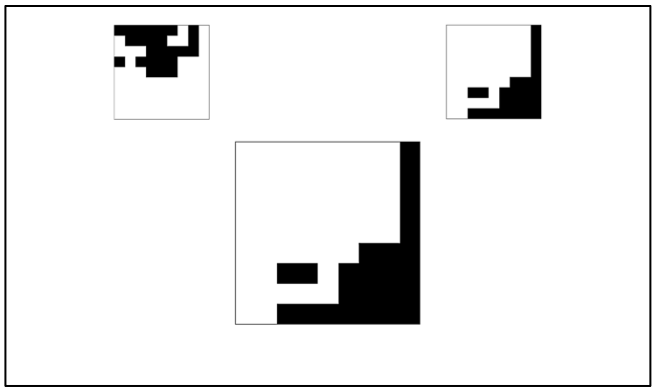
Low Randomness



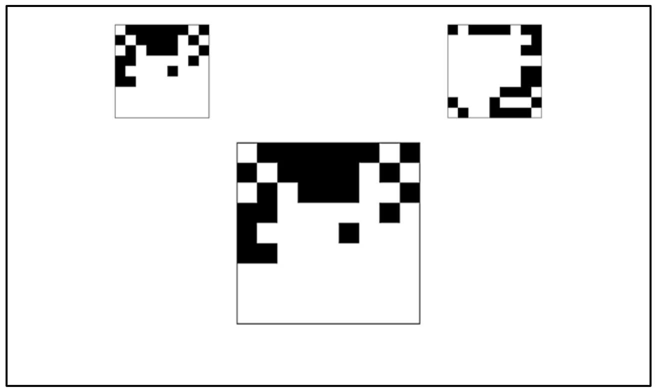
Medium Randomness



High Randomness



Very High Randomness



Results

Data Preparation

Participants were excluded from the data analyses based on two categories of pre-existing exclusion criteria[53], in the following order: 1) exclusion based on the attention and seriousness checks; and 2) exclusion based on the RT data, if the number of remaining trials was significantly less than 135 or 540 after specific RT responses were removed from the data. This procedure was done in three steps by eliminating: 1) missing RT responses, defined as RT where participants failed to press the keys; 2) anticipatory RT responses, defined as RT ≤ 100 ms ("irreducible minimum", Woodworth & Schlosberg, 1954; Snodgrass et al., 1967; Luce, 1986; Wagenmakers et al., 2004; Whelan, 2008); and 3) RT responses that fell beyond ± 3 standard deviations from the time series mean (Ratcliff, 1993; Ulrich & Miller, 1994; Whelan, 2008).

Based on the attention and seriousness checks, three participants were excluded (two for the non-specific attention check, one for the specific attention check, and none for the seriousness check). For the remaining participants, missing and anticipatory RT responses were removed, after which the mean and standard deviation of each participant's time series were calculated, and RT responses that fell beyond ± 3 standard deviations from the mean were removed. In total, two participants were further excluded based on having significantly less than 135 or 540 trials in one of their tasks.

After the exclusion, each time series was standardised or z-normalised[54] (M = 0, SD = 1).

Data Analyses

Accuracy

For each participant and condition, the number of errors was calculated, after which a paired-samples t-test was performed to determine if there was a statistically significant mean difference in accuracy between conditions.

Findings showed that participants were less accurate in the descending rank condition (M = 20.877, SD = 16.397) than in the ascending rank condition (M = 16.923, SD = 11.453), a statistically significant mean difference, $M_{Difference}$ = 3.954, $t(64)$ = 2.327, p = .023.

Recurrence Quantification Analysis

Parameter Selection[55,56]

RQA requires the a priori selection of three parameters:

I. τ = time delay, or the number of time steps that will be used to embed the time series in the m-dimensional space
II. m = embedding dimension, or the number of coordinates used in reconstructing the space
III. r = radius, or the maximum distance between two points in the time series to be considered recurrent

For this study, the input parameters were set to τ = 1, m = 5, and r = 0.6.

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[53] The motivation for the exclusion procedures based on the RT data was the same as in Studies 2B, 3B and 4.
[54] The motivation for the standardisation procedure was the same as in Studies 3B and 4.
[55] The parameter selection was based on the same reasons as in Studies 3B and 4.
[56] The delay and embedding dimension parameters were computed using the *mutual()* and *false.nearest()* functions, respectively, from the "tseriesChaos" package, while the radius parameter was computed using the *rqa()* function from the "nonlinearTseries" package in R.

***Results*[57]**

Macro-Level

To test Hypothesis 1, for all *r* parameters, the RQA values for each time series were calculated, after which the range of values was observed to determine if they were characteristic of deterministic systems in both conditions (see Table 12). This is because highly deterministic behaviour, which implies a sequential dependence in reaction times, reflects interdependent or tightly coupled processes. In contrast, if the processes operated independently or were loosely coupled, the observed dynamics would indicate highly stochastic behaviour with no underlying sequential dependence in reaction times.

For all RQA variables, findings showed that RQA values were moderate to high in the ascending rank condition and the descending rank condition. Based on the wider literature, the observed range of RQA values was characteristic of deterministic systems (e.g., Zbilut & Webber, 1992; Webber & Zbilut, 1994, 2005; Riley et al., 1999; Pellecchia & Shockley, 2005), therefore supporting Hypothesis 1.

To test Hypothesis 2, the RQA values for each time series were calculated, after which paired-samples t-tests were performed to determine if there were statistically significant mean differences in RQA values between conditions (see Table 12).

Findings showed statistically non-significant mean differences in RQA values between the ascending rank condition and the descending rank condition, $M_{Differences} \geq 0.029$, ts(64) ≥ 0.540, ps ≥ .100, therefore supporting Hypothesis 2.

After the initial analyses, the RQA values of the original data were compared with their surrogate versions. Surrogates were generated for each time series using the Fourier transform (FT) method[58] (for details, see Theiler et al., 1993), after which RQA was applied to the surrogate data under the same input parameters as the original data. Paired-samples t-tests were then conducted to determine whether there were statistically significant mean differences in RQA values between the original time series and their respective surrogates. Results indicated that RQA values were greater for the original as opposed to the surrogate data, a statistically significant mean difference, $M_{Differences} \geq 0.489$, ts(64) ≥ 7.550, ps ≤ .001. These results indicate that the observed pattern of reaction times reflects an actual property of the time series dynamics rather than a chance occurrence, thus further supporting Hypotheses 1 and 2.

Table 12
Paired-Samples T-Tests (Study 5B)

Variable	*r*	Ascending Rank		Descending Rank		*t*(64)	*p*
		M	*SD*	*M*	*SD*		
%REC	0.6	2.599	1.412	2.901	1.313	1.667	.100
%DET	0.6	80.576	5.645	81.011	5.351	0.540	.591
ENTR	0.6	1.573	0.273	1.602	0.260	0.773	.442
LMAX	0.6	16.969	8.676	18.046	7.557	0.884	.380
%LAM	0.6	38.509	16.649	40.868	14.826	1.213	.229
VMAX	0.6	14.446	9.975	15.262	7.821	0.578	.565
TT	0.6	2.975	0.620	3.074	0.685	1.160	.250

[57] RQA was computed using the *rqa()* function from the "nonlinearTseries" package in R.
[58] Surrogates were generated using the *FFTsurrogate()* function from the “nonlinearTseries” package in R.

Micro-Level
Each time series was split into non-overlapping windows of 40 time points (with the remaining time points being omitted from the analyses), which totalled 13 windows. The RQA values for each window of each time series were calculated, after which paired-samples t-tests were performed to determine if there were statistically significant mean differences in RQA values between windows in each pair of successive windows. In total, 12 paired-samples t-tests were performed in each of the conditions for the following pairs of successive windows: $w_1 - w_2$, $w_2 - w_3$, $w_3 - w_4$, $w_4 - w_5$, $w_5 - w_6$, $w_6 - w_7$, $w_7 - w_8$, $w_8 - w_9$, $w_9 - w_{10}$, $w_{10} - w_{11}$, $w_{11} - w_{12}$, and $w_{12} - w_{13}$ (see Table 13).

For %REC, there were statistically significant mean differences in RQA values between windows in the pairs $w_3 - w_4$ and $w_{10} - w_{11}$ in the ascending rank condition, $M_{Differences} \geq -3.227$, ts(64) ≥ -2.305, ps ≤ .024, and the descending rank condition, $M_{Differences} \geq -2.448$, ts(64) ≥ -2.168, ps ≤ .034.

For %DET, there were statistically significant mean differences in RQA values between windows in the pair $w_{10} - w_{11}$ in the ascending rank condition, $M_{Difference} = -3.546$, $t(64) = -3.027$, $p = .004$. There were statistically non-significant mean differences in RQA values between windows in all pairs in the descending rank condition, $M_{Differences} \geq -1.584$, ts(64) ≥ -1.368, ps ≥ .176.

For ENTR, there were statistically significant mean differences in RQA values between windows in the pair $w_6 - w_7$ in the ascending rank condition, $M_{Difference} = .172$, $t(64) = 2.207$, $p = .031$, and the descending rank condition, $M_{Difference} = -.183$, $t(64) = -2.182$, $p = .033$.

For LMAX, there were statistically significant mean differences in RQA values between windows in the pairs $w_3 - w_4$ and $w_{10} - w_{11}$ in the ascending rank condition, $M_{Differences} \geq -1.092$, ts(64) ≥ -2.076, ps ≤ .042. There were statistically non-significant mean differences in RQA values between windows in all pairs in the descending rank condition, $M_{Differences} \geq -.938$, ts(64) ≥ -1.610, ps ≥ .062.

For %LAM, there were statistically significant mean differences in RQA values between windows in the pairs $w_1 - w_2$, $w_4 - w_5$, and $w_{10} - w_{11}$ in the ascending rank condition, $M_{Differences} \geq -7.395$, ts(64) ≥ -2.286, ps ≤ .035. There were statistically non-significant mean differences in RQA values between windows in all pairs in the descending rank condition, $M_{Differences} \geq -5.443$, ts(64) ≥ -1.350, ps ≥ .140.

For VMAX, there were statistically significant mean differences in RQA values between windows in the pairs $w_4 - w_5$ and $w_{10} - w_{11}$ in the ascending rank condition, $M_{Differences} \geq -.877$, ts(64) ≥ -2.220, ps ≤ .031. There were statistically non-significant mean differences in RQA values between windows in all pairs in the descending rank condition, $M_{Differences} \geq -.646$, ts(64) ≥ -1.354, ps ≥ .052.

For TT, there were statistically non-significant mean differences in RQA values between windows in all pairs in the ascending and descending rank conditions, $M_{Differences} \geq -.426$, ts(64) ≥ -1.810, ps ≥ .058.

Table 13
Paired-Samples T-Tests for Pairs of Successive Windows (Study 5B)

Variable	Ascending Rank				Descending Rank			
	Pair	$M_{Difference}$	$t(64)$	p	Pair	$M_{Difference}$	$t(64)$	p
%REC	$w_3 - w_4$	3.784	2.947	.004	$w_3 - w_4$	3.846	2.475	.016
	$w_{10} - w_{11}$	-3.227	-2.305	.024	$w_{10} - w_{11}$	-2.448	-2.168	.034
%DET	$w_{10} - w_{11}$	-3.546	-3.027	.004	–	–	–	–
ENTR	$w_6 - w_7$	.172	2.207	.031	$w_6 - w_7$	-.183	-2.182	.033
LMAX	$w_3 - w_4$	1.677	2.535	.014	–	–	–	–
	$w_{10} - w_{11}$	-1.092	-2.076	.042	–	–	–	–
%LAM	$w_1 - w_2$*	6.544	2.160	.035	–	–	–	–
	$w_4 - w_5$	10.285	3.365	.001	–	–	–	–
	$w_{10} - w_{11}$	-7.395	-2.286	.026	–	–	–	–
VMAX	$w_4 - w_5$	.908	2.201	.031	–	–	–	–
	$w_{10} - w_{11}$	-.877	-2.220	.030	–	–	–	–

Note. * = Pair of successive windows that is not considered change, as it does not meet the criteria.

After the initial analysis, the findings were assessed against pre-existing criteria to determine (a) if they represent a change in the state of the system and, if so, (b) the speed at which that change happened and (c) the level(s) of the randomness factor at which it happened (see Table 14).

In the present research, a change in the state of the system was defined based on the following criteria:

1. There must be a statistically significant mean difference between windows in *at least one* pair of successive windows.
    a. If there is a statistically significant mean difference between windows in *only one* pair of successive windows, the change in the state of the system is considered *fast*.
    b. If there are statistically significant mean differences between windows in *more than one* pair of successive windows, the change in the state of the system is considered *slow*.
2. There must not be a statistically significant mean difference between windows in the pair of windows preceding the first window from the pair(s) identified based on criterion 1.
3. There must not be a statistically significant mean difference between windows in the pair of windows succeeding the last window from the pair(s) identified based on criterion 1.

Based on these criteria, for all RQA variables in the ascending and descending rank conditions, all pairs of successive windows met the criteria, except for pair $w_1 – w_2$ for %LAM in the ascending rank condition.

For all RQA variables in the ascending and descending rank conditions, the speed of change was considered fast, as there were statistically significant mean differences between windows in only one pair of successive windows.

For all RQA variables in the ascending rank condition, the changes happened at the transition between the low and medium and the high and very high levels, except for %DET, for which the change happened only at the transition between the high and very high levels of the randomness factor. Furthermore, ENTR was the only one for which the change happened at the transition between the medium and high levels of the randomness factor. Nevertheless, the same effects were not observed in the descending rank condition, where only %REC and ENTR showed the same changes.

Table 14
Description of Change for Pairs of Successive Windows (Study 5B)

Variable	Ascending Rank			Descending Rank		
	P_{Change}	S_{Change}	L_{Change}	P_{Change}	S_{Change}	L_{Change}
%REC	$w_3 – w_4$	Fast	Low – Medium	$w_3 – w_4$	Fast	High – Very High
	$w_{10} – w_{11}$	Fast	High – Very High	$w_{10} – w_{11}$	Fast	Low – Medium
%DET	$w_{10} – w_{11}$	Fast	High – Very High	–	–	–
ENTR	$w_6 – w_7$	Fast	Medium – High	$w_6 – w_7$	Fast	Medium – High
LMAX	$w_3 – w_4$	Fast	Low – Medium	–	–	–
	$w_{10} – w_{11}$	Fast	High – Very High	–	–	–
%LAM	$w_4 – w_5$	Fast	Low – Medium	–	–	–
	$w_{10} – w_{11}$	Fast	High – Very High	–	–	–
VMAX	$w_4 – w_5$	Fast	Low – Medium	–	–	–
	$w_{10} – w_{11}$	Fast	High – Very High	–	–	–

Note. P = Pair of successive windows that is considered change, S = Speed at which change happened, and L = Level(s) of the randomness factor at which change happened.

Sample Entropy

Parameter Selection[59]

SampEn requires the a priori selection of three parameters:

I. *N* = length of the time series
II. *m* = embedding dimension, or length of the sequence of points that will be compared
III. *r* = tolerance, or maximum distance for accepting similar patterns between two sequences

For this study, the input parameters were set to $N \approx 540$, $m = \{2, 3\}$, and $r = \{0.15, 0.2, 0.25\}$. Tolerance is standardly set as $r \times SD$, the standard deviation of the respective time series. In this study, since each time series has been standardised to $M = 0$ and $SD = 1$, the *r* was therefore set to 0.15, 0.2, and 0.25, respectively.

Results[60]

To test Hypothesis 2, for all *m* and *r* parameters, the SampEn values for each time series were calculated, after which paired-samples t-tests were performed to determine if there were statistically significant mean differences in SampEn values between conditions (see Table 15).

Findings showed statistically non-significant mean differences in SampEn values between the ascending rank condition and the descending rank condition, $M_{Differences} \geq 0.030$, ts(64) ≥ 0.885, ps ≥ .060, therefore supporting Hypothesis 2.

After the initial analyses, the SampEn values of the original data were compared with their surrogate versions. Surrogates were generated for each time series using the Fourier transform (FT) method[61] (for details, see Theiler et al., 1993), after which SampEn was applied to the surrogate data under the same input parameters as the original data. Paired-samples t-tests were then conducted to determine whether there were statistically significant mean differences in SampEn values between the original time series and their respective surrogates. Results indicated that SampEn values were greater for the surrogate as opposed to the original data, a statistically significant mean difference, $M_{Differences} \geq 0.374$, ts(64) ≥ 9.447, ps < .001. These results indicate that the observed pattern of reaction times reflects an actual property of the time series dynamics rather than a chance occurrence, thus further supporting Hypothesis 2.

Table 15
Paired-Samples T-Tests (Study 5B)

m	*r*	Ascending Rank		Descending Rank		*t*(64)	*p*
		M	*SD*	*M*	*SD*		
2	0.15	1.943	0.247	1.913	0.230	1.059	.293
	0.20	1.674	0.227	1.626	0.198	1.917	.060
	0.25	1.462	0.206	1.422	0.184	1.715	.091
3	0.15	1.860	0.343	1.819	0.278	0.885	.379
	0.20	1.601	0.302	1.545	0.235	1.680	.098
	0.25	1.383	0.242	1.345	0.209	1.260	.212

[59] The parameter selection was based on the same reasons as in Studies 3B and 4.
[60] SampEn was computed using the *SampEn()* function from the "TSEntropies" package in R.
[61] Surrogates were generated using the *FFTsurrogate()* function from the "nonlinearTseries" package in R.

Discussion

At the macro-level, this study successfully supported Hypotheses 1 and 2, which predicted that task performance will reflect interdependent as opposed to separate interacting processes, and that this performance is context-dependent, therefore showing higher entropy when embedded in a high randomness context as opposed to a low randomness context.

At the micro-level, there were three important findings. First, the change at the macro- vs. micro-levels reflects the inherent nonlinear character of complex systems, which implies that the degree of change at the micro-level will not be proportional to the degree of change at the macro-level of the system (Richardson & Chemero, 2014; Richardson et al., 2014). More specifically, despite findings showing statistically non-significant mean differences in RQA values between the ascending rank condition and the descending rank condition at the macro-level, results indicated that (a) there were statistically significant mean differences in RQA values between windows in pairs in the ascending rank condition and the descending rank condition at the micro-level, and (b) the number of changes were different depending on the condition, with the ascending rank condition having more changes (i.e., 10) than the descending rank condition (i.e., three). Second, the changes happened at the transition between all levels of the randomness factor in the ascending rank condition and the descending rank condition. Moreover, these changes were very precise, as they happened predominantly at the exact transition between all levels of the randomness factor (i.e., $w_3 – w_4$ and $w_4 – w_5$ between the low and medium levels, $w_6 – w_7$ between the medium and high levels, and $w_{10} – w_{11}$ between the high and very high levels). Third, the changes happened very fast in the ascending rank condition and the descending rank condition, but there was no discernible pattern in the findings that indicates that the speed of change depends on the levels of the randomness factor. In relation to these last two micro-level findings, the precision and speed of change further reflect the interdependence among processes and their dependency on the task environment, which allows the psychological system to meet the changing demands of the task.

On the whole, the macro- and micro-level findings directly and indirectly, respectively, support Hypotheses 1 and 2. In other words, the results indicate that the micro-level interactions among the constituent parts modulate and, simultaneously, are being modulated by the macro-level organisation of the system (Bar-Yam, 1997; Richardson & Chemero, 2014; Richardson et al., 2014).

Part III: Study 6

The purpose of this large-scale study was to examine (a) the relationship between entropy and complexity in relation to processes at the macro- and micro-levels, and (b) if the range of the micro-levels affected the examined relationship.

Method

Participants

In total, we recruited 80 individuals (Female = 44, Male = 36; Age range: 25 – 45 years; M_{Age} = 34.125, SD_{Age} = 5.909), and 70 individuals (Female = 35, Male = 35; Age range: 25 – 45 years; M_{Age} = 34.529, SD_{Age} = 5.855) remained after the exclusion criteria were applied (see Procedure section).

All participants were recruited[62] online via Prolific in exchange for a monetary reward of £3.3 (£7.92/h).

Sample Size

Sample size was determined via power analysis using G*Power (Faul et al., 2007), where an a priori power calculation was performed for a repeated measures ANOVA with the following input parameters: effect size f = 0.25, significance level α = 0.05, power (1 - β) = 0.95, number of groups = 1, and number of measurements = 4.

For this study, power analysis indicated a minimum number of 36. We recruited 122% in excess of this estimate until 80 participants to account for any participants who would not pass the exclusion criteria.

Design

The study had a 2 x 2 within-subjects design, with randomness (two levels: low, high) and range (two levels: low, high) as within-subjects factors.

The study involved a practice task (20 trials) and two experimental tasks, one for each level of randomness as a within-subjects factor (each 540 trials), which totalled 1100 trials. Each experimental task was split into two parts, one for each level of range as a within-subjects factor (each 270 trials).

After the practice task, the order in which participants completed the two experimental tasks was randomised. Each stimulus appeared equally often, and the order in which they were presented depended on the within-subjects factors: the levels of the range factor were arranged from low to high for each of the levels of the randomness factor, and at each level of the range factor, the stimuli were randomised for each participant and task.

Stimuli

In total, 40 of the stimuli used in Studies 5A and 5B were selected, 10 for each combination of levels of the within-subjects factors.

For subjective randomness, participants' average scores for each stimulus were calculated, after which they were transformed into ranks (duplicate scores were assigned an average rank), with higher ranks indicating higher subjective randomness. These ranks were then used to allocate the stimuli between conditions.

To confirm the allocation, subjective randomness scores were subjected to a two-way repeated measures ANOVA, with subjective randomness (two levels: low, high) and range (two levels: low, high) as within-subjects factors. First, there was a large and statistically significant main effect of subjective randomness, $F(1, 9) = 3772.451$, $p < .001$, partial $\eta^2 = .998$, with subjective randomness being greater

[62] The following pre-screening criteria were applied: 1) age: 25 – 45 years; 2) location: UK, USA; 3) nationality: American, British; 4) vision: normal or corrected-to-normal; 5) minimum approval rate on Prolific: 99%; 6) minimum number of previous submissions on Prolific: 300; and 7) a custom blocklist containing the Prolific IDs of the participants from the previous studies to prevent them from taking part in the present one.

in the high randomness condition than in the low randomness condition, $M_{Difference}$ = 44.160. Second, there was a large and statistically significant main effect of range, $F(1, 9) = 10.249$, $p < .001$, partial $\eta^2 = .986$, such that range was greater in the high range condition than in the low range condition, $M_{Difference}$ = 19.017. Last, there was no statistically significant subjective randomness x range interaction effect, $F(1, 9) = 0.025$, $p = .878$, partial $\eta^2 = .003$.

To also confirm the allocation of the same stimuli between conditions for objective randomness, Fourier randomness (for details, see Krpan & van Tilburg, 2022) was used. Objective randomness scores for each stimulus were computed, after which they were subjected to the same analysis as above. First, there was a large and statistically significant main effect of objective randomness, $F(1, 9) = 170.080$, $p < .001$, partial $\eta^2 = .950$, with objective randomness being greater in the high randomness condition than in the low randomness condition, $M_{Difference}$ = 31.600. Second, there was a large and statistically significant main effect of range, $F(1, 9) = 10.416$, $p = .010$, partial $\eta^2 = .536$, such that range was greater in the high range condition than in the low range condition, $M_{Difference}$ = 17.600. Last, there was no statistically significant objective randomness x range interaction effect, $F(1, 9) = 2.676$, $p = .136$, partial $\eta^2 = .229$.

Examples of stimuli can be seen in Figure 13, and the full set of stimuli can be seen in Appendix C.

Procedure

Participants read and approved the informed consent form, after which they were presented with the description and instructions of the choice RT task.

Each trial began with a set of three stimuli being presented on the screen at the same time: one in the centre, one in the top left, and one in the top right, until a response was registered.

As soon as the stimuli appeared on the screen, participants had to correctly match the stimulus in the centre to either the stimulus in the top right or the stimulus in the top left. Participants had to press the ‘C’ key if the stimulus in the centre matched the one in the top left and the ‘M’ key if the stimulus in the centre matched the one in the top right. They had to do this multiple times for as long as the stimuli kept appearing on the screen. If no response was recorded, trials timed out after 5s. Between each response and the next set of stimuli, there was a fixed 500 ms inter-trial interval during which the computer monitor was blank. RT was measured as the interval between when the stimulus was presented and when the participant pressed one of the keys.

Participants were instructed to match the stimuli as quickly as they could while making as few mistakes as possible. Moreover, participants were instructed to keep their index fingers on both response keys at all times to enable rapid response and minimise noise due to motor processes (Wagenmakers et al., 2004).

Participants first completed a practice task to get accustomed to the upcoming experimental tasks during which they received feedback for 2 s following each response. The feedback consisted of a ‘✓’ for right and ‘✖’ for wrong responses displayed at the bottom of the screen. Then, participants moved on to the experimental tasks during which no feedback was provided, and they were reminded of the instructions before the start of each task. There was a short break between the experimental tasks.

After the experimental tasks, participants were given two attention checks (Meade & Craig, 2012; Thomas & Clifford, 2017; Kung et al., 2018) and a seriousness check (Aust et al., 2013). The first attention check was non-specific to the study and consisted of a subset of 10 out of 61, 5-point (1 = *Very Untrue*, 5 = *Very True*) items from the ZTPI (Zimbardo & Boyd, 2015). Participants had to choose a specific response to one of the items[63]. The second attention check was specific to the study and involved responding correctly to the question: “Which key did you have to press when the image in the centre matched the one in the top right?”, by choosing among several answer options (i.e., A, M, Space, B, C)[64]. The seriousness check was the same as in the previous studies.

[63] “Q7: Fate determines much in my life. Please select 'Very True'.”
[64] The correct answer was M.

At the end, participants were debriefed and thanked for their participation. In total, the study lasted approximately 25 minutes.

Platform and Participant Setup

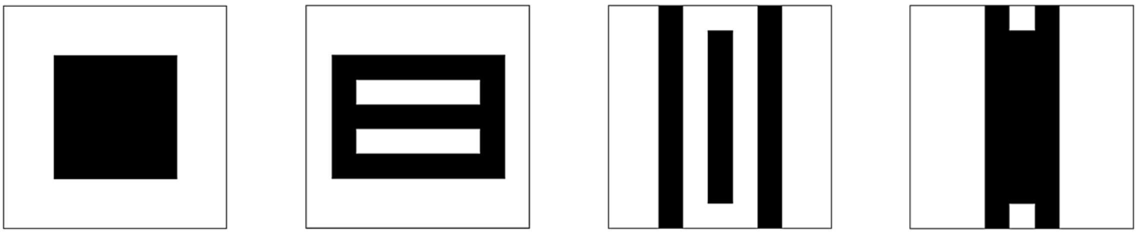
The platform and participant setup were the same as in the previous studies.

Examples of task display can be seen in Figure 14.

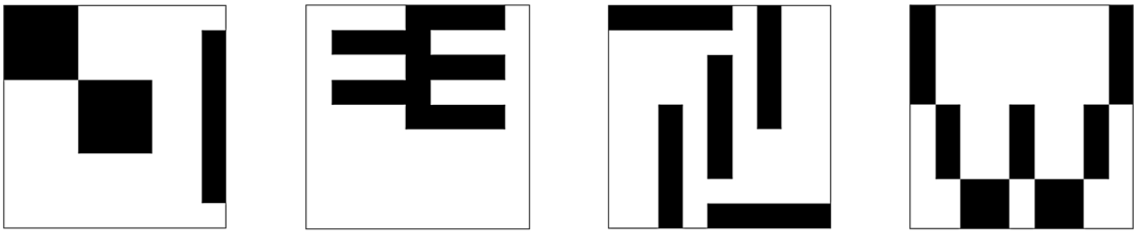
Figure 13

Examples of Stimuli for the Low and High Levels of the Randomness Factor, and the Low and High Levels of the Range Factor (Study 6)

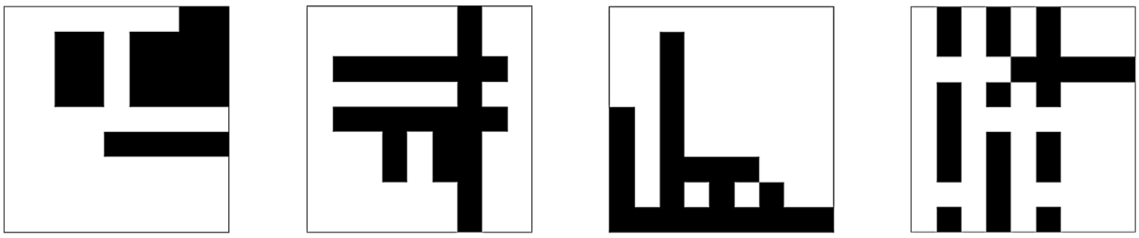
Low Randomness, Low Range



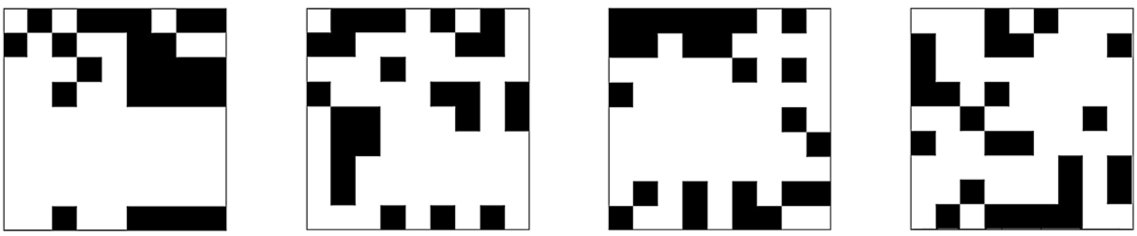
Low Randomness, High Range



High Randomness, Low Range



High Randomness, High Range

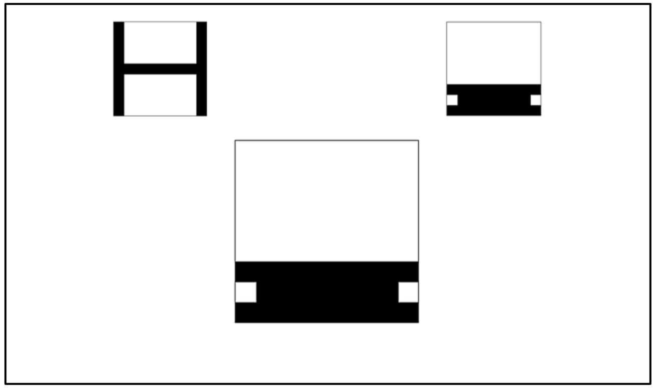


Note. The full set of stimuli can be seen in Appendix C.

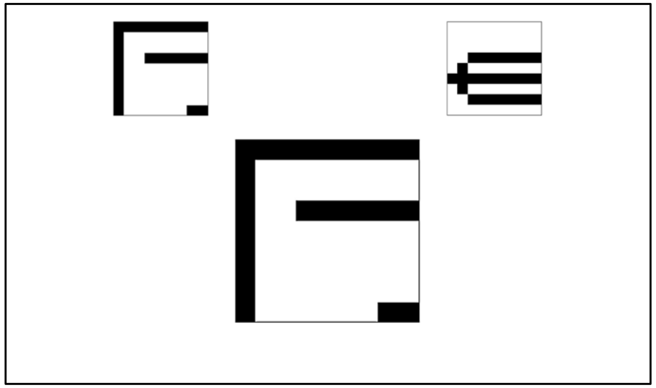
Figure 14

Examples of Task Display for the Low and High Levels of the Randomness Factor, and the Low and High Levels of the Range Factor (Study 6)

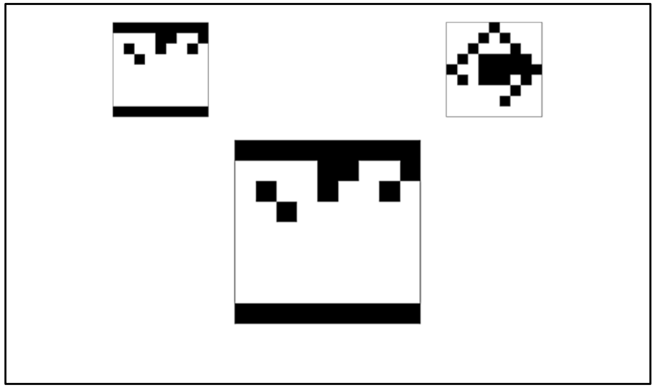
Low Randomness, Low Range



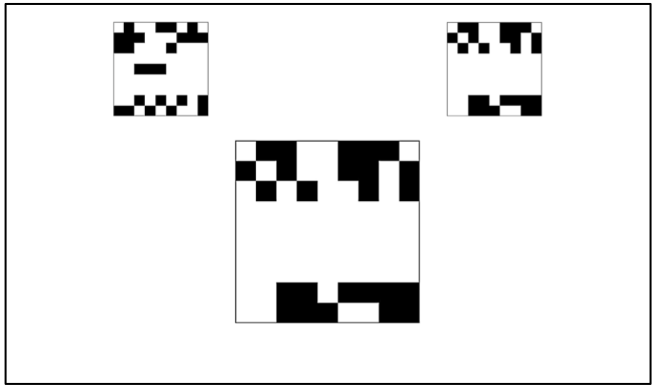
Low Randomness, High Range



High Randomness, Low Range



High Randomness, High Range



Results

Data Preparation

Participants were excluded from the data analyses based on two categories of pre-existing exclusion criteria[65], in the following order: 1) exclusion based on the attention and seriousness checks; and 2) exclusion based on the RT data, if the number of remaining trials was significantly less than 270 or 540 after specific RT responses were removed from the data. This procedure was done in three steps by eliminating: 1) missing RT responses, defined as RT where participants failed to press the keys; 2) anticipatory RT responses, defined as RT ≤ 100 ms ("irreducible minimum", Woodworth & Schlosberg, 1954; Snodgrass et al., 1967; Luce, 1986; Wagenmakers et al., 2004; Whelan, 2008); and 3) RT responses that fell beyond ± 3 standard deviations from the time series mean (Ratcliff, 1993; Ulrich & Miller, 1994; Whelan, 2008).

Based on the attention and seriousness checks, six participants were excluded (one for the non-specific attention check, five for the specific attention check, and none for the seriousness check). For the remaining participants, missing and anticipatory RT responses were removed, after which the mean and standard deviation of each participant's time series were calculated, and RT responses that fell beyond ± 3 standard deviations from the mean were removed. In total, four participants were further excluded based on having significantly less than 270 or 540 trials in one of their tasks.

After the exclusion, each time series was standardised or z-normalised[66] ($M = 0$, $SD = 1$).

Data Analyses

Accuracy

For each participant and condition, the number of errors was calculated, after which a paired-samples t-test was performed to determine if there was a statistically significant mean difference in accuracy between conditions.

Findings showed that participants were less accurate in the high randomness condition ($M = 20.943$, $SD = 16.233$) than in the low randomness condition ($M = 17.200$, $SD = 13.472$), a statistically significant mean difference, $M_{Difference} = 3.743$, $t(69) = 2.627$, $p = .011$.

Recurrence Quantification Analysis

Parameter Selection[67,68]

RQA requires the a priori selection of three parameters:

I. τ = time delay, or the number of time steps that will be used to embed the time series in the m-dimensional space
II. m = embedding dimension, or the number of coordinates used in reconstructing the space
III. r = radius, or the maximum distance between two points in the time series to be considered recurrent

For this study, the input parameters were set to $\tau = 1$, $m = 5$, and $r = 0.6$.

[65] The motivation for the exclusion procedures based on the RT data was the same as in Studies 2B, 3B, 4, and 5B.
[66] The motivation for the standardisation procedure was the same as in Studies 3B, 4, and 5B.
[67] The parameter selection was based on the same reasons as in Studies 3B, 4, and 5B.
[68] The delay and embedding dimension parameters were computed using the *mutual()* and *false.nearest()* functions, respectively, from the "tseriesChaos" package, while the radius parameter was computed using the *rqa()* function from the "nonlinearTseries" package in R.

***Results*[69]**

Macro-Level

To test Hypothesis 1, for all *r* parameters, the RQA values for each time series were calculated, after which the range of values was observed to determine if they were characteristic of deterministic systems in both conditions (see Table 16). This is because highly deterministic behaviour, which implies a sequential dependence in reaction times, reflects interdependent or tightly coupled processes. In contrast, if the processes operated independently or were loosely coupled, the observed dynamics would indicate highly stochastic behaviour with no underlying sequential dependence in reaction times.

For all RQA variables, findings showed that RQA values were moderate to high in the low randomness condition and the high randomness condition. Based on the wider literature, the observed range of RQA values was characteristic of deterministic systems (e.g., Zbilut & Webber, 1992; Webber & Zbilut, 1994, 2005; Riley et al., 1999; Pellecchia & Shockley, 2005), therefore supporting Hypothesis 1.

To test Hypothesis 2, the RQA values for each time series were calculated, after which paired-samples t-tests were performed to determine if there were statistically significant mean differences in RQA values between conditions (see Table 16).

Findings showed that RQA values were greater in the low randomness condition than in the high randomness condition, a statistically significant mean difference, $M_{Differences} \geq 0.227$, ts(69) ≥ 2.074, ps ≤ .042, therefore supporting Hypothesis 2.

After the initial analyses, the RQA values of the original data were compared with their surrogate versions. Surrogates were generated for each time series using the Fourier transform (FT) method[70] (for details, see Theiler et al., 1993), after which RQA was applied to the surrogate data under the same input parameters as the original data. Paired-samples t-tests were then conducted to determine whether there were statistically significant mean differences in RQA values between the original time series and their respective surrogates. Results indicated that RQA values were greater for the original as opposed to the surrogate data, a statistically significant mean difference, $M_{Differences} \geq 0.533$, ts(69) ≥ 9.042, ps ≤ .001. These results indicate that the observed pattern of reaction times reflects an actual property of the time series dynamics rather than a chance occurrence, thus further supporting Hypotheses 1 and 2

Table 16
Paired-Samples T-Tests (Study 6)

Variable	*r*	Low Randomness		High Randomness		*t*(69)	*p*
		M	*SD*	*M*	*SD*		
%REC	0.6	3.935	2.790	3.186	1.591	2.074	.042
%DET	0.6	84.227	7.256	79.177	5.043	5.322	< .001
ENTR	0.6	1.772	0.407	1.545	0.217	4.550	< .001
LMAX	0.6	20.271	11.546	15.814	5.409	3.202	.002
%LAM	0.6	47.838	20.883	38.313	12.675	3.750	< .001
VMAX	0.6	17.671	11.772	13.071	4.935	3.150	.002
TT	0.6	3.371	0.834	2.843	0.372	5.129	< .001

Micro-Level

Each time series was split into non-overlapping windows of 40 time points (with the remaining time points being omitted from the analyses), which totalled 13 windows. The RQA values for each window of each time series were calculated, after which paired-samples t-tests were performed to determine if there were statistically significant mean differences in RQA values between windows in each pair of successive windows. In total, 12 paired-samples t-tests were performed in each of the conditions for

69 RQA was computed using the *rqa()* function from the "nonlinearTseries" package in R.

70 Surrogates were generated using the *FFTsurrogate()* function from the “nonlinearTseries” package in R.

the following pairs of successive windows: $w_1 - w_2$, $w_2 - w_3$, $w_3 - w_4$, $w_4 - w_5$, $w_5 - w_6$, $w_6 - w_7$, $w_7 - w_8$, $w_8 - w_9$, $w_9 - w_{10}$, $w_{10} - w_{11}$, $w_{11} - w_{12}$, and $w_{12} - w_{13}$ (see Table 17).

For %REC, there were statistically significant mean differences in RQA values between windows in pairs $w_6 - w_7$, $w_7 - w_8$, and $w_{11} - w_{12}$ in the low randomness condition, $M_{Differences} \geq -1.041$, $ts(69) \geq -3.358$, $ps \leq .001$, and $w_6 - w_7$ and $w_7 - w_8$ the high randomness condition, $M_{Differences} \geq 3.036$, $ts(69) \geq 3.538$, $ps < .001$.

For %DET, there were statistically significant mean differences in RQA values between windows in pair $w_6 - w_7$ in the low randomness condition, $M_{Difference} = -2.254$, $t(69) = -2.049$, $p = .044$, and $w_4 - w_5$ in the high randomness condition, $M_{Difference} = 2.172$, $t(69) = 2.029$, $p = .046$.

For ENTR, there were statistically significant mean differences in RQA values between windows in pairs $w_5 - w_6$, $w_6 - w_7$, and $w_7 - w_8$ in the low randomness condition, $M_{Differences} \geq -.130$, $ts(69) \geq -2.052$, $ps \leq .044$, and $w_7 - w_8$ in the high randomness condition, $M_{Difference} = .459$, $t(69) = 5.077$, $p < .001$.

For LMAX, there were statistically significant mean differences in RQA values between windows in pairs $w_5 - w_6$, $w_6 - w_7$, and $w_7 - w_8$ in the low randomness condition, $M_{Differences} \geq -1.129$, $ts(69) \geq -2.009$, $ps \leq .048$, and $w_7 - w_8$ in the high randomness condition, $M_{Difference} = 2.643$, $t(69) = 5.174$, $p < .001$.

For %LAM, there were statistically significant mean differences in RQA values between windows in pairs $w_7 - w_8$ and $w_{11} - w_{12}$ in the low randomness condition, $M_{Differences} \geq -5.033$, $ts(69) \geq -2.150$, $ps \leq .035$, and $w_7 - w_8$ in the high randomness condition, $M_{Difference} = 21.796$, $t(69) = 6.165$, $p < .001$.

For VMAX, there were statistically significant mean differences in RQA values between windows in pairs $w_7 - w_8$ and $w_{11} - w_{12}$ in the low randomness condition, $M_{Differences} \geq -.686$, $ts(69) \geq -2.264$, $ps \leq .027$, and $w_7 - w_8$ in the high randomness condition, $M_{Difference} = 3.171$, $t(69) = 5.895$, $p < .001$.

For TT, there were statistically significant mean differences in RQA values between windows in pair $w_7 - w_8$ in the low randomness condition, $M_{Difference} = 2.242$, $t(69) = 7.545$, $p < .001$, and $w_3 - w_4$ and $w_7 - w_8$ in the high randomness condition, $M_{Differences} \geq -.458$, $ts(69) \geq -2.146$, $ps \leq .035$.

Table 17
Paired-Samples T-Tests for Pairs of Successive Windows (Study 6)

Variable	Low Randomness				High Randomness			
	Pair	$M_{Difference}$	$t(69)$	p	Pair	$M_{Difference}$	$t(69)$	p
%REC	$w_6 - w_7$	5.783	3.631	< .001	$w_6 - w_7$	3.336	3.538	< .001
	$w_7 - w_8$	8.406	7.773	< .001	$w_7 - w_8$	3.036	5.182	< .001
	$w_{11} - w_{12}$*	-1.041	-3.358	.001	–	–	–	–
%DET	$w_6 - w_7$	-2.254	-2.049	.044	$w_4 - w_5$	2.172	2.029	.046
ENTR	$w_5 - w_6$	-.130	-2.052	.044	–	–	–	–
	$w_6 - w_7$	.144	2.203	.031	–	–	–	–
	$w_7 - w_8$	.821	10.206	< .001	$w_7 - w_8$	.459	5.077	< .001
LMAX	$w_5 - w_6$	-1.129	-2.009	.048	–	–	–	–
	$w_6 - w_7$	1.500	2.240	.028	–	–	–	–
	$w_7 - w_8$	5.557	8.690	< .001	$w_7 - w_8$	2.643	5.174	< .001
%LAM	$w_7 - w_8$	36.113	9.973	< .001	$w_7 - w_8$	21.796	6.165	< .001
	$w_{11} - w_{12}$*	-5.033	-2.150	.035	–	–	–	–
VMAX	$w_7 - w_8$	5.357	8.292	< .001	$w_7 - w_8$	3.171	5.895	< .001
	$w_{11} - w_{12}$*	-.686	-2.264	.027	–	–	–	–
TT	–	–	–	–	$w_3 - w_4$	-.458	-2.146	.035
	$w_7 - w_8$	2.242	7.545	< .001	$w_7 - w_8$	1.586	5.004	< .001

Note. * = Pair of successive windows that is not considered change, as it does not meet the criteria.

After the initial analysis, the findings were assessed against pre-existing criteria to determine (a) if they represent a change in the state of the system and, if so, (b) the speed at which that change happened and (c) the level(s) of the range factor at which it happened (see Table 18).

In the present research, a change in the state of the system was defined based on the following criteria[71]:

1. There must be a statistically significant mean difference between windows in *at least one* pair of successive windows.
    a. If there is a statistically significant mean difference between windows in *only one* pair of successive windows, the change in the state of the system is considered *fast*.
    b. If there are statistically significant mean differences between windows in *more than one* pair of successive windows, the change in the state of the system is considered *slow*.
2. There must not be a statistically significant mean difference between windows in the pair of windows preceding the first window from the pair(s) identified based on criterion 1.
3. There must not be a statistically significant mean difference between windows in the pair of windows succeeding the last window from the pair(s) identified based on criterion 1.

Based on these criteria, for all RQA variables in the low and high randomness conditions, all pairs of successive windows met the criteria, except for pair $w_{11} – w_{12}$ for %REC, %LAM, and VMAX in the low randomness condition.

For %DET, %LAM, VMAX, and TT in the low randomness condition, the speed of change was considered fast, as there were statistically significant mean differences between windows in only one pair of successive windows. For %REC, ENTR, and LMAX in the low randomness condition, the speed of change was considered slow, as there were statistically significant mean differences between windows in more than one pair of successive windows. For all RQA variables in the high randomness condition, except for %REC, the speed of change was considered fast, as there were statistically significant mean differences between windows in only one pair of successive windows.

For all RQA variables in the low randomness condition, the changes happened at the transition between the low and high levels of the range factor. Similar effects were observed in the high randomness condition, where the changes happened at the transition between the low and high levels of the range factor, except for %DET and TT, for which the changes happened at the low level of the range factor.

Table 18
Description of Change for Pairs of Successive Windows (Study 6)

Variable	Low Randomness			High Randomness		
	P_{Change}	S_{Change}	L_{Change}	P_{Change}	S_{Change}	L_{Change}
%REC	$w_6 – w_7 – w_8$	Slow	Low – High	$w_6 – w_7 – w_8$	Slow	Low – High
%DET	$w_6 – w_7$	Fast	Low – High	$w_4 – w_5$	Fast	Low
ENTR	$w_5 – w_6 – w_7 – w_8$	Slow	Low – High	$w_7 – w_8$	Fast	Low – High
LMAX	$w_5 – w_6 – w_7 – w_8$	Slow	Low – High	$w_7 – w_8$	Fast	Low – High
%LAM	$w_7 – w_8$	Fast	Low – High	$w_7 – w_8$	Fast	Low – High
VMAX	$w_7 – w_8$	Fast	Low – High	$w_7 – w_8$	Fast	Low – High
TT	–	–	–	$w_3 – w_4$	Fast	Low
	$w_7 – w_8$	Fast	Low – High	$w_7 – w_8$	Fast	Low – High

Note. P = Pair of successive windows that is considered change, S = Speed at which change happened, and L = Level(s) of the range factor at which change happened.

[71] The criteria were the same as in Study 5B.

Sample Entropy

Parameter Selection[72]

SampEn requires the a priori selection of three parameters:

I. *N* = length of the time series
II. *m* = embedding dimension, or length of the sequence of points that will be compared
III. *r* = tolerance, or maximum distance for accepting similar patterns between two sequences

For this study, the input parameters were set to $N \approx 540$, $m = \{2, 3\}$, and $r = \{0.15, 0.2, 0.25\}$. Tolerance is standardly set as $r \times SD$, the standard deviation of the respective time series. In this study, since each time series has been standardised to $M = 0$ and $SD = 1$, the *r* was therefore set to 0.15, 0.2, and 0.25, respectively.

Results[73]

To test Hypothesis 2, for all *m* and *r* parameters, the SampEn values for each time series were calculated, after which paired-samples t-tests were performed to determine if there were statistically significant mean differences in SampEn values between conditions (see Table 19).

Findings showed that SampEn values were greater in the high randomness condition than in the low randomness condition, a statistically significant mean difference, $M_{Differences} \geq 0.133$, ts(69) ≥ 3.540, ps < .001, therefore supporting Hypothesis 2.

After the initial analyses, the SampEn values of the original data were compared with their surrogate versions. Surrogates were generated for each time series using the Fourier transform (FT) method[74] (for details, see Theiler et al., 1993), after which SampEn was applied to the surrogate data under the same input parameters as the original data. Paired-samples t-tests were then conducted to determine whether there were statistically significant mean differences in SampEn values between the original time series and their respective surrogates. Results indicated that SampEn values were greater for the surrogate as opposed to the original data, a statistically significant mean difference, $M_{Differences} \geq 0.475$, ts(69) ≥ 10.400, ps < .001. These results indicate that the observed pattern of reaction times reflects an actual property of the time series dynamics rather than a chance occurrence, thus further supporting Hypothesis 2.

Table 19
Paired-Samples T-Tests (Study 6)

m	*r*	Low Randomness		High Randomness		*t*(69)	*p*
		M	*SD*	*M*	*SD*		
2	0.15	1.761	0.312	1.917	0.167	4.138	< .001
	0.20	1.496	0.295	1.642	0.158	4.183	< .001
	0.25	1.302	0.284	1.434	0.147	3.906	< .001
3	0.15	1.700	0.377	1.887	0.241	3.540	< .001
	0.20	1.426	0.325	1.612	0.194	4.447	< .001
	0.25	1.219	0.298	1.393	0.173	4.602	< .001

[72] The parameter selection was based on the same reasons as in Studies 3B, 4, and 5B.
[73] SampEn was computed using the *SampEn()* function from the "TSEntropies" package in R.
[74] Surrogates were generated using the *FFTsurrogate()* function from the “nonlinearTseries” package in R.

Discussion

At the macro-level, this study successfully supported Hypotheses 1 and 2, which predicted that task performance will reflect interdependent as opposed to separate interacting processes, and that this performance is context-dependent, therefore showing higher entropy when embedded in a high randomness context as opposed to a low randomness context.

At the micro-level, there were three important findings. First, the change at the macro- vs. micro-levels reflects the inherent nonlinear character of complex systems, which implies that the degree of change at the micro-level will not be proportional to the degree of change at the macro-level of the system (Richardson & Chemero, 2014; Richardson et al., 2014). Second, the changes happened at the transition between the low and high levels of the range factor in the low randomness condition and the high randomness condition (for the latter condition, except for %DET and TT, for which the changes happened at the low level of the range factor). Moreover, these changes were very precise, as they happened predominantly at the exact transition between the low and high levels of the range factor (i.e., $w_7 – w_8$). Third, the changes happened very fast in general, although there were a few instances where it was slow (i.e., for %REC in the low and high randomness conditions and for ENTR and LMAX in the former condition). Therefore, it can be concluded that (a) changes were fast in general and slow in particular instances, and (b) there was no discernible pattern in the findings that indicates that the speed of change depends on the levels of the range factor. In relation to these last two micro-level findings, the precision and speed of change further reflect the interdependence among processes and their dependency on the task environment, which enable the system to adapt in response to the evolving demands of the task.

On the whole, the macro- and micro-level findings directly and indirectly, respectively, support Hypotheses 1 and 2. In other words, the results indicate that the micro-level interactions among the constituent parts modulate and, simultaneously, are being modulated by the macro-level organisation of the system (Bar-Yam, 1997; Richardson & Chemero, 2014; Richardson et al., 2014).

Discussion

The link between entropy and complexity is the cornerstone of all complex systems. In spite of their importance and the existing body of research showing that the principles of entropy and complexity can be extended to psychological systems, a theoretically and methodologically comprehensive investigation of their link has been limited in psychology. Therefore, the purpose of the present research was to investigate the link between entropy and complexity in psychological systems. Drawing on the theoretical and methodological approaches of complexity science, this research examined the link across three distinct yet interrelated lines of investigation that consisted of nine online studies (N = 665) and used a combination of linear and nonlinear analysis techniques. In Part I, the link was examined in relation to *patterns*, with the evaluation of the stimulus being the focus of the investigation. In Parts II and III, the link was examined in relation to *processes*, with the response to the stimulus being the focus of the investigation. More specifically, Part II focused on processes at the macro-level, after which Part III extended the focus to both the macro- and micro-levels.

In this section, the findings and their contributions in each Part are discussed, followed by a discussion of the general contributions alongside the limitations of the present research.

In Part I, the findings and their contributions are as follows. First, despite the observed mean differences between the levels of the quality factor (i.e., randomness vs. non-randomness vs. complexity vs. simplicity), the very large effect sizes of the correlations showed that the levels of the quality factor represented either the same or opposite aspects of the same construct. In this respect, the present research was the first to investigate the link between entropy and complexity in relation to patterns in general and binary patterns in particular, where entropy was expressed as a continuum between randomness and non-randomness as its endpoints and complexity was expressed as a continuum between complexity and simplicity as its endpoints. In contrast, previous research either (a) examined randomness and complexity only separately, or (b) overlooked non-randomness and simplicity, respectively, as their opposite endpoints (e.g., Chipman, 1977; Falk & Konold, 1997; Van Geert & Wagemans, 2020, 2021; Krpan & van Tilburg, 2022).

Second, the observed effects between the levels of the quality factor were sustained at the low and high levels of the ratio factor. This implies that whether the stimulus contains more or less white vs. black squares does not influence the perception of the quality of that stimulus. Therefore, what matters is not the number of white vs. black squares in the stimulus but their structure (i.e., how they are arranged). In this respect, the present research was also the first to investigate the role of ratio in relation to patterns in general and binary patterns in particular. In contrast, (a) the majority of previous studies have examined stimuli with unequal ratios (e.g., Chipman & Mendelson, 1975, 1979; Chipman, 1977; Van Geert & Wagemans, 2020, 2021; Krpan & van Tilburg, 2022), and (b) a few studies have examined stimuli with equal ratios (e.g., Falk & Konold, 1997). Thus, ratio could neither be excluded as a confounding variable nor could any conclusions be drawn regarding its effects.

Third, the present research showed that stimuli perception is not sensitive to the colour (i.e., white, black) and size of the stimuli, therefore (a) adding to other factors that were excluded as confounds in the literature (i.e., mode of presentation and rating method; Chipman, 1977; Krpan & van Tilburg, 2022), and (b) indicating the existence of a robust underlying mechanism that governs the perception of these qualities, consistent with previous research (e.g., Chipman, 1977; Falk & Konold, 1997; Van Geert & Wagemans, 2020, 2021; Krpan & van Tilburg, 2022).

In Parts II and III, the findings and their contributions are as follows. First, at the macro-level, findings successfully supported Hypothesis 1, which predicted that task performance will reflect interdependent as opposed to separate interacting processes. In this respect, the observed range of RQA values was characteristic of deterministic systems (e.g., Zbilut & Webber, 1992; Webber & Zbilut, 1994, 2005; Riley et al., 1999; Pellecchia & Shockley, 2005). This highly deterministic behaviour, which implies a sequential dependence in reaction times, reflects interdependent or tightly coupled processes. In contrast, if the processes operated independently or were loosely coupled, the observed dynamics would indicate highly stochastic behaviour with no underlying sequential dependence in reaction times.

Second, at the macro-level, results successfully supported Hypothesis 2, which predicted that task performance will reflect contextual dependency (i.e., task performance will show higher entropy when embedded in a high randomness context as opposed to a low randomness context). In this respect, findings showed that (a) RQA values were greater in the low randomness condition than in the high randomness condition, and (b) SampEn values were greater in the high randomness condition than in the low randomness condition. More specifically, higher RQA and lower SampEn values indicate that the pattern of reaction times has a higher degree of regularity and is therefore characterised by lower entropy (Pincus, 1991, 1995; Zbilut & Webber, 1992; Webber & Zbilut, 1994; Richman & Moorman, 2000; Marwan et al., 2002; Richman et al., 2004).

These results obtained using the original data were further validated by surrogate analysis, which indicated that the observed pattern of reaction times reflected an actual property of the time series dynamics rather than a chance occurrence (Theiler et al., 1991, 1992, 1993; Schreiber & Schmitz, 2000; Nichols & Murphy, 2016), thus further supporting Hypotheses 1 and 2.

The aforementioned findings are consistent with those from previous studies in visual cognition and therefore add to the discussion about whether this type of cognition is subserved by interdependent or separate processes (e.g., Lee & Nguyen, 2001; Angelucci et al., 2002; Aks et al., 2002; Aks & Sprott, 2003; Magnuson et al., 2003; Bar, 2004; Spivey & Dale, 2004; Stephen & Mirman, 2010; Coey et al., 2012; Castillo et al., 2015a, 2015b). In this respect, the results represent a great departure from the traditional perspective, according to which the observed dynamics of the visual system would reflect the highly delineated and independent contribution of its components (e.g., attention, recognition, feature detection, feature integration), each having a specific and predetermined function in shaping the dynamics of cognition. In this case, the experience of visual cognition would be reduced to the effects of these components separately (Marr, 1982; Fodor, 1983; Treisman, 1998; Dietrich & Markman, 2003). In contrast, the present findings show that the observed dynamics of visual cognition are attributed to these components interacting interdependently. Therefore, the visual experience would reflect the outcome of their interactions rather than their separate effects.

Moreover, despite the experimental design being significantly different, the findings more generally replicate previous results in the literature, according to which human performance reflects an emergent feature of the brain and body’s interdependent rather than separately interacting processes, bounded by a certain task environment, by mirroring the findings of motor, perceptual, and cognitive tasks (Riley & Turvey, 2002; Van Orden & Holden, 2002; Van Orden et al., 2003, 2005, 2010; Kello et al., 2007, 2010; Shockley et al., 2007; Turvey, 2007; Holden et al., 2009, 2011; Malone et al., 2014).

Third, at the micro-level, there were three important findings showing that (1) the change at the macro- vs. micro-levels reflects the inherent nonlinear character of complex systems, which implies that the degree of change at the micro-level will not be proportional to the degree of change at the macro-level of the system (Richardson & Chemero, 2014; Richardson et al., 2014); (2) the changes happened at the transition between the levels of the factors, and these changes were very precise, as they happened predominantly at the exact transition between the levels of these factors; and (3) the changes were fast in general and slow in particular instances, and there was no discernible pattern in the findings that indicates that the speed of change depends on the levels of the factors. In relation to these last two micro-level findings, the precision and speed of change further reflect the interdependence among processes and their dependency on the task environment, which enable the system to adapt in response to the evolving demands of the task. On the whole, the micro-level findings indirectly reflect the interdependent property, which was predicted by Hypothesis 1, as well as the contextual dependence, which was predicted by Hypothesis 2. In other words, the results indicate that the micro-level interactions among the constituent parts modulate and, simultaneously, are being modulated by the macro-level organisation of the system (Bar-Yam, 1997; Richardson & Chemero, 2014; Richardson et al., 2014).

To further convey the robustness of the results, it is important to accentuate the strengths of the methodological apparatus. First, as time and task influence performance, the within-subjects design allowed to (a) trace the effects of time or influences of task changes that could lead to different interpretations of similar tasks, and (b) control for individual differences between participants, which would not have been possible with a between-subjects design (Wallot & Stephen, 2018). Second, the studies involved time spans that collected a sufficient number of points to conduct several types of nonlinear analyses (i.e., RQA and SampEn), while avoiding cognitive exhaustion or learning effects in participants that should be generally avoided in practice (Wallot & Stephen, 2018; Amon & Holden, 2019). Last, as the experimental paradigm was carefully expanded vertically, this allowed to look at what particularly caused the observed effects, therefore providing a more precise measurement and an overall robust design, consistent with recommendations (Wallot & Stephen, 2018).

On the whole, the main contributions of this thesis are the following. First, the present research is the first to provide a theoretically and methodologically comprehensive investigation of the link between entropy and complexity in psychological systems. This is important as the link between entropy and complexity has remained largely unexplored in psychology despite the significance of the concepts and previous research indicating that the principles of entropy and complexity can be applied to psychological phenomena (e.g., Vallacher & Nowak, 1994, 1997; Nowak & Vallacher, 1998; Vallacher et al., 2002, 2015; Van Orden & Holden, 2002; Van Orden et al., 2003, 2005, 2010, 2012; Holden, 2005; Riley & Van Orden, 2005; Friston et al., 2006; Friston, 2009, 2010; Holden et al., 2009, 2011; Stephen et al., 2009; Hirsh et al., 2012; Riley & Holden, 2012; Van Orden & Stephen, 2012; Richardson & Chemero, 2014; Richardson et al., 2014; Dalege et al., 2018; Wallot & Stephen, 2018; Amon & Holden, 2019; Annand & Holden, 2023).

Second, this research is the first to examine the link between entropy and complexity in psychological systems in relation to patterns and processes at macro- and micro-levels, therefore unifying three distinct yet interrelated lines of research that have never been investigated in relation to one another. This provided not only a comprehensive investigation of the link between entropy and complexity, but also the deep interlink between the system and its surroundings by showing that the vision and motor responses of a psychological system reflect a complex system that is continuously adapting to meet the changing demands of the task environment it is embedded in (e.g., Anderson, 2003; Anderson et al., 2012; Chemero, 2013; Richardson & Chemero, 2014; Richardson et al., 2014; Favela et al., 2015; Anderson & Chemero, 2016; Lobo et al., 2018), consistent with the notion that "visual perception serves behavior, and behavior is controlled by perception" (Gibson, 1979, p. 223).

Third, further contributions are made by adopting a complexity science approach. From a theoretical standpoint, a complexity science approach provided new theoretical insights that mainstream approaches would not have been able to since they rarely acknowledge the complexity of psychological systems (e.g., Riley & Holden, 2012; Van Orden et al., 2012; Van Orden & Stephen, 2012; Richardson & Chemero, 2014; Richardson et al., 2014; Wallot & Stephen, 2018; Amon & Holden, 2019). From a methodological standpoint, complexity science tools (i.e., RQA and SampEn) captured the dynamics of psychological systems more precisely than traditional methods, therefore allowing the investigation of these new theoretical insights more convincingly than previously available methods (e.g., Holden, 2005; Riley & Van Orden, 2005; Riley & Holden, 2012; Van Orden et al., 2012; Van Orden & Stephen, 2012; Richardson & Chemero, 2014; Richardson et al., 2014; Wallot & Stephen, 2018; Amon & Holden, 2019).

Last, drawing on the multidisciplinary literature in which the concepts of entropy and complexity are important and integrating them with existing psychological theory provided a more precise understanding of the examined link and placed it within a broader multidisciplinary context. This ultimately contributes to building a very robust foundation for this work, in line with recommendations (e.g., Wallot & Stephen, 2018; Amon & Holden, 2019).

There are several limitations to the present research. First, findings cannot be generalised beyond the white and black colours or the visual context, as the research was conducted using only binary stimuli. Nevertheless, this was an intentional choice as (a) visual stimuli in general are the most used type of stimuli in research practice (Haber & Hershenson, 1973; Bruce et al., 2003; Gordon, 2004), (b) binary stimuli in particular are used for studying entropy and complexity (e.g., Chipman, 1977; Falk & Konold, 1997; Van Geert & Wagemans, 2020, 2021; Krpan & van Tilburg, 2022), and (c) the unification of the three lines of research would not have been possible without using binary stimuli. In this respect, future research should implement a wider variety of stimuli to study the robustness of the mechanisms across different settings. Second, at the micro-level, this research has not determined the reasons behind the discrepancy in the observed changes between the ascending rank condition and the descending rank condition, or more precisely, why there were more changes in the former than the latter. In this respect, future research should determine (a) if there is a pattern of change and, if so, (b) what pattern (i.e., under which conditions change happens or not in regard to rank). Last, at the micro-level, the speed of change was determined based on subjectively established criteria and therefore needs to be tested more in-depth, namely (a) if there is a speed pattern and, if so, (b) what type of speed pattern (i.e., under which conditions speed is fast vs. slow).

In conclusion, the present research investigated the link between entropy and complexity in psychological systems, providing a comprehensive and empirically robust conceptualisation and measurement of how entropy and complexity – two fundamental concepts that are essential for understanding complex systems in nature – shape the dynamics of psychological systems. Anton Chekhov (as cited in Stanley, 2014), one of the greatest writers of all time, famously stated that “only entropy comes easy" (p. 3) in recognition of the unstoppable nature of *entropy*. Still, with the advent of complexity, it might be that *complexity* itself comes just as easily.

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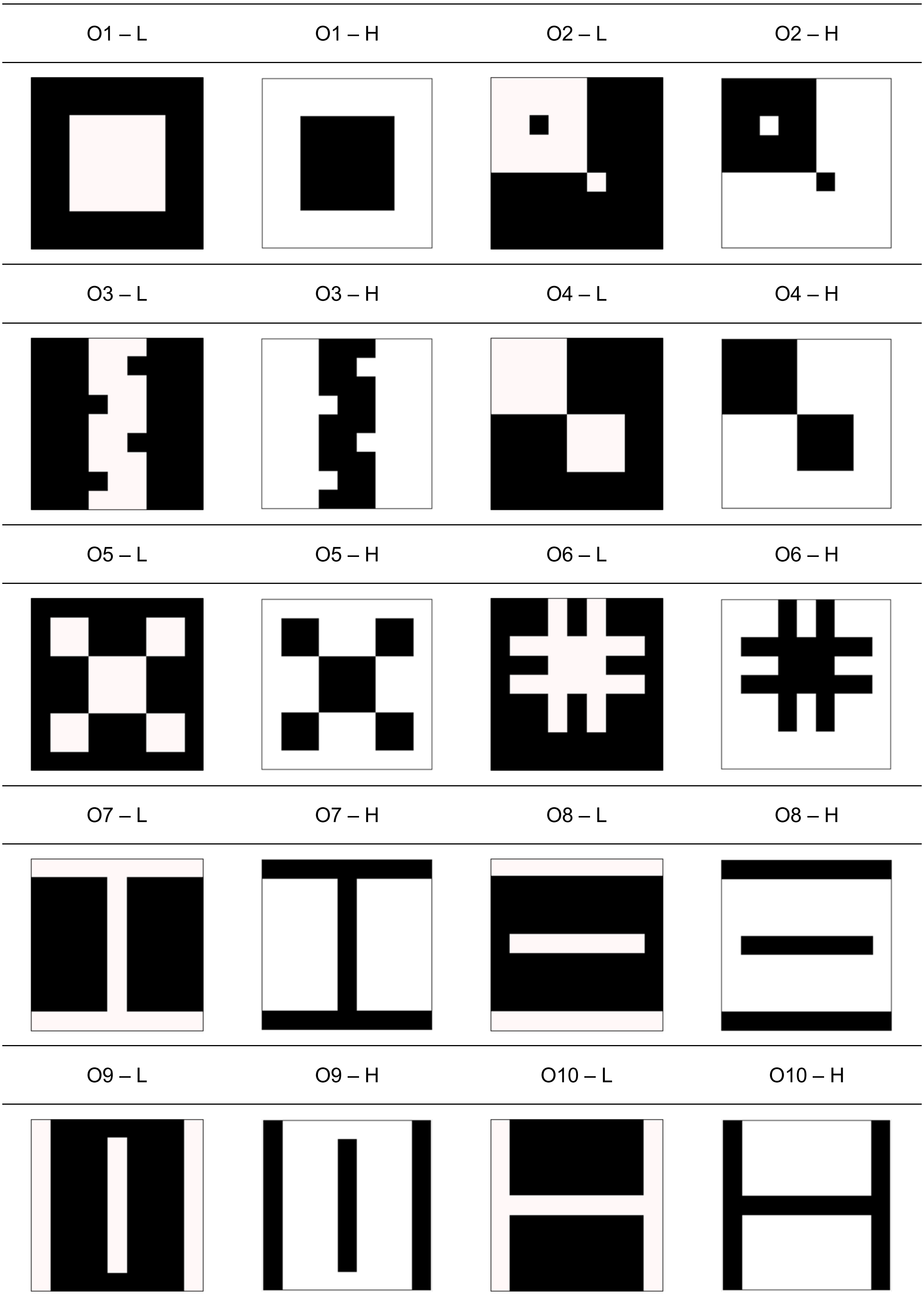
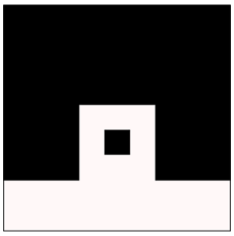
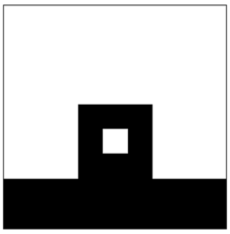
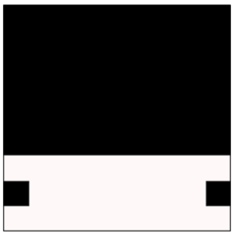
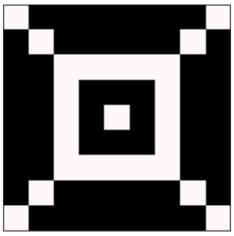
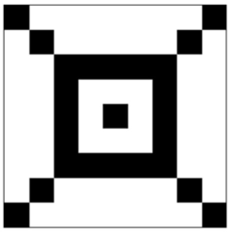
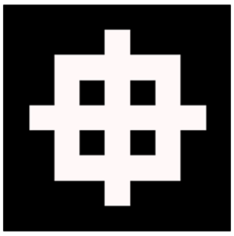
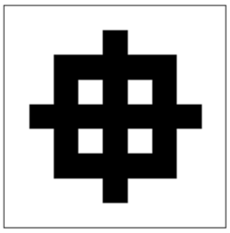
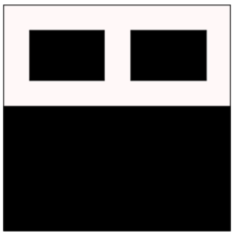
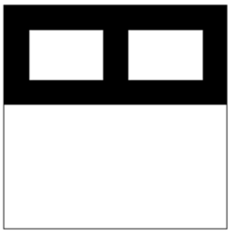
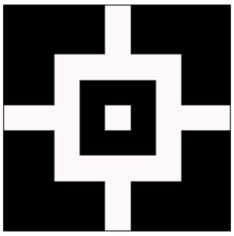
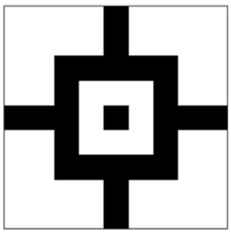
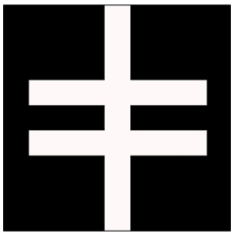
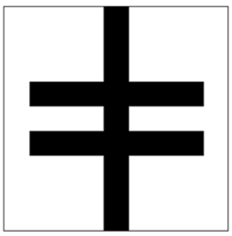
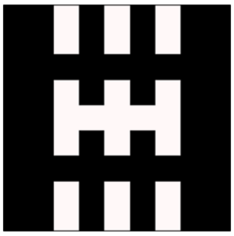
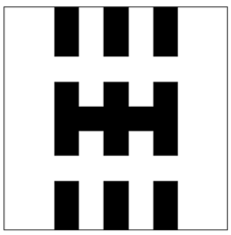
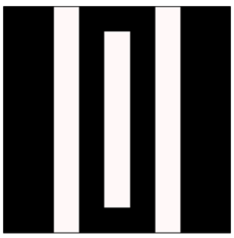
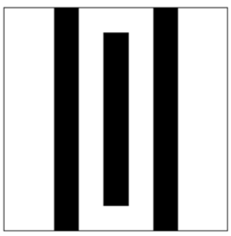
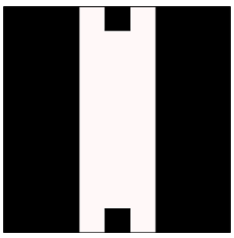
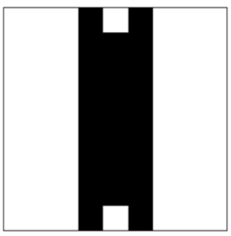
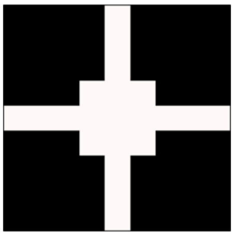
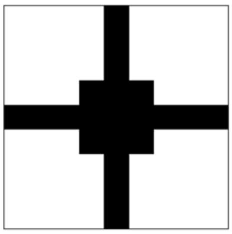
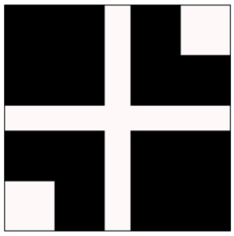
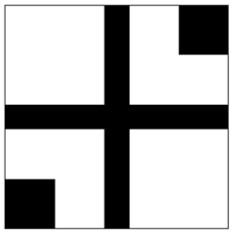
Appendix A – Stimuli for Study 1

Figure A1
Stimuli for the Low and High Levels of the Ratio Factor (Study 1)



O11 – L	O11 – H	O12 – L	O12 – H
			
O13 – L	O13 – H	O14 – L	O14 – H
			
O15 – L	O15 – H	O16 – L	O16 – H
			
O17 – L	O17 – H	O18 – L	O18 – H
			
O19 – L	O19 – H	O20 – L	O20 – H
			

O21 – L	O21 – H	O22 – L	O22 – H
			
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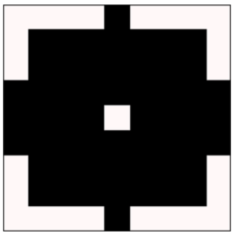
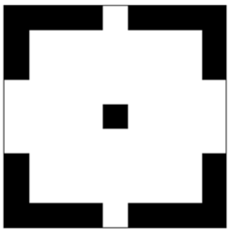
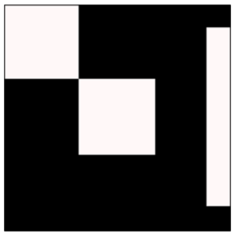
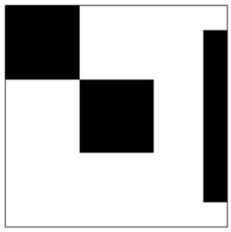
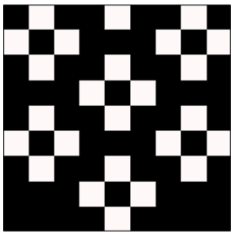
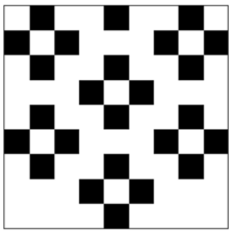
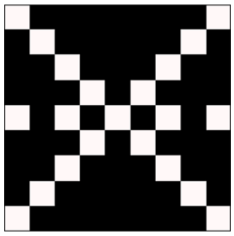
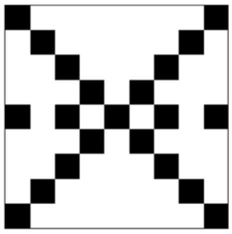
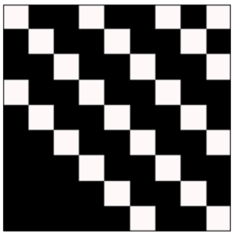
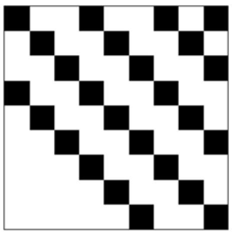
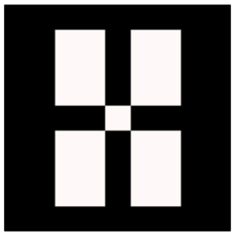
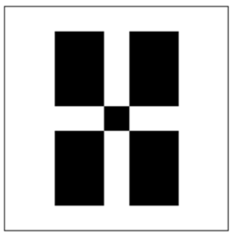
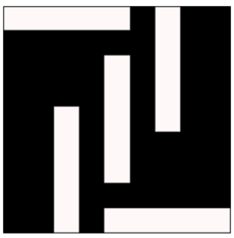
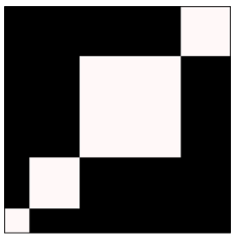
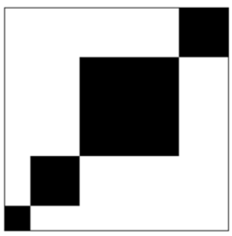
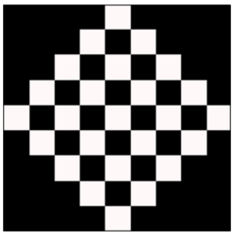
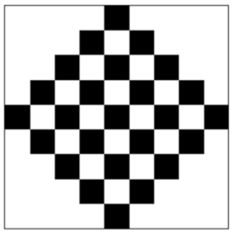
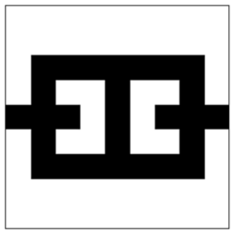
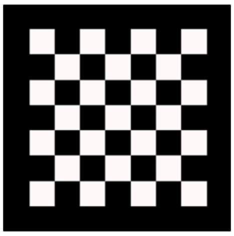
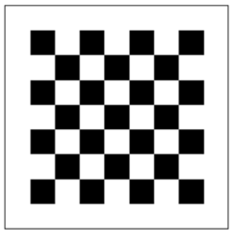
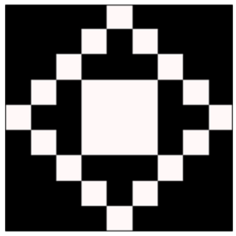
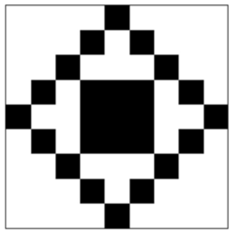
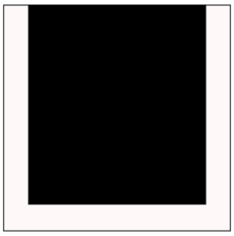
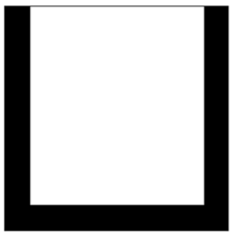
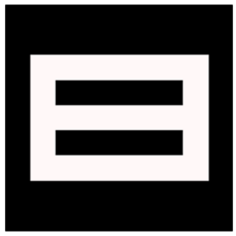
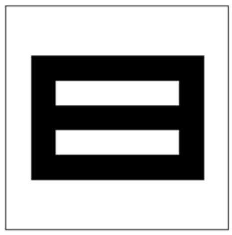
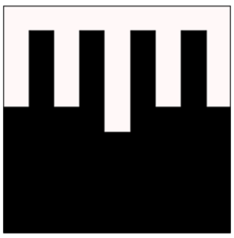
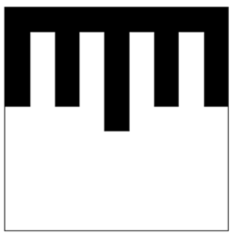
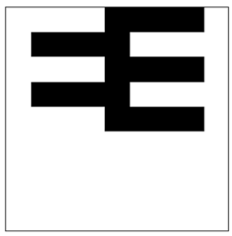
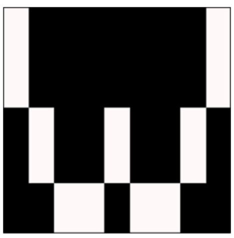
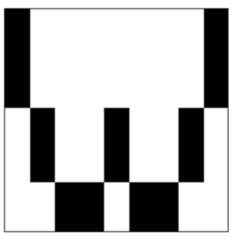
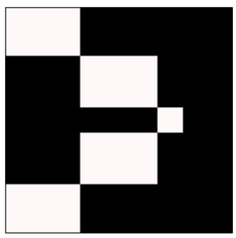
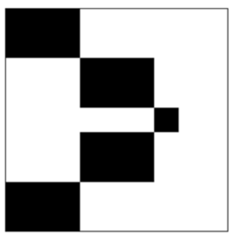
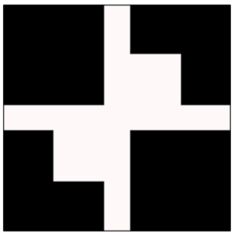
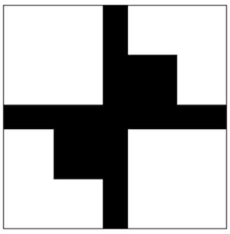
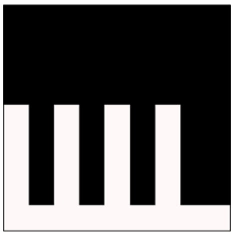
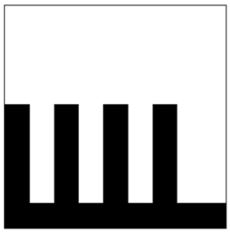
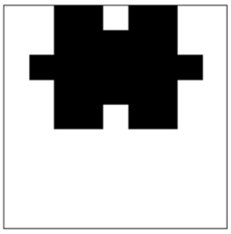
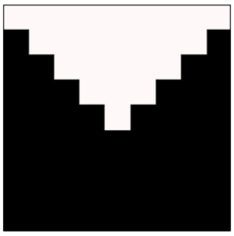
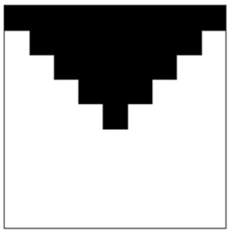
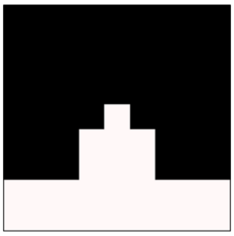
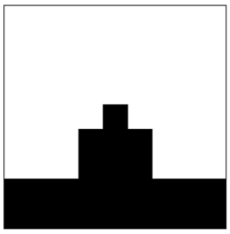
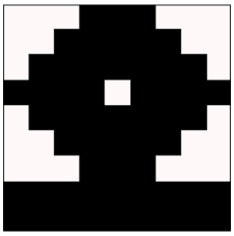
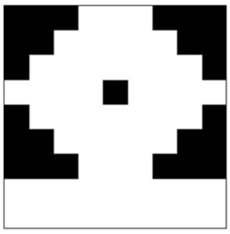
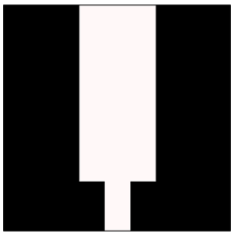
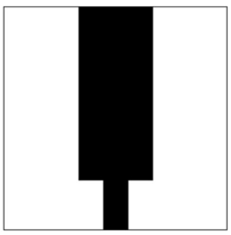
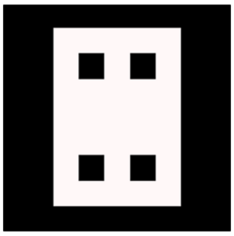
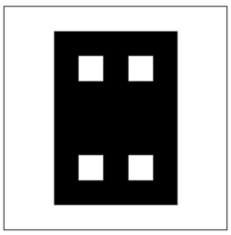
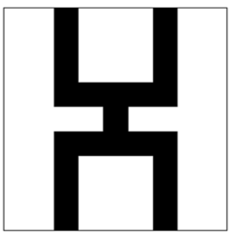
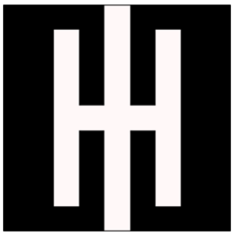
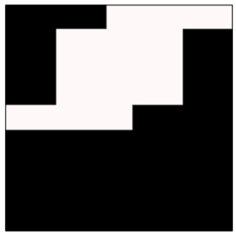
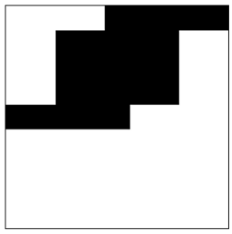
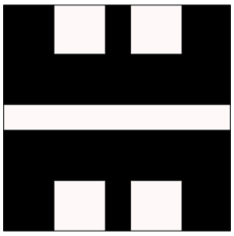
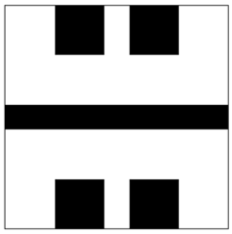
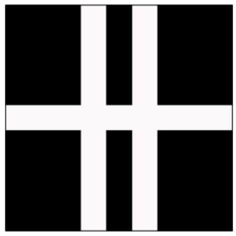
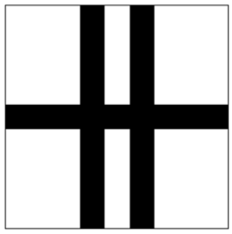
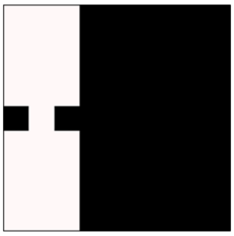
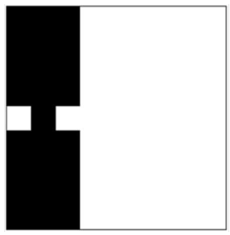
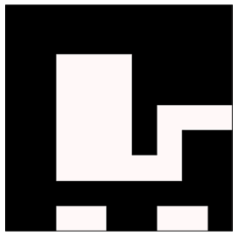
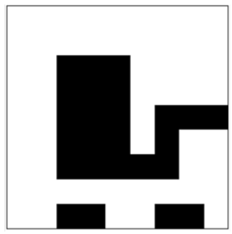
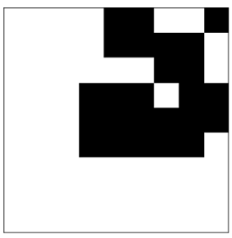
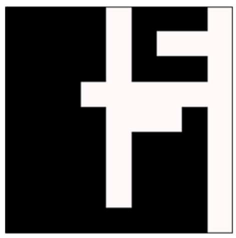
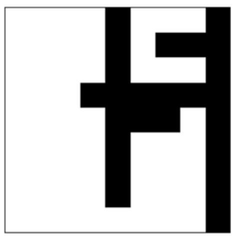
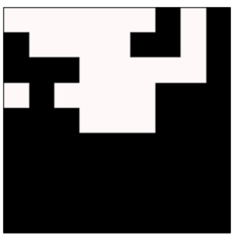
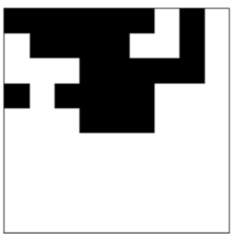
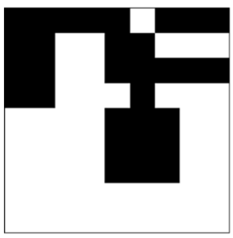
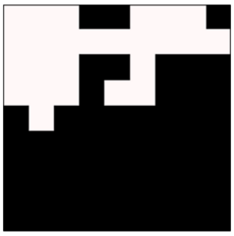
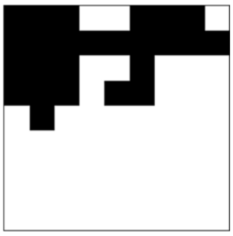
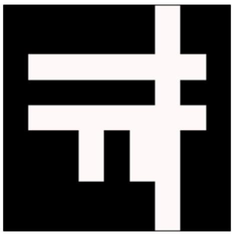
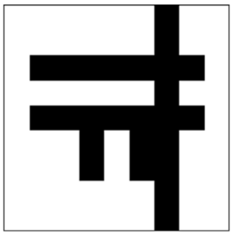
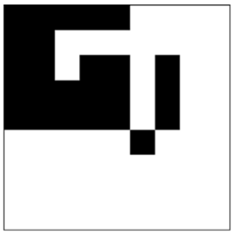
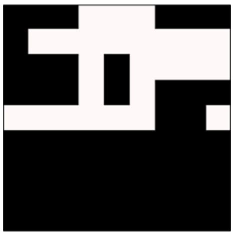
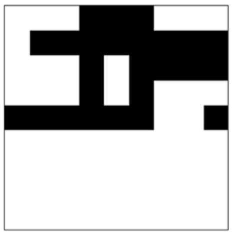
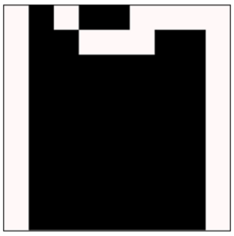
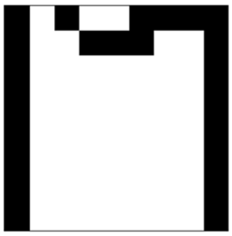
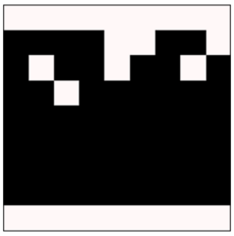
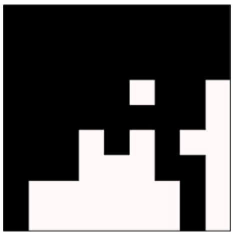
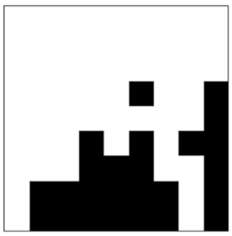
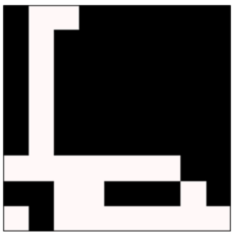
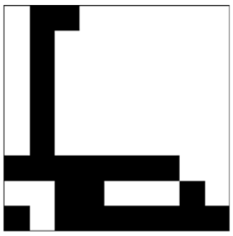
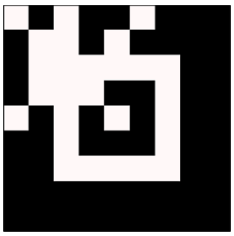
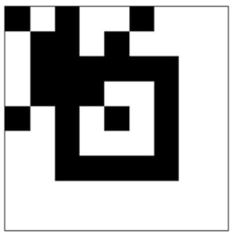
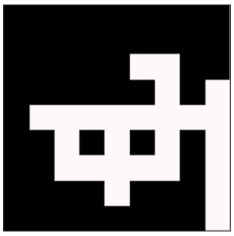
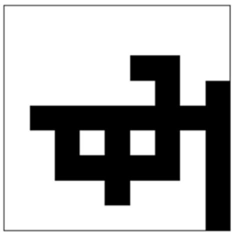
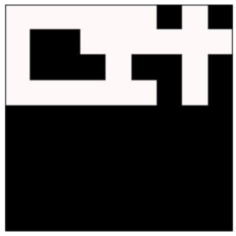
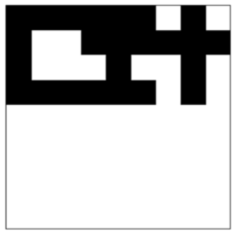
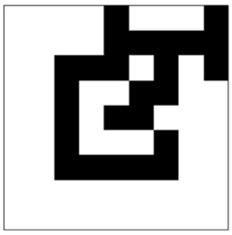
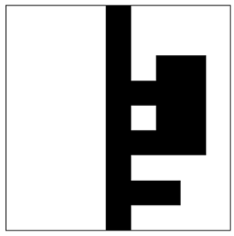
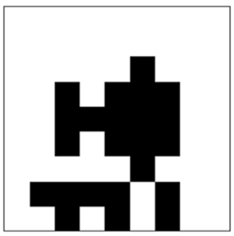
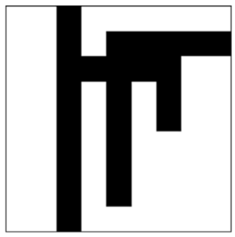
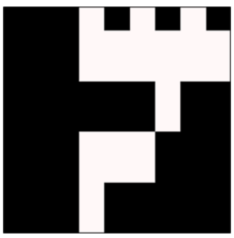
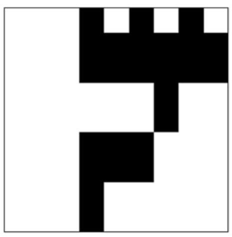
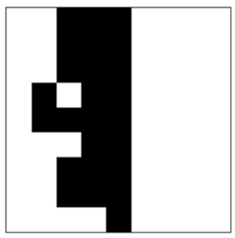
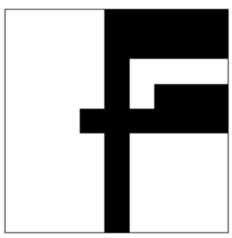
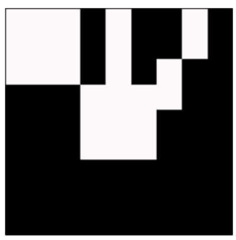
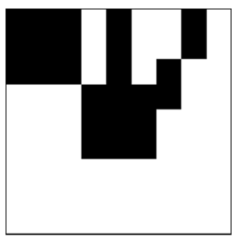
			
O25 – L	O25 – H	O26 – L	O26 – H
			
O27 – L	O27 – H	O28 – L	O28 – H
			
O29 – L	O29 – H	O30 – L	O30 – H
			

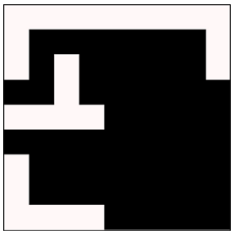
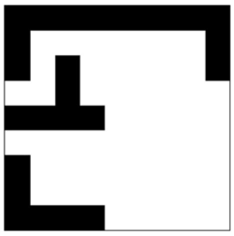
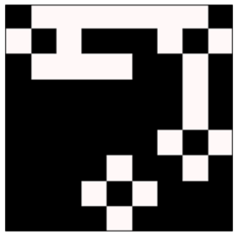
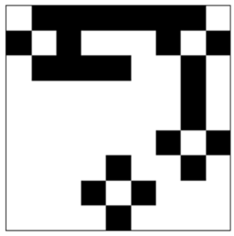
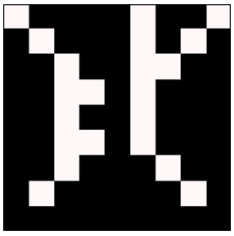
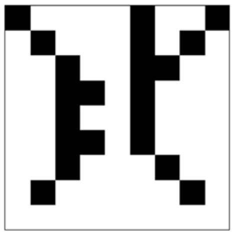
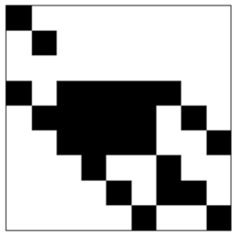
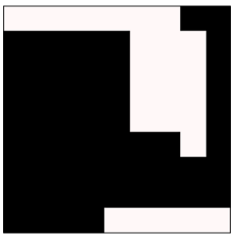
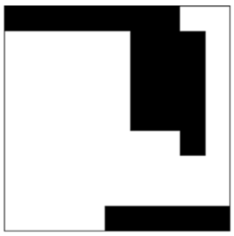
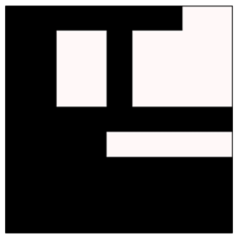
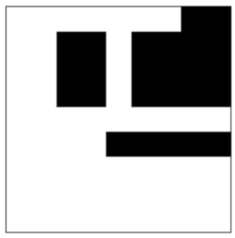
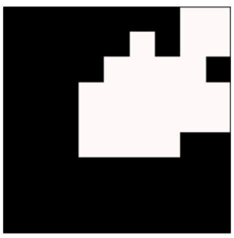
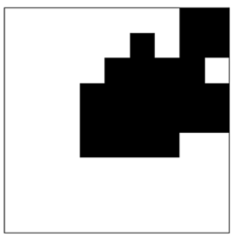
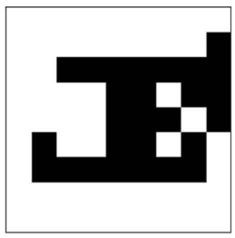
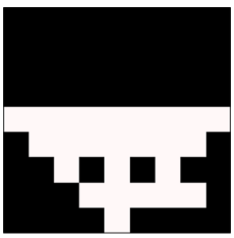
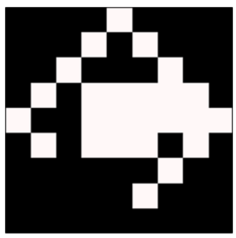
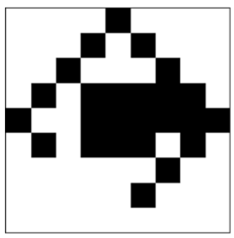
O31 – L	O31 – H	O32 – L	O32 – H
			
O33 – L	O33 – H	O34 – L	O34 – H
			
O35 – L	O35 – H	O36 – L	O36 – H
			
O37 – L	O37 – H	O38 – L	O38 – H
			
O39 – L	O39 – H	O40 – L	O40 – H
			

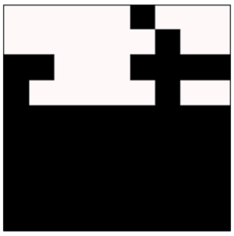
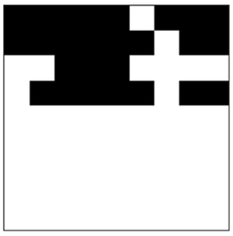
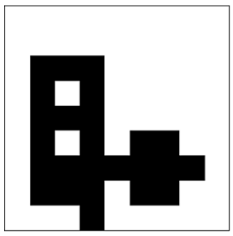
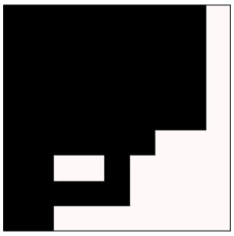
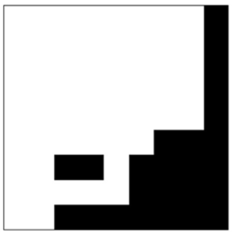
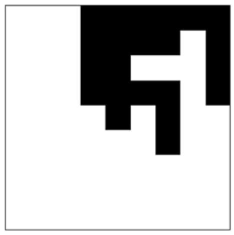
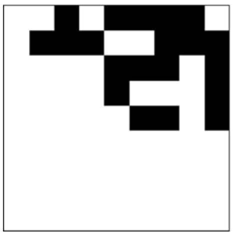
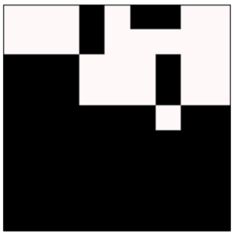
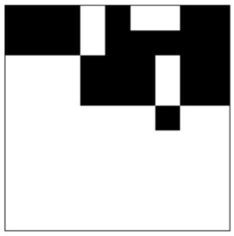
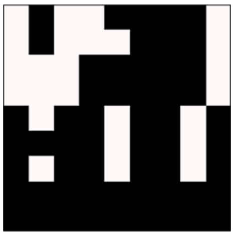
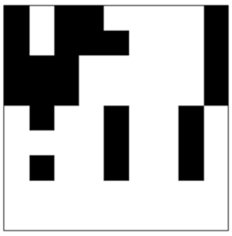
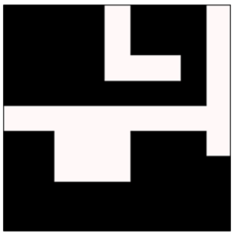
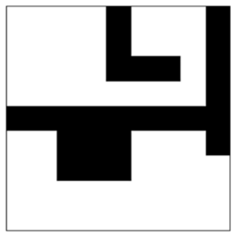
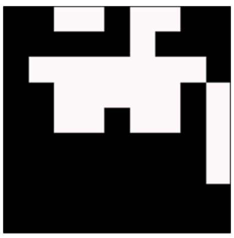
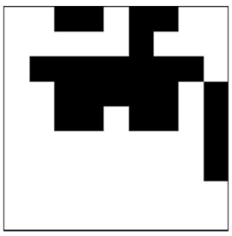
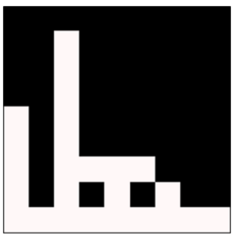
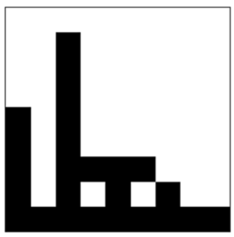
O41 – L	O41 – H	O42 – L	O42 – H
			
O43 – L	O43 – H	O44 – L	O44 – H
			
O45 – L	O45 – H	O46 – L	O46 – H
			
O47 – L	O47 – H	O48 – L	O48 – H
			
O49 – L	O49 – H	O50 – L	O50 – H
			

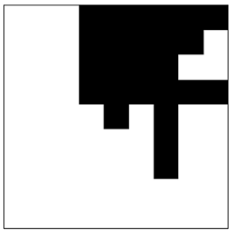
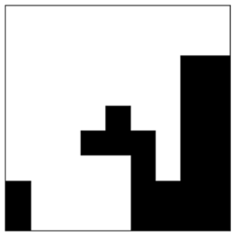
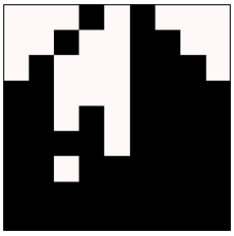
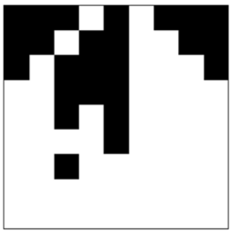
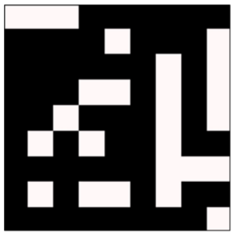
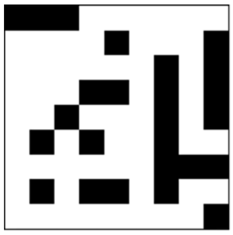
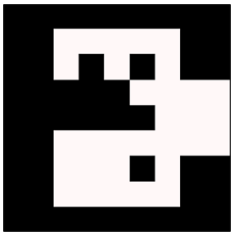
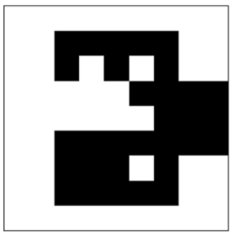
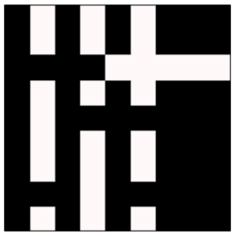
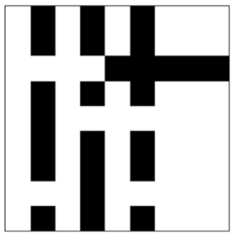
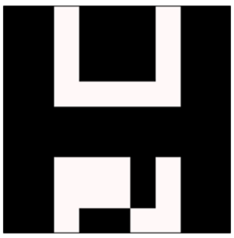
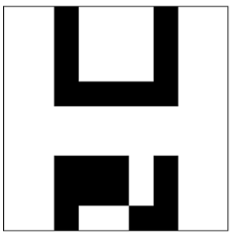
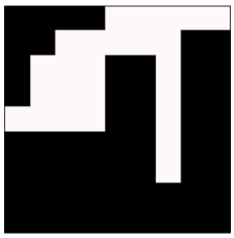
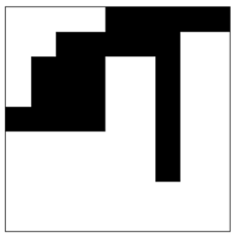
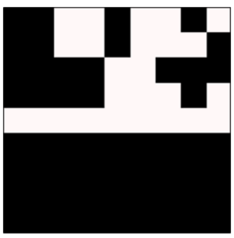
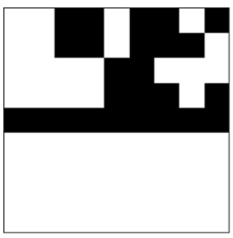
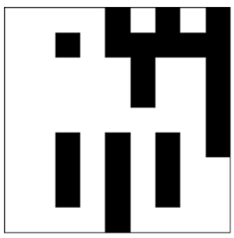
O51 – L	O51 – H	O52 – L	O52 – H
			
O53 – L	O53 – H	O54 – L	O54 – H
			
O55 – L	O55 – H	C1 – L	C1 – H
			
C2 – L	C2 – H	C3 – L	C3 – H
			
C4 – L	C4 – H	C5 – L	C5 – H
			

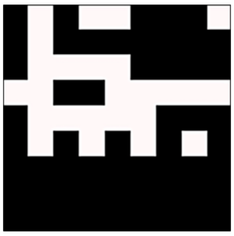
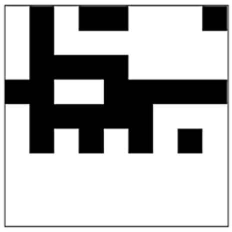
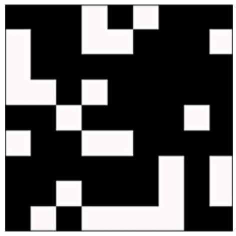
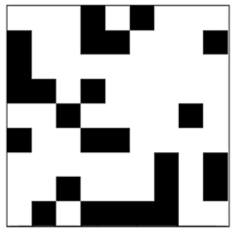
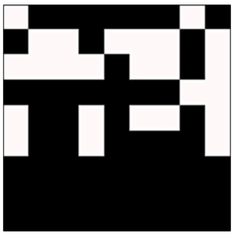
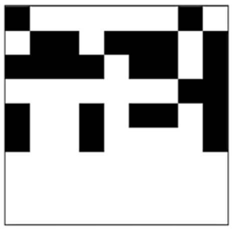
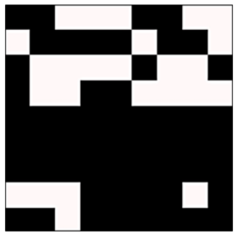
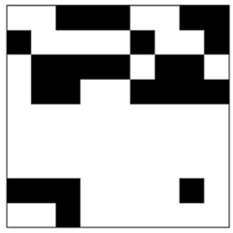
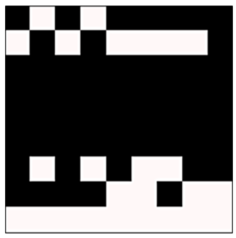
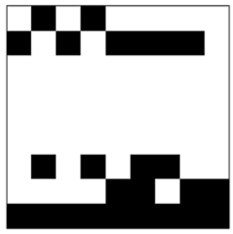
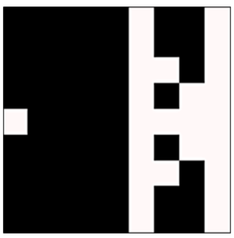
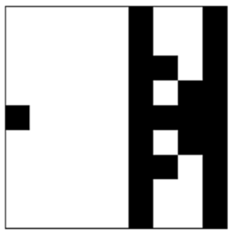
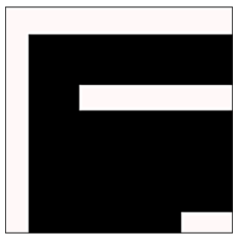
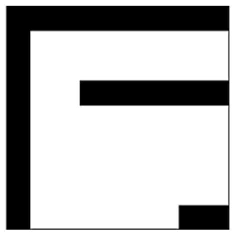
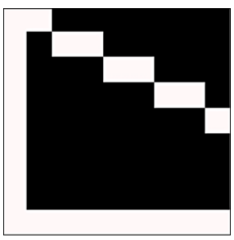
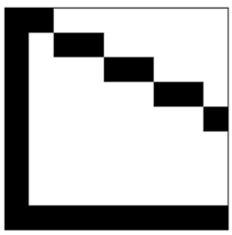
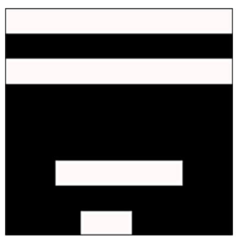
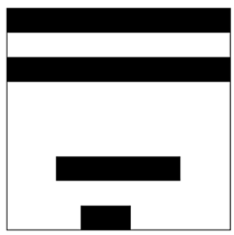
C6 – L	C6 – H	C7 – L	C7 – H
			
C8 – L	C8 – H	C9 – L	C9 – H
			
C10 – L	C10 – H	C11 – L	C11 – H
			
C12 – L	C12 – H	C13 – L	C13 – H
			
C14 – L	C14 – H	C15 – L	C15 – H
			

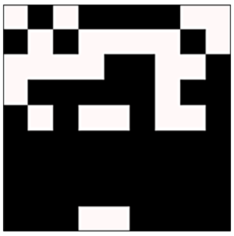
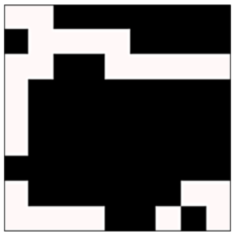
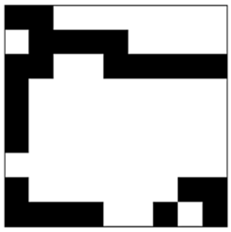
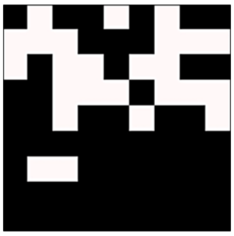
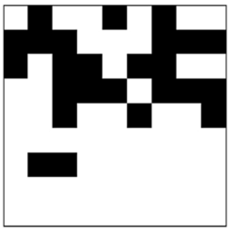
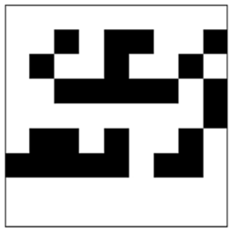
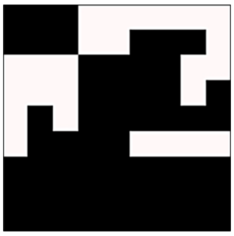
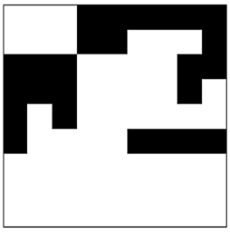
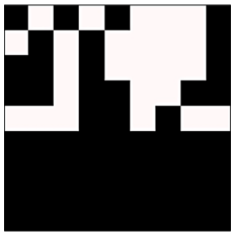
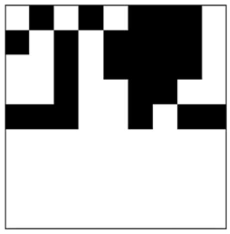
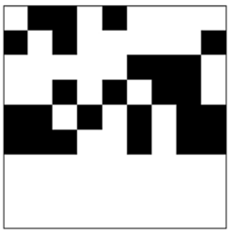
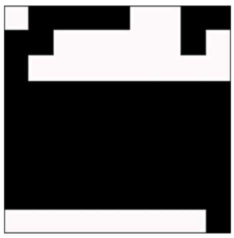
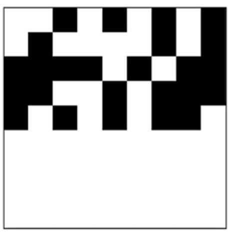
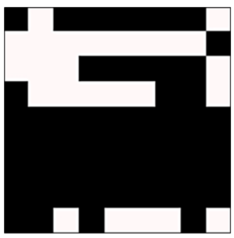
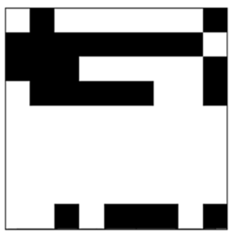
C16 – L	C16 – H	C17 – L	C17 – H
			
C18 – L	C18 – H	C19 – L	C19 – H
			
C20 – L	C20 – H	C21 – L	C21 – H
			
C22 – L	C22 – H	C23 – L	C23 – H
			
C24 – L	C24 – H	C25 – L	C25 – H
			

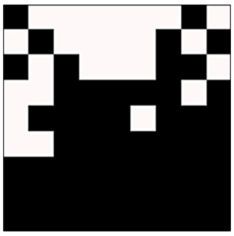
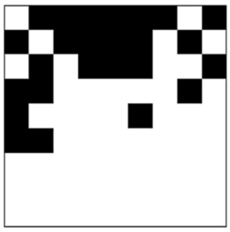
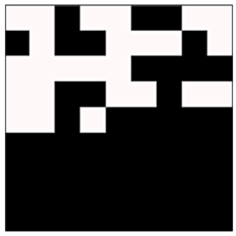
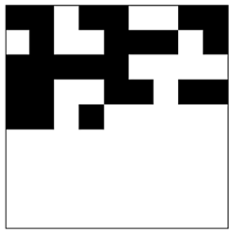
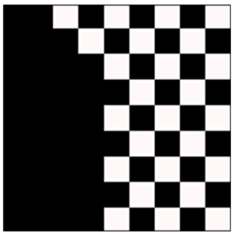
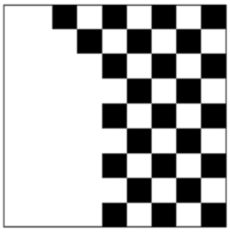
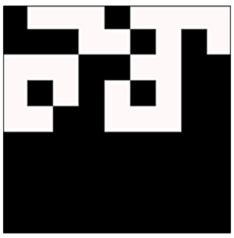
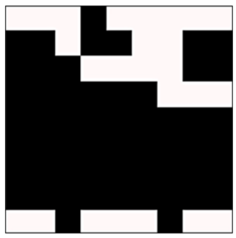
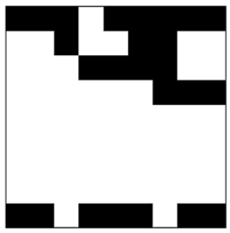
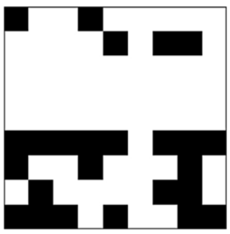
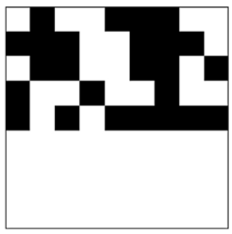
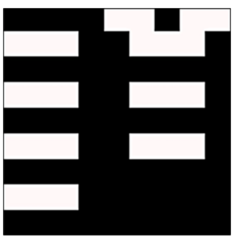
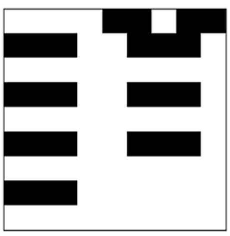
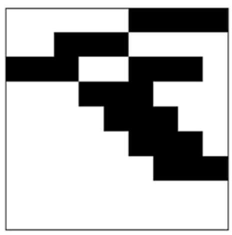
C26 – L	C26 – H	C27 – L	C27 – H
			
C28 – L	C28 – H	C29 – L	C29 – H
			
C30 – L	C30 – H	C31 – L	C31 – H
			
C32 – L	C32 – H	C33 – L	C33 – H
			
C34 – L	C34 – H	C35 – L	C35 – H
			

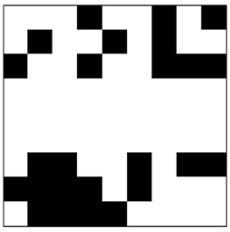
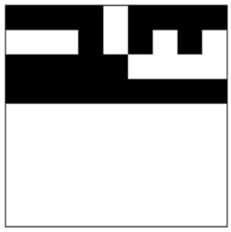
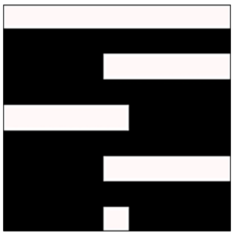
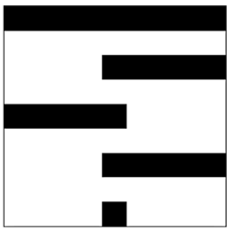
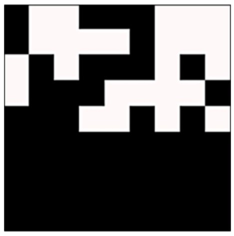
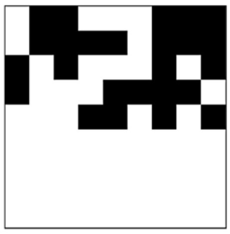
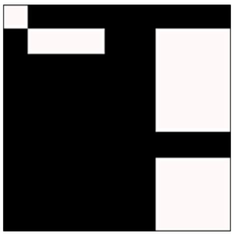
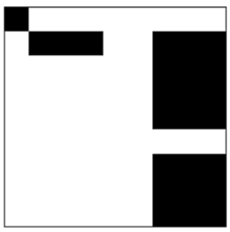
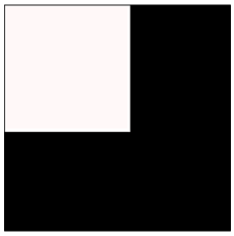
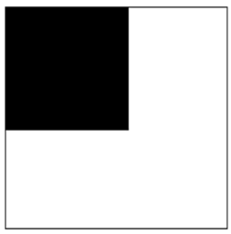
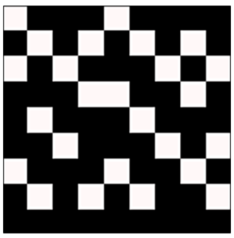
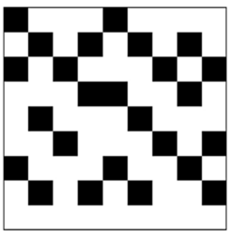
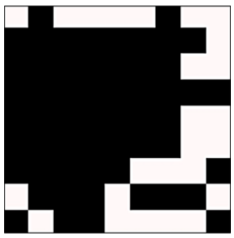
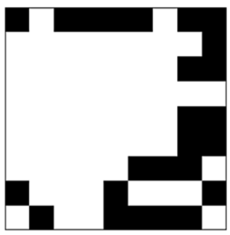
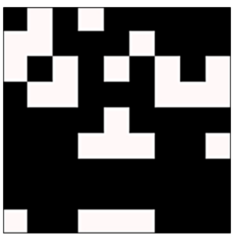
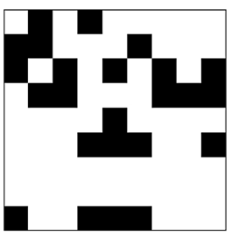
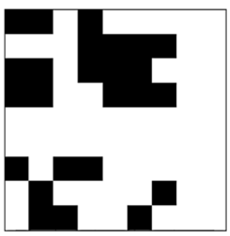
C36 – L	C36 – H	C37 – L	C37 – H
			
C38 – L	C38 – H	C39 – L	C39 – H
			
C40 – L	C40 – H	C41 – L	C41 – H
			
C42 – L	C42 – H	C43 – L	C43 – H
			
C44 – L	C44 – H	C45 – L	C45 – H
			

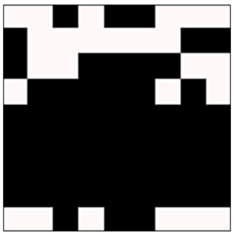
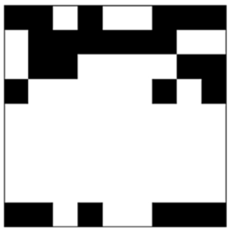
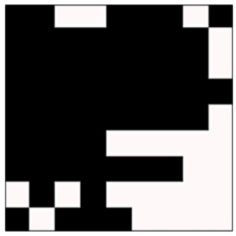
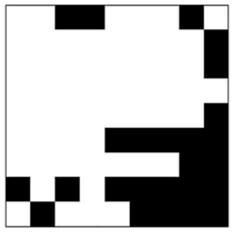
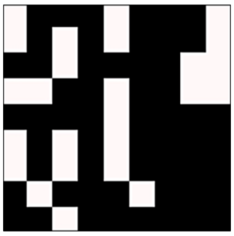
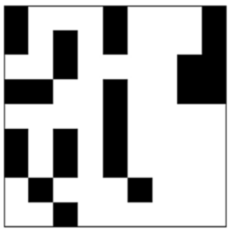
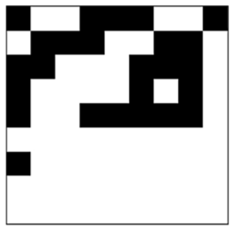
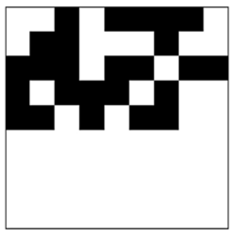
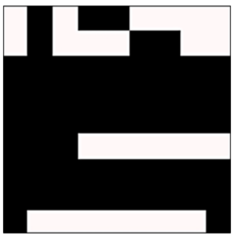
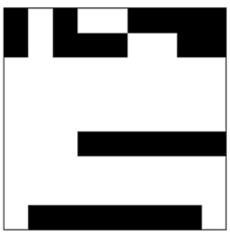
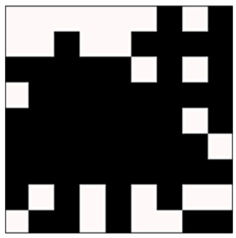
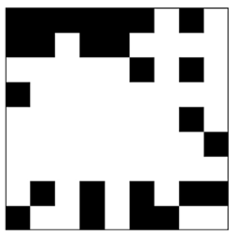
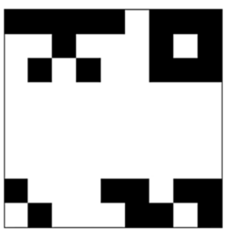
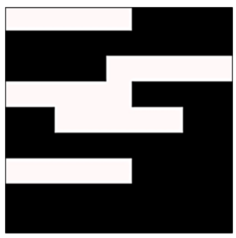
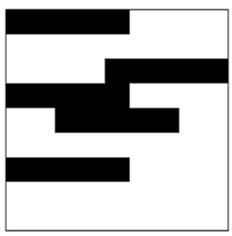
C46 – L	C46 – H	C47 – L	C47 – H
			
C48 – L	C48 – H	C49 – L	C49 – H
			
C50 – L	C50 – H	C51 – L	C51 – H
			
C52 – L	C52 – H	C53 – L	C53 – H
			
C54 – L	C54 – H	C55 – L	C55 – H
			

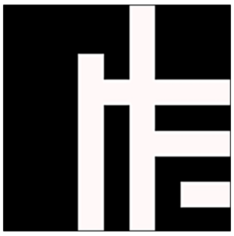
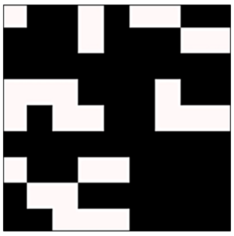
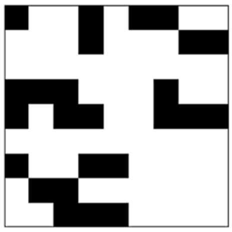
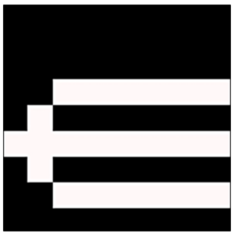
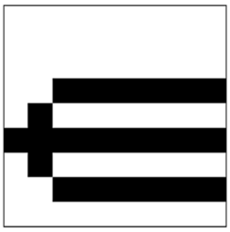
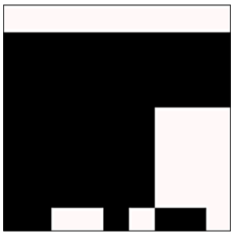
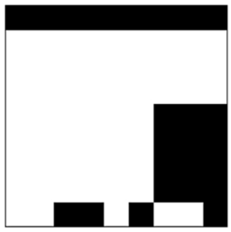
P1 – L	P1 – H	P2 – L	P2 – H
			
P3 – L	P3 – H	P4 – L	P4 – H
			
P5 – L	P5 – H	P6 – L	P6 – H
			
P7 – L	P7 – H	P8 – L	P8 – H
			
P9 – L	P9 – H	P10 – L	P10 – H
			

P11 – L	P11 – H	P12 – L	P12 – H
			
P13 – L	P13 – H	P14 – L	P14 – H
			
P15 – L	P15 – H	P16 – L	P16 – H
			
P17 – L	P17 – H	P18 – L	P18 – H
			
P19 – L	P19 – H	P20 – L	P20 – H
			

P21 – L	P21 – H	P22 – L	P22 – H
			
P23 – L	P23 – H	P24 – L	P24 – H
			
P25 – L	P25 – H	P26 – L	P26 – H
			
P27 – L	P27 – H	P28 – L	P28 – H
			
P29 – L	P29 – H	P30 – L	P30 – H
			

P31 – L	P31 – H	P32 – L	P32 – H
			
P33 – L	P33 – H	P34 – L	P34 – H
			
P35 – L	P35 – H	P36 – L	P36 – H
			
P37 – L	P37 – H	P38 – L	P38 – H
			
P39 – L	P39 – H	P40 – L	P40 – H
			

P41 – L	P41 – H	P42 – L	P42 – H
			
P43 – L	P43 – H	P44 – L	P44 – H
			
P45 – L	P45 – H	P46 – L	P46 – H
			
P47 – L	P47 – H	P48 – L	P48 – H
			
P49 – L	P49 – H	P50 – L	P50 – H
			

P51 – L	P51 – H	P52 – L	P52 – H
			
P53 – L	P53 – H	P54 – L	P54 – H
			
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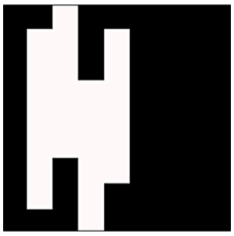
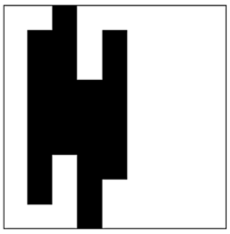
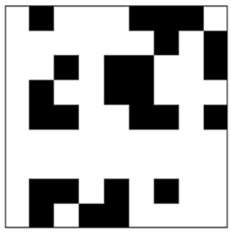
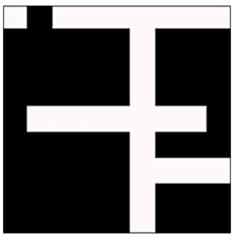
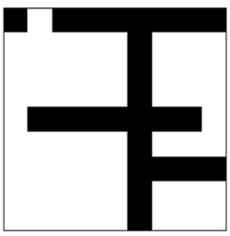
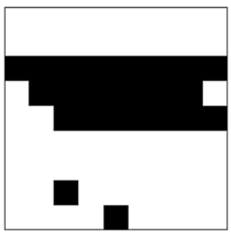
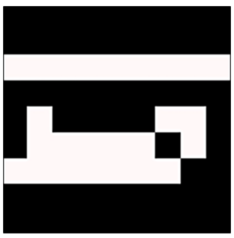
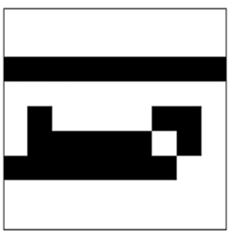
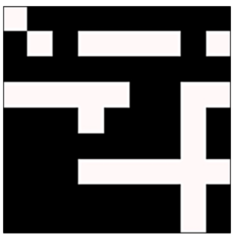
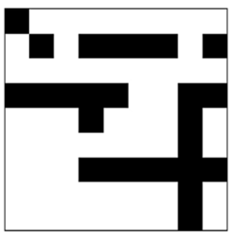
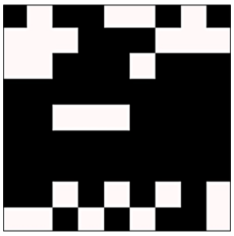
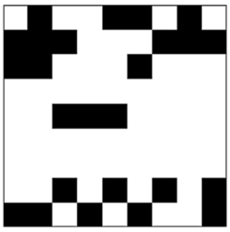
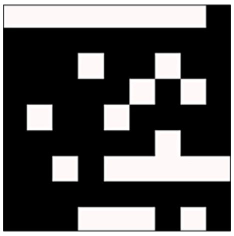
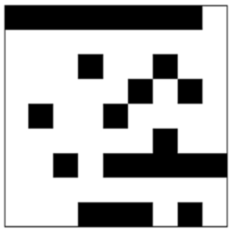
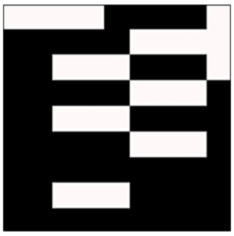
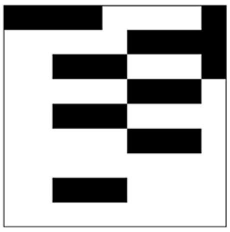
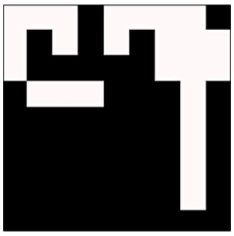
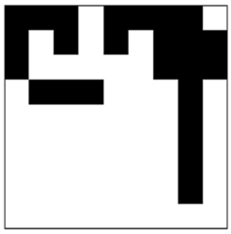
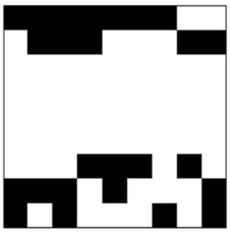
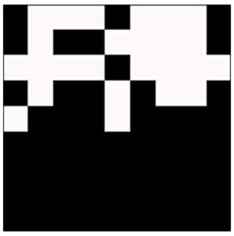
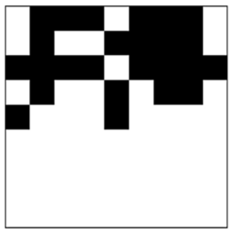
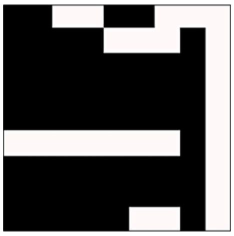
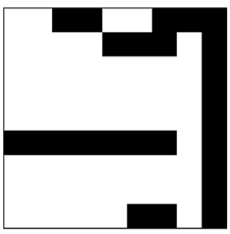
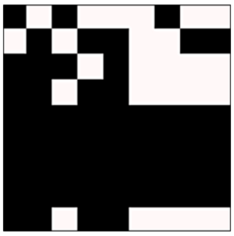
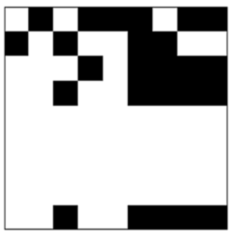
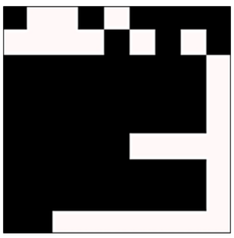
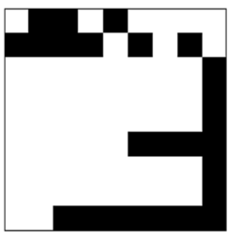
			
P57 – L	P57 – H	P58 – L	P58 – H
			
P59 – L	P59 – H	P60 – L	P60 – H
			

P61 – L	P61 – H	P62 – L	P62 – H
			
P63 – L	P63 – H	P64 – L	P64 – H
			
P65 – L	P65 – H	P66 – L	P66 – H
			
P67 – L	P67 – H	P68 – L	P68 – H
			
P69 – L	P69 – H	P70 – L	P70 – H
			

Note. The first part of the labels, which includes a letter (i.e., O, C, or P) and a number, is only for identification. L = Low and H = High.

Appendix B – Results for Study 1

Table B1
Mean Scores for the Low and High Levels of the Ratio Factor at Each Level of the Quality Factor for Each Stimulus (Study 1)

Stimulus	R		NR		C		S	
	L	H	L	H	L	H	L	H
O1	3.819	5.667	89.355	86.934	7.026	5.143	80.800	78.320
O2	13.972	15.097	70.461	69.474	19.104	16.701	64.187	65.187
O3	16.361	15.375	77.868	74.026	26.753	29.766	61.440	61.013
O4	14.069	16.194	70.961	68.539	14.545	11.468	71.173	69.653
O5	8.139	9.847	84.816	86.645	22.571	19.403	70.387	69.133
O6	10.264	11.250	75.487	76.013	28.987	25.870	64.107	65.840
O7	7.444	7.389	86.145	84.250	12.429	10.286	76.480	73.907
O8	8.903	7.778	85.000	82.276	11.805	9.662	75.760	74.893
O9	5.764	7.458	85.632	80.868	13.974	11.935	74.653	74.200
O10	7.389	6.847	85.013	84.382	11.364	9.169	76.867	77.307
O11	12.167	14.236	77.382	76.461	18.506	18.961	67.853	69.347
O12	13.000	10.625	79.487	76.105	14.987	11.844	69.587	69.280
O13	7.972	10.278	87.553	88.618	39.364	40.662	63.267	64.480
O14	8.833	10.333	85.382	84.289	34.844	31.805	67.147	66.547
O15	10.333	9.708	80.461	79.039	16.403	14.662	69.840	72.547
O16	9.444	6.708	86.671	84.105	31.701	28.935	67.480	66.667
O17	9.917	8.625	85.092	81.737	20.792	19.052	72.173	69.573
O18	12.042	12.236	80.132	80.750	37.247	35.649	59.853	61.000
O19	7.722	7.917	83.947	82.776	17.403	14.779	71.373	69.960
O20	10.347	10.778	81.763	79.342	15.208	13.662	70.800	70.067
O21	8.542	8.403	86.026	85.329	20.325	19.948	71.947	69.667
O22	12.986	11.972	80.434	81.776	24.987	21.870	64.133	66.867
O23	10.167	9.278	87.066	85.066	24.325	22.831	70.947	71.373
O24	27.639	27.722	57.658	55.592	19.610	18.156	62.240	63.213
O25	10.653	14.542	81.395	78.539	57.221	57.481	56.093	54.107
O26	12.819	11.139	82.961	83.553	56.338	52.818	56.627	59.613

O27	17.403	14.347	78.158	76.329	53.766	48.429	53.493	56.253
O28	8.694	7.472	85.276	82.553	25.247	23.026	68.573	71.600
O29	24.056	26.500	67.816	63.776	29.377	27.481	56.680	58.360
O30	15.694	16.611	74.329	75.697	25.714	22.896	63.040	63.920
O31	7.625	8.347	88.382	84.684	52.545	50.325	62.587	65.707
O32	9.236	10.542	85.737	84.487	33.117	31.597	64.787	61.973
O33	8.139	9.125	88.750	87.618	47.909	47.416	67.067	65.880
O34	9.694	8.292	87.039	85.092	52.299	48.091	60.933	60.787
O35	7.806	7.278	81.197	79.329	9.377	6.104	76.867	77.440
O36	7.181	8.319	85.079	82.329	18.935	15.766	70.907	70.533
O37	11.111	13.833	76.632	78.750	24.844	23.792	64.520	64.640
O38	21.944	21.542	65.671	64.803	28.091	26.273	55.973	55.680
O39	18.042	18.903	75.539	79.592	35.636	33.299	51.493	53.720
O40	25.667	22.681	65.237	73.487	32.078	26.286	51.187	54.760
O41	13.806	17.458	79.500	81.092	28.688	28.909	57.000	58.853
O42	18.486	19.083	66.816	65.461	23.026	21.584	62.013	64.253
O43	17.083	16.569	66.816	71.908	25.636	22.935	62.467	61.053
O44	9.778	9.917	82.079	79.776	25.883	23.455	68.467	68.160
O45	10.931	15.361	78.039	76.263	17.506	17.156	67.240	68.507
O46	11.736	13.764	78.224	78.368	40.532	36.948	58.600	62.333
O47	10.417	12.528	80.132	73.171	14.779	11.545	73.067	69.533
O48	8.458	9.736	85.105	83.921	21.273	19.065	69.493	70.760
O49	19.611	16.389	72.500	69.855	22.429	17.052	60.853	63.440
O50	9.556	9.653	84.289	84.039	23.766	23.442	69.253	67.720
O51	9.194	9.444	83.263	82.618	25.558	20.909	70.387	67.760
O52	32.250	36.389	53.842	52.855	26.935	23.662	58.520	58.600
O53	8.222	8.861	82.066	84.237	23.623	21.597	67.373	66.027
O54	6.181	8.292	83.934	82.763	19.974	18.494	70.880	71.547
O55	17.583	14.028	67.895	70.197	17.766	15.208	64.400	64.680
C1	47.431	49.986	37.947	37.592	34.506	31.312	49.373	42.707
C2	62.014	58.833	33.842	33.579	37.753	39.701	40.373	42.093

C3	57.125	57.875	34.368	33.197	39.987	41.506	39.107	41.333
C4	59.875	60.583	32.513	29.079	42.909	43.182	35.067	35.733
C5	58.958	59.042	31.724	37.908	43.403	42.234	37.733	39.840
C6	59.222	57.403	30.447	29.816	40.909	39.909	35.173	37.920
C7	48.542	50.722	38.829	40.079	40.221	40.208	41.827	43.013
C8	55.486	50.556	36.500	33.684	37.260	35.753	40.480	40.187
C9	53.486	57.528	32.789	28.882	40.195	41.013	37.373	39.693
C10	56.806	57.736	35.684	35.618	41.896	41.286	39.173	41.040
C11	39.875	39.153	43.895	44.961	28.338	25.403	52.440	54.400
C12	51.639	50.667	36.013	37.158	36.922	36.571	40.013	44.213
C13	59.278	61.403	32.382	31.303	43.039	42.662	37.427	40.853
C14	59.403	56.069	32.947	31.368	41.766	39.026	40.093	41.573
C15	55.986	53.306	36.039	37.934	54.701	53.091	33.280	37.613
C16	50.264	53.694	37.447	38.487	43.234	45.312	39.613	38.707
C17	56.278	52.319	31.658	33.566	42.740	42.649	37.467	39.040
C18	53.083	55.764	35.263	34.079	48.714	50.026	34.173	37.200
C19	50.264	53.944	36.645	38.303	36.961	37.078	42.680	42.560
C20	58.056	59.653	33.303	30.961	46.779	46.584	36.133	33.933
C21	40.569	45.333	46.250	42.461	33.468	32.013	48.413	47.640
C22	54.653	54.125	36.237	32.816	38.390	40.974	40.947	37.000
C23	46.847	50.431	37.921	33.868	32.545	33.818	43.107	46.827
C24	48.028	50.764	37.342	38.355	34.468	31.351	48.960	46.547
C25	56.764	56.236	34.013	31.447	38.714	39.234	37.853	40.720
C26	53.097	50.028	37.118	38.737	34.883	33.052	39.853	41.707
C27	52.306	52.542	41.368	38.829	57.065	56.753	33.933	35.573
C28	52.444	57.125	36.355	42.355	50.039	52.442	35.040	37.080
C29	61.014	59.236	34.618	37.092	58.039	57.078	27.787	31.120
C30	48.583	49.917	37.053	39.618	29.506	27.481	47.107	47.627
C31	48.125	52.097	39.632	40.118	30.649	27.974	49.347	47.613
C32	55.986	59.333	30.158	31.105	34.610	33.948	42.173	41.733
C33	56.319	57.625	31.816	32.816	43.481	44.974	38.227	36.467

C34	51.181	47.958	41.237	42.671	43.078	46.805	39.013	39.693
C35	46.278	43.806	43.711	46.934	59.130	58.519	33.040	37.840
C36	57.556	56.917	30.158	30.316	40.299	39.000	37.360	39.560
C37	49.486	48.750	40.513	37.776	42.857	42.078	39.173	43.907
C38	48.833	52.236	40.395	39.408	30.948	31.935	48.747	45.560
C39	56.319	58.792	30.961	31.697	38.247	36.766	40.747	40.587
C40	62.847	63.139	31.632	27.487	45.519	46.455	35.933	33.853
C41	58.153	56.278	33.342	31.053	40.766	39.766	36.680	37.667
C42	60.389	59.972	30.868	31.763	48.286	43.792	32.227	32.733
C43	50.069	57.167	38.289	33.553	36.468	35.455	43.067	42.467
C44	59.792	60.903	33.474	29.197	46.623	40.844	37.013	39.640
C45	46.264	45.528	35.053	36.750	39.688	37.247	41.547	40.187
C46	54.917	56.819	32.724	34.868	38.506	36.130	40.213	44.773
C47	56.458	57.472	33.461	32.500	36.805	37.013	40.280	43.000
C48	59.000	60.458	34.829	34.053	48.610	48.351	36.000	36.880
C49	67.472	67.958	29.895	28.645	57.299	54.974	29.653	29.560
C50	56.569	56.292	39.684	35.158	47.909	46.468	34.653	35.840
C51	45.625	46.014	43.776	41.013	49.727	50.532	36.160	36.920
C52	39.889	43.708	45.711	38.513	31.961	33.156	45.787	45.147
C53	53.167	54.125	40.408	36.368	37.052	34.545	45.000	44.200
C54	57.597	59.889	33.026	32.605	43.701	45.052	34.600	35.987
C55	52.806	53.000	39.671	38.803	43.909	43.623	39.333	39.387
P1	60.653	64.528	29.658	29.895	53.519	49.312	31.467	35.213
P2	74.958	76.806	24.947	28.211	64.532	64.662	27.547	30.707
P3	67.292	65.389	30.039	27.566	56.597	53.234	31.480	29.307
P4	66.819	67.236	27.289	28.105	54.052	53.468	30.093	31.627
P5	63.361	66.486	31.184	30.105	56.870	55.403	30.773	32.587
P6	58.917	61.736	35.118	33.382	49.948	50.221	32.613	32.373
P7	49.736	52.181	51.737	45.566	44.481	42.584	35.493	42.040
P8	34.889	33.458	49.855	51.974	24.429	20.143	56.467	59.907
P9	27.111	25.403	63.368	65.408	35.766	31.195	52.747	50.147

P10	23.806	23.653	63.039	57.395	25.286	21.286	60.493	61.880
P11	68.542	66.694	30.447	26.145	59.143	53.584	27.440	32.587
P12	58.264	62.319	28.329	27.789	46.481	42.013	30.627	33.667
P13	67.472	67.306	26.882	28.408	57.818	56.961	28.093	29.667
P14	66.625	65.778	31.250	28.382	57.091	58.078	30.600	31.267
P15	61.431	60.694	31.303	30.079	42.182	40.688	36.427	37.573
P16	62.597	61.361	31.289	28.868	51.571	50.143	30.173	30.960
P17	66.569	67.028	28.816	27.434	59.494	58.416	28.440	31.053
P18	59.417	54.583	32.276	33.947	34.597	32.130	41.787	42.387
P19	62.806	65.931	30.171	33.184	56.558	54.974	31.267	33.533
P20	60.264	61.486	31.171	28.868	46.390	42.740	33.040	36.160
P21	64.819	64.722	30.855	31.592	54.390	55.519	30.213	30.467
P22	64.125	59.375	28.671	29.724	53.104	51.532	32.533	32.187
P23	26.542	23.514	66.342	68.118	52.104	49.000	51.613	54.013
P24	67.806	70.083	29.434	28.421	60.312	58.636	30.773	29.680
P25	62.861	59.931	31.921	35.632	51.026	50.571	31.613	35.587
P26	59.889	58.583	31.539	34.500	42.753	46.052	34.307	35.533
P27	68.139	66.278	27.197	27.908	58.701	54.091	26.733	30.293
P28	64.417	65.778	30.474	28.053	55.013	51.922	33.173	31.600
P29	29.667	34.472	54.842	53.947	39.013	35.779	47.347	45.093
P30	57.958	56.472	35.250	36.158	47.221	48.117	34.267	37.867
P31	71.083	69.625	28.408	29.632	60.195	54.792	30.160	31.227
P32	57.056	57.208	33.342	34.539	40.013	39.299	40.360	39.000
P33	33.458	34.750	55.342	52.053	31.779	25.506	56.253	52.800
P34	64.000	64.819	28.474	29.947	53.065	51.545	30.360	32.813
P35	44.833	49.639	41.513	40.026	31.013	23.714	44.653	51.067
P36	11.083	10.819	73.461	74.158	7.247	5.481	79.613	77.680
P37	57.056	53.625	43.237	44.816	69.961	64.065	31.880	32.720
P38	68.986	67.639	31.605	27.224	54.610	54.065	30.627	30.320
P39	67.403	68.903	27.711	29.895	61.935	59.727	27.000	30.733
P40	67.194	64.958	30.276	27.118	54.623	51.182	30.027	30.573

P41	64.222	65.847	27.158	29.684	54.260	50.909	31.293	31.480
P42	67.069	66.972	28.289	26.868	52.013	47.922	30.973	31.653
P43	65.278	67.153	27.724	25.789	56.169	52.727	27.360	32.187
P44	64.000	66.903	30.711	29.592	50.455	49.818	31.720	31.280
P45	63.542	64.917	27.447	28.013	54.338	50.130	28.573	32.293
P46	61.875	61.556	27.658	27.947	54.273	51.325	30.693	32.173
P47	56.778	55.819	31.250	31.474	40.013	35.545	37.507	39.800
P48	70.444	69.833	25.882	28.737	62.325	56.909	27.867	29.667
P49	63.306	64.944	28.724	33.789	54.805	53.506	31.213	30.347
P50	44.736	49.069	44.645	44.026	34.143	31.416	43.787	45.627
P51	41.347	43.403	43.368	43.026	37.481	37.377	42.133	43.200
P52	68.306	69.264	29.145	26.605	58.844	55.610	30.520	32.360
P53	17.847	18.500	68.961	69.671	28.481	26.571	55.053	57.013
P54	50.278	51.306	33.145	34.987	29.610	28.338	46.307	45.573
P55	40.486	43.069	45.763	44.711	30.390	30.351	48.093	50.440
P56	70.986	70.319	27.895	26.908	61.065	59.883	29.200	26.600
P57	47.389	50.222	37.882	36.605	37.403	35.091	41.840	45.960
P58	51.181	51.889	37.447	35.895	33.065	30.429	41.853	42.947
P59	55.153	54.194	35.132	34.197	37.974	37.052	41.533	40.840
P60	61.097	64.500	31.079	32.724	47.338	47.792	29.453	35.627
P61	64.250	66.500	29.421	28.908	62.545	60.273	25.347	32.227
P62	63.208	66.417	31.303	29.289	53.727	55.182	29.987	31.040
P63	36.500	41.278	53.697	49.382	41.416	41.195	45.320	43.987
P64	61.708	61.750	29.776	30.816	44.182	41.987	34.893	34.507
P65	65.833	62.444	29.671	27.066	53.909	46.623	31.840	32.867
P66	64.819	62.847	26.605	27.276	50.987	47.455	34.493	32.707
P67	58.125	56.097	39.750	32.342	38.727	36.026	40.693	40.120
P68	65.292	63.750	26.789	27.803	54.675	52.974	30.613	32.093
P69	68.208	66.236	31.145	29.618	59.506	54.870	27.920	30.147
P70	63.333	58.417	30.066	31.987	45.104	42.974	35.147	31.693

Note. The labels of the stimuli, which include a letter (i.e., O, C, or P) and a number, are only for identification. R = Randomness, NR = Non-Randomness, C = Complexity, S = Simplicity, L = Low, and H = High.

Table B2
Main Effects of Quality for Each Stimulus (Study 1)

Stimulus	*F*	*p*	η_p^2
O1	333.532	**.001**	.772
O2	149.957	**.001**	.603
O3	154.696	**.001**	.611
O4	170.880	**.001**	.634
O5	246.009	**.001**	.714
O6	184.997	**.001**	.652
O7	273.936	**.001**	.735
O8	272.990	**.001**	.735
O9	280.942	**.001**	.740
O10	284.668	**.001**	.743
O11	212.092	**.001**	.682
O12	212.887	**.001**	.683
O13	193.353	**.001**	.662
O14	192.125	**.001**	.661
O15	233.123	**.001**	.703
O16	209.352	**.001**	.680
O17	272.371	**.001**	.734
O18	162.958	**.001**	.623
O19	276.995	**.001**	.737
O20	235.796	**.001**	.705
O21	255.873	**.001**	.722
O22	182.139	**.001**	.649
O23	248.797	**.001**	.716
O24	84.418	**.001**	.461
O25	113.546	**.001**	.535
O26	135.285	**.001**	.578
O27	107.004	**.001**	.520
O28	269.626	**.001**	.732
O29	71.121	**.001**	.419
O30	145.839	**.001**	.596
O31	140.975	**.001**	.588
O32	228.148	**.001**	.698
O33	136.774	**.001**	.581
O34	161.240	**.001**	.620
O35	255.468	**.001**	.721
O36	271.885	**.001**	.734
O37	191.981	**.001**	.661
O38	93.896	**.001**	.488
O39	138.876	**.001**	.585
O40	78.921	**.001**	.444
O41	172.546	**.001**	.636
O42	133.724	**.001**	.575
O43	132.773	**.001**	.574
O44	198.607	**.001**	.668
O45	208.742	**.001**	.679

O46	147.767	**.001**	.600
O47	223.444	**.001**	.694
O48	244.495	**.001**	.712
O49	154.881	**.001**	.611
O50	242.102	**.001**	.710
O51	244.100	**.001**	.712
O52	42.343	**.001**	.300
O53	254.195	**.001**	.720
O54	251.607	**.001**	.718
O55	160.636	**.001**	.619
C1	11.201	**.001**	.102
C2	32.837	**.001**	.250
C3	24.346	**.001**	.198
C4	38.803	**.001**	.282
C5	25.859	**.001**	.208
C6	33.019	**.001**	.251
C7	4.790	**.003**	.046
C8	14.153	**.001**	.125
C9	26.347	**.001**	.211
C10	21.171	**.001**	.177
C11	26.929	**.001**	.214
C12	11.640	**.001**	.106
C13	34.664	**.001**	.260
C14	27.485	**.001**	.218
C15	25.324	**.001**	.204
C16	8.728	**.001**	.081
C17	21.168	**.001**	.177
C18	22.599	**.001**	.186
C19	11.933	**.001**	.108
C20	36.128	**.001**	.268
C21	9.843	**.001**	.091
C22	18.023	**.001**	.154
C23	11.516	**.001**	.105
C24	13.410	**.001**	.120
C25	23.174	**.001**	.190
C26	12.525	**.001**	.113
C27	21.136	**.001**	.176
C28	17.624	**.001**	.152
C29	49.361	**.001**	.333
C30	18.735	**.001**	.160
C31	19.331	**.001**	.164
C32	32.819	**.001**	.250
C33	28.987	**.001**	.227
C34	4.795	**.003**	.046
C35	21.085	**.001**	.176
C36	31.207	**.001**	.240
C37	4.160	**.007**	.040
C38	15.131	**.001**	.133
C39	27.874	**.001**	.220

C40	51.355	**.001**	.342
C41	27.489	**.001**	.218
C42	40.247	**.001**	.290
C43	16.017	**.001**	.140
C44	39.537	**.001**	.286
C45	3.838	**.010**	.037
C46	20.226	**.001**	.170
C47	24.647	**.001**	.200
C48	32.741	**.001**	.249
C49	77.288	**.001**	.439
C50	21.721	**.001**	.180
C51	7.125	**.001**	.067
C52	7.674	**.001**	.072
C53	13.240	**.001**	.118
C54	34.024	**.001**	.256
C55	8.835	**.001**	.082
P1	60.203	**.001**	.379
P2	121.717	**.001**	.552
P3	82.331	**.001**	.455
P4	74.786	**.001**	.431
P5	59.365	**.001**	.376
P6	41.406	**.001**	.296
P7	5.516	**.001**	.053
P8	45.571	**.001**	.316
P9	54.618	**.001**	.356
P10	91.709	**.001**	.482
P11	82.820	**.001**	.456
P12	45.036	**.001**	.313
P13	86.036	**.001**	.466
P14	73.447	**.001**	.427
P15	0.282	.839	.003
P16	61.794	**.001**	.385
P17	83.540	**.001**	.458
P18	27.206	**.001**	.216
P19	60.247	**.001**	.379
P20	43.317	**.001**	.305
P21	72.245	**.001**	.423
P22	57.672	**.001**	.369
P23	49.336	**.001**	.333
P24	83.816	**.001**	.459
P25	42.761	**.001**	.302
P26	32.150	**.001**	.246
P27	90.176	**.001**	.478
P28	66.912	**.001**	.404
P29	20.221	**.001**	.170
P30	24.599	**.001**	.200
P31	87.874	**.001**	.471
P32	22.661	**.001**	.187
P33	36.609	**.001**	.271

P34	64.649	**.001**	.396
P35	18.534	**.001**	.158
P36	220.932	**.001**	.691
P37	1.781	.151	.018
P38	79.259	**.001**	.445
P39	88.994	**.001**	.474
P40	68.085	**.001**	.408
P41	64.187	**.001**	.394
P42	72.367	**.001**	.423
P43	83.038	**.001**	.457
P44	65.982	**.001**	.401
P45	67.567	**.001**	.406
P46	63.296	**.001**	.391
P47	24.791	**.001**	.201
P48	93.806	**.001**	.487
P49	64.185	**.001**	.394
P50	9.364	**.001**	.087
P51	1.651	.178	.016
P52	81.564	**.001**	.453
P53	127.911	**.001**	.565
P54	0.294	.830	.003
P55	13.590	**.001**	.121
P56	95.618	**.001**	.492
P57	7.653	**.001**	.072
P58	0.648	.585	.007
P59	16.886	**.001**	.146
P60	48.629	**.001**	.330
P61	77.899	**.001**	.441
P62	64.270	**.001**	.394
P63	6.659	**.001**	.063
P64	46.048	**.001**	.318
P65	2.147	.094	.021
P66	58.154	**.001**	.371
P67	25.539	**.001**	.206
P68	77.068	**.001**	.439
P69	81.538	**.001**	.452
P70	38.290	**.001**	.280

Note. The labels of the stimuli, which include a letter (i.e., O, C, or P) and a number, are only for identification. In the grey shade, stimuli for which the main effect of quality was significant. In bold, *p*-values < .05.

Table B3
Multiple Comparisons Between All Levels of the Quality Factor for Each Stimulus (Study 1)

Stimulus	R – NR		C – S		R – C		R – S		NR – C		NR – S	
	$M_{Difference}$	*p*	$M_{Difference}$	*p*	$M_{Difference}$	*p*	$M_{Difference}$	*p*	$M_{Difference}$	*p*	$M_{Difference}$	*p*
O1	-83.400	**.001**	-73.480	**.001**	-1.340	.704	-74.820	**.001**	82.060	**.001**	8.580	**.015**
O2	-55.430	**.001**	-46.780	**.001**	-3.370	.327	-50.150	**.001**	52.060	**.001**	5.280	.122
O3	-60.080	**.001**	-32.970	**.001**	-12.390	**.001**	-45.360	**.001**	47.690	**.001**	14.720	**.001**
O4	-54.620	**.001**	-57.410	**.001**	2.130	.546	-55.280	**.001**	56.740	**.001**	-0.660	.849
O5	-76.740	**.001**	-48.770	**.001**	-11.990	**.001**	-60.770	**.001**	64.740	**.001**	15.970	**.001**
O6	-76.798	**.001**	-37.540	**.001**	-16.670	**.001**	-54.220	**.001**	48.320	**.001**	10.780	**.001**
O7	-77.780	**.001**	-63.840	**.001**	-3.940	.265	-67.780	**.001**	73.840	**.001**	10.000	**.005**
O8	-75.300	**.001**	-64.590	**.001**	-2.390	.492	-66.990	**.001**	72.900	**.001**	8.310	**.017**
O9	-76.640	**.001**	-61.470	**.001**	-6.340	.063	-67.820	**.001**	70.300	**.001**	8.820	**.009**
O10	-77.580	**.001**	-66.820	**.001**	-3.150	.372	-69.970	**.001**	74.430	**.001**	7.610	**.030**
O11	-63.720	**.001**	-49.870	**.001**	-5.530	.087	-55.400	**.001**	58.190	**.001**	8.320	**.010**
O12	-65.980	**.001**	-56.020	**.001**	-1.600	.642	-57.620	**.001**	64.380	**.001**	8.360	**.015**
O13	-78.960	**.001**	-23.860	**.001**	-30.890	**.001**	-54.750	**.001**	48.070	**.001**	24.210	**.001**
O14	-75.250	**.001**	-33.520	**.001**	-23.740	**.001**	-57.260	**.001**	51.510	**.001**	17.990	**.001**
O15	-69.730	**.001**	-55.660	**.001**	-5.510	.104	-61.170	**.001**	64.220	**.001**	8.560	**.011**
O16	-77.310	**.001**	-36.760	**.001**	-22.240	**.001**	-59.000	**.001**	55.070	**.001**	18.310	**.001**
O17	-74.140	**.001**	-50.950	**.001**	-10.650	**.001**	-61.600	**.001**	63.490	**.001**	12.540	**.001**
O18	-68.300	**.001**	-23.980	**.001**	-24.310	**.001**	-48.290	**.001**	43.990	**.001**	20.010	**.001**
O19	-75.540	**.001**	-54.580	**.001**	-8.270	**.011**	-62.850	**.001**	67.270	**.001**	12.700	**.001**
O20	-69.990	**.001**	-56.000	**.001**	-3.870	.254	-59.870	**.001**	66.120	**.001**	10.120	**.003**
O21	-77.210	**.001**	-50.670	**.001**	-11.660	**.001**	-62.330	**.001**	65.540	**.001**	14.870	**.001**
O22	-68.630	**.001**	-42.070	**.001**	-10.950	**.002**	-53.020	**.001**	57.680	**.001**	15.610	**.001**
O23	-76.340	**.001**	-47.580	**.001**	-13.860	**.001**	-61.440	**.001**	62.490	**.001**	14.910	**.001**
O24	-28.940	**.001**	-43.840	**.001**	8.800	**.009**	-35.050	**.001**	37.740	**.001**	-6.100	.066
O25	-67.370	**.001**	2.250	.540	-44.750	**.001**	-42.500	**.001**	22.620	**.001**	24.870	**.001**
O26	-71.280	**.001**	-3.540	.317	-42.600	**.001**	-46.140	**.001**	28.680	**.001**	25.140	**.001**
O27	-61.370	**.001**	-3.780	.270	-35.220	**.001**	-39.000	**.001**	26.150	**.001**	22.370	**.001**

O28	-75.830	**.001**	-45.950	**.001**	-16.050	**.001**	-62.000	**.001**	59.780	**.001**	13.830	**.001**
O29	-40.520	**.001**	-29.090	**.001**	-3.150	.360	-32.240	**.001**	37.370	**.001**	8.280	**.016**
O30	-58.860	**.001**	-39.170	**.001**	-8.150	**.017**	-47.330	**.001**	50.710	**.001**	11.530	**.001**
O31	-78.550	**.001**	-12.710	**.001**	-43.450	**.001**	-56.160	**.001**	35.100	**.001**	22.390	**.001**
O32	-75.220	**.001**	-31.020	**.001**	-22.470	**.001**	-53.490	**.001**	52.750	**.001**	21.730	**.001**
O33	-79.550	**.001**	-18.810	**.001**	-39.030	**.001**	-57.840	**.001**	40.520	**.001**	21.710	**.001**
O34	-77.070	**.001**	-10.670	**.003**	-41.200	**.001**	-51.870	**.001**	35.870	**.001**	25.210	**.001**
O35	-72.720	**.001**	-69.410	**.001**	-0.200	.957	-69.610	**.001**	72.520	**.001**	3.110	.391
O36	-75.950	**.003**	-53.370	**.001**	-9.600	**.001**	-62.970	**.001**	66.350	**.001**	12.980	**.001**
O37	-65.220	**.001**	-40.260	**.001**	-11.850	**.001**	-52.110	**.001**	53.370	**.001**	13.110	**.001**
O38	-43.490	**.001**	-28.640	**.001**	-5.440	.082	-34.080	**.001**	38.060	**.001**	9.410	**.003**
O39	-59.090	**.001**	-18.140	**.001**	-16.000	**.001**	-34.130	**.001**	43.100	**.001**	24.960	**.001**
O40	-45.190	.138	-23.790	**.001**	-5.010	**.001**	-28.800	**.001**	40.180	**.001**	16.390	**.001**
O41	-64.660	**.001**	-29.130	**.001**	-13.170	**.001**	-42.290	**.001**	51.500	**.001**	22.370	**.001**
O42	-47.350	**.001**	-40.830	**.001**	-3.520	.262	-44.350	**.001**	43.830	**.001**	3.000	.334
O43	-52.540	**.022**	-37.470	**.001**	-7.460	**.001**	-44.930	**.001**	45.080	**.001**	7.600	**.019**
O44	-71.080	**.001**	-43.640	**.001**	-14.820	**.001**	-58.470	**.001**	56.260	**.001**	12.610	**.001**
O45	-64.010	.202	-50.540	**.001**	-4.190	**.001**	-54.730	**.001**	59.820	**.001**	9.280	**.005**
O46	-65.550	**.001**	-21.730	**.001**	-25.990	**.001**	-47.720	**.001**	39.560	**.001**	17.830	**.001**
O47	-65.180	**.001**	-58.140	**.001**	-1.690	.618	-59.830	**.001**	63.490	**.001**	5.350	.113
O48	-75.420	**.001**	-49.960	**.001**	-11.070	**.001**	-61.030	**.001**	64.340	**.001**	14.390	**.001**
O49	-53.180	**.001**	-42.410	**.001**	-1.740	.584	-44.150	**.001**	51.440	**.001**	9.030	**.004**
O50	-74.560	**.001**	-44.880	**.001**	-14.000	**.001**	-58.880	**.001**	60.560	**.001**	15.680	**.001**
O51	-73.620	**.001**	-45.840	**.001**	-13.910	**.001**	-59.750	**.001**	59.710	**.001**	13.870	**.001**
O52	-19.030	**.009**	-33.260	**.001**	9.020	**.001**	-24.240	**.001**	28.050	**.001**	-5.210	.128
O53	-74.610	**.001**	-44.090	**.001**	-14.070	**.001**	-58.160	**.001**	60.540	**.001**	16.450	**.001**
O54	-76.110	**.001**	-51.980	**.001**	-12.000	**.001**	-63.980	**.001**	64.110	**.001**	12.140	**.001**
O55	-53.240	.836	-48.050	**.001**	-0.680	**.001**	-48.730	**.001**	52.560	**.001**	4.510	.168
C1	10.940	**.001**	-13.130	**.001**	15.800	**.001**	2.670	.393	4.860	.113	-8.270	**.008**
C2	26.710	**.001**	-2.510	.377	21.700	**.001**	19.190	**.001**	-5.020	.077	-7.520	**.009**
C3	23.720	**.001**	0.530	.854	16.750	**.001**	17.280	**.001**	-6.960	**.015**	-6.440	**.025**

C4	29.430	**.001**	7.650	**.008**	17.180	**.001**	24.830	**.001**	-12.250	**.001**	-4.600	.113
C5	24.180	**.001**	4.030	.165	16.180	**.001**	20.210	**.001**	-8.000	**.006**	-3.970	.173
C6	28.180	**.001**	3.860	.187	17.900	**.001**	21.770	**.001**	-10.280	**.001**	-6.420	**.029**
C7	10.180	**.001**	-2.210	.455	9.420	**.002**	7.210	**.017**	-0.760	.796	-2.970	.316
C8	17.930	**.001**	-3.830	.205	16.510	**.001**	12.690	**.001**	-1.410	.638	-5.240	.084
C9	24.670	**.001**	2.070	.459	14.900	**.001**	16.970	**.001**	-9.770	**.001**	-7.700	.006
C10	21.620	**.001**	1.480	.602	15.680	**.001**	17.160	**.001**	-5.940	**.037**	-4.460	.119
C11	-4.910	.110	-26.550	**.001**	12.640	**.001**	-13.910	**.001**	17.560	**.001**	-8.990	**.003**
C12	14.570	**.001**	-5.370	.055	14.410	**.001**	9.040	**.002**	-0.160	.954	-5.530	**.049**
C13	28.500	**.001**	3.710	.195	17.490	**.001**	21.200	**.001**	-11.010	**.001**	-7.300	**.011**
C14	25.580	**.001**	-0.440	.878	17.340	**.001**	16.900	**.001**	-8.240	**.004**	-8.680	**.003**
C15	17.660	**.001**	18.450	**.001**	0.750	.799	19.200	**.001**	-16.910	**.001**	1.540	.599
C16	14.010	**.001**	5.110	.089	7.710	**.011**	12.820	**.001**	-6.310	**.036**	-1.190	.692
C17	21.690	**.001**	4.440	.111	11.600	**.001**	16.050	**.001**	-10.080	**.001**	-5.640	**.044**
C18	19.750	**.001**	13.680	**.001**	5.050	.086	18.740	**.001**	-14.700	**.001**	-1.020	.728
C19	14.630	**.001**	-5.600	**.048**	15.080	**.001**	9.480	**.001**	0.450	.872	-5.150	.070
C20	26.720	**.001**	11.650	**.001**	12.170	**.001**	23.820	**.001**	-14.550	**.001**	-2.900	.307
C21	-1.400	.640	-15.290	**.001**	10.210	**.001**	-5.080	.093	11.620	**.001**	-3.670	.217
C22	19.860	**.001**	0.710	.802	14.710	**.001**	15.420	**.001**	-5.160	.068	-4.450	.117
C23	12.740	**.001**	-11.780	**.001**	15.460	**.001**	3.670	.233	2.710	.369	-9.070	**.003**
C24	11.550	**.001**	-14.840	**.001**	16.490	**.001**	1.640	.595	4.940	.104	-9.900	**.001**
C25	23.770	**.001**	-0.310	.916	17.530	**.001**	17.210	**.001**	-6.240	**.034**	-6.560	**.027**
C26	13.630	**.001**	-6.810	**.022**	17.590	**.001**	10.780	**.001**	3.960	.181	-2.850	.339
C27	12.320	**.001**	22.160	**.001**	-4.490	.163	17.670	**.001**	-16.810	**.001**	5.350	.094
C28	15.430	**.001**	15.180	**.001**	3.540	.246	18.720	**.001**	-11.880	**.001**	3.300	.277
C29	24.270	**.001**	28.110	**.001**	2.570	.408	30.670	**.001**	-21.700	**.001**	6.400	**.038**
C30	10.910	**.001**	-18.870	**.001**	20.760	**.001**	1.880	.550	9.840	**.002**	-9.030	**.004**
C31	10.240	**.001**	-19.170	**.001**	20.800	**.001**	1.630	.600	10.560	**.001**	-8.610	**.005**
C32	27.030	**.001**	-7.670	**.009**	23.380	**.001**	15.710	**.001**	-3.650	.210	-11.320	**.001**
C33	24.660	**.001**	6.880	**.013**	12.740	**.001**	19.630	**.001**	-11.910	**.001**	-5.030	**.070**
C34	7.620	**.007**	5.590	**.046**	4.630	.101	10.220	**.001**	-2.990	.282	2.600	.353

C35	-0.280	.926	23.380	**.001**	-13.780	**.001**	9.600	**.002**	-13.500	**.001**	9.880	**.001**
C36	27.000	**.001**	1.190	.674	17.590	**.001**	18.780	**.001**	-9.410	**.001**	-8.220	**.004**
C37	9.970	**.001**	0.930	.750	6.650	**.024**	7.580	**.011**	-3.320	.252	-2.400	.412
C38	10.630	**.001**	-15.710	**.001**	19.090	**.001**	3.380	.278	8.460	**.006**	-7.250	**.019**
C39	26.230	**.001**	-3.160	.285	20.050	**.001**	16.890	**.001**	-6.180	**.037**	-9.340	**.002**
C40	33.430	**.001**	11.090	**.001**	17.010	**.001**	28.100	**.001**	-16.430	**.001**	-5.330	.065
C41	25.020	**.001**	3.090	.283	16.950	**.001**	20.040	**.001**	-8.070	**.005**	-4.980	.085
C42	28.860	**.001**	13.560	**.001**	14.140	**.001**	27.700	**.001**	-14.720	**.001**	-1.160	.696
C43	17.700	**.001**	-6.810	**.020**	17.660	**.001**	10.850	**.001**	-0.040	.989	-6.850	**.019**
C44	29.010	**.001**	5.410	**.049**	16.610	**.001**	22.020	**.001**	-12.400	**.001**	-6.990	**.011**
C45	9.990	**.001**	-2.400	.428	7.430	**.016**	5.030	.103	-2.570	.395	-4.970	.103
C46	22.070	**.001**	-5.180	.085	18.550	**.001**	13.370	**.001**	-3.520	.239	-8.700	**.004**
C47	23.990	**.001**	-4.730	.109	20.060	**.001**	15.330	**.001**	-3.930	.181	-8.660	**.004**
C48	25.290	**.001**	12.040	**.001**	11.250	**.001**	23.290	**.001**	-14.040	**.001**	-2.000	.486
C49	38.450	**.001**	26.530	**.001**	11.580	**.001**	38.110	**.001**	-26.870	**.001**	-0.340	.913
C50	19.010	**.001**	11.940	**.001**	9.240	**.002**	21.180	**.001**	-9.770	**.001**	2.170	.457
C51	3.420	.267	13.590	**.001**	-4.310	.161	9.280	**.003**	-7.740	**.011**	5.850	.055
C52	-0.310	.913	-12.910	**.001**	9.240	**.001**	-3.670	.204	9.550	**.001**	-3.350	.239
C53	15.260	**.001**	-8.800	**.004**	17.850	**.001**	9.050	**.004**	2.590	.394	-6.210	**.043**
C54	25.930	**.001**	9.080	**.001**	14.370	**.001**	23.450	**.001**	-11.560	**.001**	-2.480	.378
C55	13.670	**.001**	4.410	.142	9.140	**.003**	13.540	**.001**	-4.530	.130	-0.120	.967
P1	32.810	**.001**	18.080	**.001**	11.170	**.001**	29.250	**.001**	-21.640	**.001**	-3.560	.202
P2	49.300	**.001**	35.470	**.001**	11.280	**.001**	46.760	**.001**	-38.020	**.001**	-2.550	.442
P3	37.540	**.001**	24.520	**.001**	11.420	**.001**	35.950	**.001**	-26.110	**.001**	-1.590	.579
P4	39.330	**.001**	22.900	**.001**	13.270	**.001**	36.170	**.001**	-26.060	**.001**	-3.160	.300
P5	34.280	**.001**	24.460	**.001**	8.790	**.006**	33.240	**.001**	-25.490	**.001**	-1.040	.743
P6	26.080	**.001**	17.590	**.001**	10.240	**.001**	27.830	**.001**	-15.830	**.001**	1.760	.544
P7	2.310	.483	4.770	.142	7.430	**.024**	12.190	**.001**	5.120	.114	9.880	**.003**
P8	-16.740	**.001**	-35.900	**.001**	11.890	**.001**	-24.010	**.001**	28.630	**.001**	-7.270	**.034**
P9	-38.130	**.001**	-17.970	**.001**	-7.220	**.030**	-25.190	**.001**	30.910	**.001**	12.940	**.001**
P10	-36.490	**.001**	-37.900	**.001**	0.440	.889	-37.460	**.001**	36.930	**.001**	-0.970	.759

P11	39.320	**.001**	26.350	**.001**	11.250	**.001**	37.600	**.001**	-28.070	**.001**	-1.720	.568
P12	32.230	**.001**	12.100	**.001**	16.040	**.001**	28.150	**.001**	-16.190	**.001**	-4.090	.176
P13	39.740	**.001**	28.510	**.001**	10.000	**.001**	38.510	**.001**	-29.740	**.001**	-1.240	.685
P14	36.390	**.001**	26.650	**.001**	8.620	**.005**	35.270	**.001**	-27.770	**.001**	-1.120	.713
P15	30.370	**.001**	4.440	.109	19.630	**.001**	24.060	**.001**	-10.740	**.001**	-6.310	**.023**
P16	31.900	**.001**	20.290	**.001**	11.120	**.001**	31.410	**.001**	-20.780	**.001**	-0.490	.862
P17	38.670	**.001**	29.210	**.001**	7.840	**.011**	37.050	**.001**	-30.830	**.001**	-1.620	.596
P18	23.890	**.001**	-8.720	**.004**	23.640	**.001**	14.910	**.001**	-0.250	.933	-8.970	**.003**
P19	32.690	**.001**	23.370	**.001**	8.600	**.005**	31.970	**.001**	-24.090	**.001**	-0.720	.809
P20	30.860	**.001**	9.960	**.001**	16.310	**.001**	26.280	**.001**	-14.550	**.001**	-4.180	.115
P21	33.550	**.001**	24.610	**.001**	9.820	**.001**	34.430	**.001**	-23.730	**.001**	0.880	.756
P22	32.550	**.001**	19.960	**.001**	9.430	**.001**	29.390	**.001**	-23.120	**.001**	-3.160	.276
P23	-42.200	**.001**	-2.260	.516	-25.520	**.001**	-27.790	**.001**	16.680	**.001**	14.420	**.001**
P24	40.020	**.001**	29.250	**.001**	9.470	**.003**	38.720	**.001**	-30.550	**.001**	-1.300	.678
P25	27.620	**.001**	17.200	**.001**	10.600	**.001**	27.800	**.001**	-17.020	**.001**	0.180	.952
P26	26.220	**.001**	9.480	**.001**	14.830	**.001**	24.320	**.001**	-11.380	**.001**	-1.900	.519
P27	39.660	**.001**	27.880	**.001**	10.810	**.001**	38.690	**.001**	-28.840	**.001**	-0.960	.745
P28	35.830	**.001**	21.080	**.001**	11.630	**.001**	32.710	**.001**	-24.200	**.001**	-3.120	.288
P29	-22.330	**.001**	-8.820	**.004**	-5.330	.086	-14.150	**.001**	17.000	**.001**	8.170	**.008**
P30	21.510	**.001**	11.960	**.001**	9.550	**.001**	21.150	**.001**	-11.960	**.001**	-0.360	.901
P31	41.330	**.001**	26.800	**.001**	12.860	**.001**	39.660	**.001**	-28.470	**.001**	-1.670	.583
P32	23.190	**.001**	-0.020	.993	17.480	**.001**	17.450	**.001**	-5.720	.051	-5.740	.052
P33	-19.590	**.001**	-25.880	**.001**	5.460	.083	-20.420	**.001**	25.050	**.001**	-0.830	.790
P34	35.200	**.001**	20.720	**.001**	12.100	**.001**	32.820	**.001**	-23.900	**.001**	-2.380	.420
P35	6.470	**.042**	-20.500	**.001**	19.870	**.001**	-0.620	.844	13.410	**.001**	-7.090	**.024**
P36	-62.860	**.001**	-72.280	**.001**	4.590	.221	-67.700	**.001**	67.450	**.001**	-4.840	.193
P37	11.310	**.002**	34.710	**.001**	-11.670	**.001**	23.040	**.001**	-22.990	**.001**	11.730	**.001**
P38	38.900	**.001**	23.860	**.001**	13.970	**.001**	37.840	**.001**	-24.920	**.001**	-1.060	.723
P39	39.350	**.001**	31.960	**.001**	7.320	**.020**	39.290	**.001**	-32.030	**.001**	-0.060	.984
P40	37.380	**.001**	22.600	**.001**	13.170	**.001**	35.780	**.001**	-24.210	**.001**	-1.600	.603
P41	36.610	**.001**	21.200	**.001**	12.450	**.001**	33.650	**.001**	-24.160	**.001**	-2.970	.333

P42	39.440	**.001**	18.650	**.001**	17.050	**.001**	35.710	**.001**	-22.390	**.001**	-3.730	.213
P43	39.460	**.001**	24.670	**.001**	11.770	**.001**	36.440	**.001**	-27.690	**.001**	-3.020	.307
P44	35.300	**.001**	18.640	**.001**	15.320	**.001**	33.950	**.001**	-19.990	**.001**	-1.350	.641
P45	36.500	**.001**	21.800	**.001**	12.000	**.001**	33.800	**.001**	-24.500	**.001**	-2.700	.367
P46	33.910	**.001**	21.370	**.001**	8.920	**.002**	30.280	**.001**	-25.000	**.001**	-3.630	.211
P47	24.940	**.001**	-0.870	.770	18.520	**.001**	17.650	**.001**	-6.420	**.032**	-7.290	**.015**
P48	42.830	**.001**	30.850	**.001**	10.520	**.001**	41.370	**.001**	-32.310	**.001**	-1.460	.643
P49	32.870	**.001**	23.380	**.001**	9.970	**.001**	33.340	**.001**	-22.900	**.001**	0.480	.871
P50	2.570	.390	-11.930	**.001**	14.120	**.001**	2.200	.464	11.560	**.001**	-0.370	.900
P51	-0.820	.784	-5.240	.078	4.950	.099	-0.290	.923	5.770	.051	0.530	.858
P52	40.910	**.001**	25.790	**.001**	11.560	**.001**	37.340	**.001**	-29.350	**.001**	-3.570	.249
P53	-51.140	**.001**	-28.510	**.001**	-9.350	**.002**	-37.860	**.001**	41.790	**.001**	13.280	**.001**
P54	16.730	**.001**	-16.970	**.001**	21.820	**.001**	4.850	.105	5.090	.082	-11.870	**.001**
P55	-3.460	.276	-18.900	**.001**	11.410	**.001**	7.490	**.019**	14.870	**.001**	-4.030	.200
P56	43.250	**.001**	32.570	**.001**	10.180	**.001**	42.750	**.001**	-33.070	**.001**	-0.500	.876
P57	11.560	**.001**	-7.650	**.011**	12.560	**.001**	4.910	.107	1.000	.738	-6.660	**.027**
P58	14.860	**.001**	-10.650	**.001**	19.790	**.001**	9.130	**.003**	4.920	.102	-5.730	.059
P59	20.010	**.001**	-3.670	.221	17.160	**.001**	13.490	**.001**	-2.850	.340	-6.520	**.031**
P60	30.900	**.001**	15.020	**.001**	15.230	**.001**	30.260	**.001**	-15.660	**.001**	-0.640	.828
P61	36.210	**.001**	32.620	**.001**	3.970	.216	36.590	**.001**	-32.240	**.001**	0.380	.905
P62	34.520	**.001**	23.940	**.001**	10.360	**.001**	34.300	**.001**	-24.160	**.001**	-0.220	.943
P63	-12.650	**.001**	-3.350	.264	-2.420	.424	-5.760	.059	10.230	**.001**	6.890	**.022**
P64	31.430	**.001**	8.380	**.001**	18.640	**.001**	27.030	**.001**	-12.790	**.001**	-4.400	.124
P65	35.770	**.001**	17.910	**.001**	13.870	**.001**	31.790	**.001**	-21.900	**.001**	-3.980	.172
P66	36.890	**.001**	15.620	**.001**	14.610	**.001**	30.230	**.001**	-22.280	**.001**	-6.660	**.029**
P67	21.070	**.001**	-3.030	.259	19.730	**.001**	16.700	**.001**	-1.330	.619	-4.360	.106
P68	37.220	**.001**	22.470	**.001**	10.700	**.001**	33.170	**.001**	-26.530	**.001**	-4.060	.156
P69	36.840	**.001**	28.150	**.001**	10.030	**.001**	38.190	**.001**	-26.810	**.001**	1.350	.652
P70	29.850	**.001**	10.620	**.001**	16.840	**.001**	27.460	**.001**	-13.010	**.001**	-2.390	.435

Note. The labels of the stimuli, which include a letter (i.e., O, C, or P) and a number, are only for identification. R = Randomness, NR = Non-Randomness, C = Complexity, and S = Simplicity. In the grey shade, stimuli for which at least one pairwise comparison was significant. In bold, *p*-values < .05.

Table B4
Main Effects of Ratio for Each Stimulus (Study 1)

Stimulus	*F*	*p*	η_p^2
O1	1.311	.253	.004
O2	0.102	.750	.000
O3	0.264	.608	.001
O4	1.291	.257	.004
O5	0.050	.823	.000
O6	0.001	.975	.000
O7	2.768	.097	.009
O8	2.849	.092	.010
O9	1.826	.178	.006
O10	0.615	.433	.002
O11	0.529	.468	.002
O12	5.197	**.023**	.017
O13	2.363	.125	.008
O14	0.786	.376	.003
O15	0.086	.769	.000
O16	4.748	**.030**	.016
O17	5.747	**.017**	.019
O18	0.007	.932	.000
O19	1.577	.210	.005
O20	0.893	.346	.003
O21	0.844	.359	.003
O22	0.000	.989	.000
O23	0.901	.343	.003
O24	0.233	.629	.001
O25	0.032	.857	.000
O26	0.125	.724	.000
O27	3.110	.079	.010
O28	0.527	.468	.002
O29	0.109	.741	.000
O30	0.006	.936	.000
O31	0.215	.643	.001
O32	1.262	.262	.004
O33	0.229	.632	.001
O34	3.089	.080	.010
O35	1.614	.205	.005
O36	1.737	.188	.006
O37	1.198	.275	.004
O38	0.535	.465	.002
O39	0.972	.325	.003
O40	0.390	.533	.001
O41	2.631	.106	.009
O42	0.000	.993	.000
O43	0.009	.924	.000
O44	1.409	.236	.005
O45	0.758	.385	.003

O46	0.280	.587	.001
O47	6.176	**.014**	.020
O48	0.077	.782	.000
O49	3.894	**.049**	.013
O50	0.260	.611	.001
O51	4.991	**.026**	.017
O52	0.000	.995	.000
O53	0.023	.881	.000
O54	0.001	.974	.000
O55	0.510	.476	.002
C1	2.460	.118	.008
C2	0.002	.962	.000
C3	0.493	.483	.002
C4	0.201	.654	.001
C5	2.515	.114	.008
C6	0.025	.875	.000
C7	0.920	.338	.003
C8	4.402	**.037**	.015
C9	0.464	.496	.002
C10	0.216	.643	.001
C11	0.016	.900	.000
C12	0.639	.425	.002
C13	0.731	.393	.002
C14	1.700	.193	.006
C15	0.127	.721	.000
C16	1.450	.229	.005
C17	0.013	.908	.000
C18	1.515	.219	.005
C19	1.264	.262	.004
C20	0.477	.490	.002
C21	0.059	.809	.000
C22	1.188	.277	.004
C23	0.934	.335	.003
C24	0.136	.712	.000
C25	0.004	.948	.000
C26	0.086	.770	.000
C27	0.037	.847	.000
C28	9.441	**.002**	.031
C29	0.551	.459	.002
C30	0.222	.638	.001
C31	0.000	.992	.000
C32	0.430	.513	.001
C33	0.219	.640	.001
C34	0.254	.615	.001
C35	0.973	.325	.003
C36	0.009	.923	.000
C37	0.009	.924	.000
C38	0.002	.986	.000
C39	0.132	.717	.000

C40	1.191	.276	.004
C41	0.748	.388	.003
C42	0.736	.392	.002
C43	0.025	.875	.000
C44	2.119	.147	.007
C45	0.366	.546	.001
C46	1.814	.179	.006
C47	0.362	.548	.001
C48	0.071	.790	.000
C49	0.523	.470	.002
C50	1.249	.265	.004
C51	0.025	.874	.000
C52	0.293	.589	.001
C53	2.071	.151	.007
C54	1.024	.312	.003
C55	0.035	.851	.000
P1	0.678	.411	.002
P2	3.332	.069	.011
P3	5.458	**.020**	.018
P4	0.281	.596	.001
P5	0.263	.608	.001
P6	0.051	.821	.000
P7	0.027	.870	.000
P8	0.001	.974	.000
P9	2.048	.153	.007
P10	0.283	.094	.009
P11	2.622	.106	.009
P12	0.237	.627	.001
P13	0.250	.618	.001
P14	0.209	.648	.001
P15	0.262	.609	.001
P16	0.932	.335	.003
P17	0.020	.888	.000
P18	1.250	.265	.004
P19	2.037	.155	.007
P20	0.127	.722	.000
P21	0.211	.646	.001
P22	1.762	.185	.006
P23	0.204	.652	.001
P24	0.127	.721	.000
P25	0.836	.361	.003
P26	1.790	.182	.006
P27	0.291	.590	.001
P28	1.883	.171	.006
P29	0.100	.752	.000
P30	0.696	.405	.002
P31	1.030	.311	.003
P32	0.024	.876	.000
P33	5.586	**.019**	.019

P34	0.689	.407	.002
P35	0.207	.649	.001
P36	0.667	.415	.002
P37	1.663	.198	.006
P38	2.116	.147	.007
P39	1.232	.268	.004
P40	3.831	.051	.013
P41	0.049	.826	.000
P42	1.466	.227	.005
P43	0.083	.773	.000
P44	0.030	.862	.000
P45	0.107	.744	.000
P46	0.089	.766	.000
P47	0.426	.515	.001
P48	0.102	.750	.000
P49	0.863	.354	.003
P50	0.309	.579	.001
P51	0.278	.598	.001
P52	0.459	.499	.002
P53	0.091	.763	.000
P54	0.025	.874	.000
P55	0.527	.468	.002
P56	1.918	.167	.006
P57	0.469	.494	.002
P58	0.286	.593	.001
P59	0.573	.450	.002
P60	7.421	**.007**	.024
P61	2.100	.148	.007
P62	0.631	.428	.002
P63	0.052	.820	.000
P64	0.115	.735	.000
P65	6.837	**.009**	.023
P66	2.512	.114	.008
P67	6.352	**.012**	.021
P68	0.029	.864	.000
P69	1.476	.225	.005
P70	3.190	.075	.011

Note. The labels of the stimuli, which include a letter (i.e., O, C, or P) and a number, are only for identification. In the grey shade, stimuli for which the main effect of ratio was significant. In bold, *p*-values < .05.

Table B5
Interaction Effects for Each Stimulus (Study 1)

Stimulus	*F*	*p*	η_p^2
O1	0.899	.442	.009
O2	0.733	.533	.007
O3	1.698	.168	.017
O4	1.138	.334	.011
O5	1.530	.207	.015
O6	1.138	.334	.011
O7	0.299	.826	.003
O8	0.184	.907	.002
O9	1.730	.161	.017
O10	0.346	.792	.003
O11	0.379	.769	.004
O12	0.482	.695	.005
O13	0.085	.968	.001
O14	1.039	.375	.010
O15	1.236	.297	.012
O16	0.214	.887	.002
O17	0.238	.870	.002
O18	0.324	.808	.003
O19	0.332	.802	.003
O20	0.285	.837	.003
O21	0.257	.857	.003
O22	1.733	.160	.017
O23	0.254	.858	.003
O24	0.300	.825	.003
O25	2.393	.069	.024
O26	1.528	.207	.015
O27	2.618	.051	.026
O28	1.473	.222	.015
O29	1.235	.297	.012
O30	0.821	.483	.008
O31	1.863	.136	.019
O32	0.800	.495	.008
O33	0.275	.843	.003
O34	0.609	.610	.006
O35	0.697	.555	.007
O36	1.072	.361	.011
O37	0.963	.411	.010
O38	0.091	.965	.001
O39	1.252	.291	.013
O40	6.861	**.001**	.065
O41	0.387	.763	.004
O42	0.660	.577	.007
O43	2.041	.108	.020
O44	0.415	.743	.004
O45	1.662	.175	.017

O46	2.079	.103	.021
O47	2.522	.058	.025
O48	1.339	.262	.013
O49	2.390	.069	.024
O50	0.129	.943	.001
O51	1.620	.185	.016
O52	1.080	.358	.011
O53	1.056	.368	.011
O54	0.738	.530	.007
O55	1.166	.323	.012
C1	2.566	.055	.025
C2	0.984	.401	.010
C3	0.387	.763	.004
C4	1.015	.386	.010
C5	2.033	.109	.020
C6	0.802	.494	.008
C7	0.140	.936	.001
C8	0.746	.525	.008
C9	2.017	.112	.020
C10	0.233	.874	.002
C11	0.745	.526	.007
C12	0.837	.474	.008
C13	0.781	.505	.008
C14	0.815	.487	.008
C15	1.401	.242	.014
C16	0.601	.615	.006
C17	1.174	.320	.012
C18	0.652	.582	.007
C19	0.535	.659	.005
C20	0.662	.576	.007
C21	1.917	.127	.019
C22	1.552	.201	.015
C23	2.418	.066	.024
C24	1.322	.267	.013
C25	1.019	.384	.010
C26	1.016	.386	.010
C27	0.475	.700	.005
C28	0.592	.621	.006
C29	1.469	.223	.015
C30	0.596	.618	.006
C31	1.266	.286	.013
C32	0.562	.641	.006
C33	0.492	.688	.005
C34	1.220	.303	.012
C35	1.777	.152	.018
C36	0.497	.685	.005
C37	1.620	.185	.016
C38	1.078	.359	.011
C39	0.584	.626	.006

C40	1.041	.375	.010
C41	0.364	.779	.004
C42	1.492	.216	.015
C43	4.281	**.006**	.042
C44	3.548	**.015**	.035
C45	0.567	.637	.006
C46	1.581	.194	.016
C47	0.392	.759	.004
C48	0.175	.913	.002
C49	0.322	.809	.003
C50	1.156	.327	.012
C51	0.460	.710	.005
C52	3.237	**.023**	.032
C53	0.934	.425	.009
C54	0.248	.863	.003
C55	0.038	.990	.000
P1	2.975	**.032**	.029
P2	0.412	.744	.004
P3	0.090	.965	.001
P4	0.187	.905	.002
P5	0.910	.437	.009
P6	0.579	.629	.006
P7	3.794	**.011**	.037
P8	2.091	.101	.021
P9	1.369	.252	.014
P10	1.718	.163	.017
P11	5.610	**.001**	.054
P12	3.262	**.022**	.032
P13	0.351	.789	.004
P14	0.619	.603	.006
P15	43.518	**.001**	.306
P16	0.367	.777	.004
P17	0.719	.541	.007
P18	1.708	.165	.017
P19	0.882	.451	.009
P20	1.923	.126	.019
P21	0.606	.981	.001
P22	1.342	.261	.013
P23	1.904	.129	.019
P24	0.708	.548	.007
P25	2.007	.113	.020
P26	0.818	.485	.008
P27	2.967	**.032**	.029
P28	0.868	.458	.009
P29	2.045	.108	.020
P30	0.769	.512	.008
P31	1.926	.125	.019
P32	0.231	.875	.002
P33	1.571	.197	.016

P34	0.769	.512	.008
P35	5.573	**.001**	.053
P36	0.399	.754	.004
P37	34.437	**.001**	.259
P38	0.698	.554	.007
P39	1.174	.320	.012
P40	0.744	.526	.007
P41	1.357	.256	.014
P42	1.072	.361	.011
P43	2.668	**.048**	.026
P44	0.800	.494	.008
P45	2.287	.079	.023
P46	0.563	.640	.006
P47	1.641	.180	.016
P48	2.991	**.031**	.029
P49	1.450	.228	.015
P50	1.433	.233	.014
P51	0.189	.904	.002
P52	1.321	.268	.013
P53	0.490	.690	.005
P54	0.294	.830	.003
P55	0.457	.712	.005
P56	0.188	.904	.002
P57	1.620	.185	.016
P58	15.507	**.001**	.136
P59	0.003	1.000	.000
P60	1.358	.256	.014
P61	3.355	**.019**	.033
P62	0.862	.461	.009
P63	2.448	.064	.024
P64	0.381	.767	.004
P65	63.531	**.001**	.392
P66	0.705	.550	.007
P67	1.386	.247	.014
P68	0.579	.629	.006
P69	1.365	.254	.014
P70	1.494	.216	.015

Note. The labels of the stimuli, which include a letter (i.e., O, C, or P) and a number, are only for identification. In the grey shade, stimuli for which the interaction effect was significant. In bold, *p*-values < .05.

Table B6

Simple Main Effects of Quality at the Low and High Levels of the Ratio Factor for Each Stimulus (Study 1)

Stimulus	R – NR		C – S		R – C		R – S		NR – C		NR – S	
	$M_{Difference}$	*p*	$M_{Difference}$	*p*	$M_{Difference}$	*p*	$M_{Difference}$	*p*	$M_{Difference}$	*p*	$M_{Difference}$	*p*
O1 – L	-85.536	**.001**	-73.774	**.001**	-3.207	.374	-76.981	**.001**	82.329	**.001**	8.555	**.017**
O1 – H	-81.268	**.001**	-73.177	**.001**	0.524	.898	-72.653	**.001**	81.791	**.001**	8.614	**.034**
O2 – L	-56.488	**.001**	-45.083	**.001**	-5.132	.170	-50.214	**.001**	51.357	**.001**	6.274	.092
O2 – H	-54.376	**.001**	-48.485	**.001**	-1.604	.664	-50.089	**.001**	52.772	**.001**	4.287	.242
O3 – L	-61.507	**.001**	-34.687	**.001**	-10.392	**.002**	-45.079	**.001**	51.115	**.001**	16.428	**.001**
O3 – H	-58.651	**.001**	-31.247	**.001**	-14.391	**.001**	-45.638	**.001**	44.260	**.001**	13.013	**.001**
O4 – L	-56.891	**.001**	-56.628	**.001**	-0.476	.900	-57.104	**.001**	56.415	**.001**	-0.213	.955
O4 – H	-52.345	**.001**	-58.186	**.001**	4.727	.226	-53.459	**.001**	57.072	**.001**	-1.114	.774
O5 – L	-76.677	**.001**	-47.815	**.001**	-14.433	**.001**	-62.248	**.001**	62.244	**.001**	14.429	**.001**
O5 – H	-76.798	**.001**	-49.731	**.001**	-9.555	**.010**	-59.286	**.001**	67.242	**.001**	17.511	**.001**
O6 – L	-65.223	**.001**	-35.120	**.001**	-18.723	**.001**	-53.843	**.001**	46.500	**.001**	11.380	**.001**
O6 – H	-64.763	**.001**	-39.970	**.001**	-14.620	**.001**	-54.590	**.001**	50.143	**.001**	10.173	**.003**
O7 – L	-78.700	**.001**	-64.051	**.001**	-4.984	.181	-69.036	**.001**	73.716	**.001**	9.665	**.009**
O7 – H	-76.861	**.001**	-63.621	**.001**	-2.897	.457	-66.518	**.001**	73.964	**.001**	10.343	**.008**
O8 – L	-76.097	**.001**	-63.955	**.001**	-2.902	.444	-66.857	**.001**	73.195	**.001**	9.240	**.015**
O8 – H	-74.499	**.001**	-65.231	**.001**	-1.885	.616	-67.116	**.001**	72.614	**.001**	7.383	**.048**
O9 – L	-79.868	**.001**	-60.679	**.001**	-8.210	**.021**	-68.889	**.001**	71.658	**.001**	10.978	**.002**
O9 – H	-73.410	**.001**	-62.265	**.001**	-4.477	.245	-66.742	**.001**	68.933	**.001**	6.668	.082
O10 – L	-77.624	**.001**	-65.503	**.001**	-3.975	.285	-69.478	**.001**	73.650	**.001**	8.146	**.028**
O10 – H	-77.534	**.001**	-68.138	**.001**	-2.322	.542	-70.459	**.001**	75.213	**.001**	7.075	.062
O11 – L	-65.215	**.001**	-49.347	**.001**	-6.340	.074	-55.687	**.001**	58.875	**.001**	9.528	**.007**
O11 – H	-62.224	**.001**	-50.386	**.001**	-4.725	.187	-55.111	**.001**	57.499	**.001**	7.114	**.046**
O12 – L	-66.487	**.001**	-54.600	**.001**	-1.987	.606	-56.587	**.001**	64.500	**.001**	9.900	**.010**
O12 – H	-65.480	**.001**	-57.436	**.001**	-1.219	.735	-58.655	**.001**	64.261	**.001**	6.825	.057
O13 – L	-79.580	**.001**	-23.903	**.001**	-31.391	**.001**	-55.294	**.001**	48.189	**.001**	24.286	**.001**
O13 – H	-78.341	**.001**	-23.818	**.001**	-30.385	**.001**	-54.202	**.001**	47.956	**.001**	24.138	**.001**

O14 – L	-76.548	**.001**	-32.303	**.001**	-26.011	**.001**	-58.313	**.001**	50.537	**.001**	18.235	**.001**
O14 – H	-73.956	**.001**	-34.741	**.001**	-21.472	**.001**	-56.213	**.001**	52.484	**.001**	17.743	**.001**
O15 – L	-70.127	**.001**	-53.437	**.001**	-6.069	.099	-59.507	**.001**	64.058	**.001**	10.621	**.004**
O15 – H	-69.331	**.001**	-57.884	**.001**	-4.954	.169	-62.838	**.001**	64.377	**.001**	6.493	.069
O16 – L	-77.227	**.001**	-35.779	**.001**	-22.257	**.001**	-58.036	**.001**	54.970	**.001**	19.191	**.001**
O16 – H	-77.397	**.001**	-37.732	**.001**	-22.227	**.001**	-59.958	**.001**	55.170	**.001**	17.439	**.001**
O17 – L	-75.175	**.001**	-51.381	**.001**	-10.876	**.001**	-62.257	**.001**	64.300	**.001**	12.919	**.001**
O17 – H	-73.112	**.001**	-50.521	**.001**	-10.427	**.003**	-60.948	**.001**	62.685	**.001**	12.164	**.001**
O18 – L	-68.090	**.001**	-22.607	**.001**	-25.205	**.001**	-47.812	**.001**	42.885	**.001**	20.278	**.001**
O18 – H	-68.514	**.001**	-25.351	**.001**	-23.413	**.001**	-48.764	**.001**	45.101	**.001**	19.750	**.001**
O19 – L	-76.225	**.001**	-53.971	**.001**	-9.680	**.006**	-63.651	**.001**	66.545	**.001**	12.574	**.001**
O19 – H	-74.860	**.001**	-55.181	**.001**	-6.863	.056	-62.043	**.001**	67.997	**.001**	12.816	**.001**
O20 – L	-71.416	**.001**	-55.592	**.001**	-4.861	.193	-60.453	**.001**	66.555	**.001**	10.963	**.003**
O20 – H	-68.564	**.001**	-56.404	**.001**	-2.885	.445	-59.289	**.001**	65.680	**.001**	9.275	**.014**
O21 – L	-77.485	**.001**	-51.622	**.001**	-11.783	**.001**	-63.405	**.001**	65.702	**.001**	14.080	**.001**
O21 – H	-76.926	**.001**	-49.719	**.001**	-11.545	**.002**	-61.264	**.001**	65.381	**.001**	15.662	**.001**
O22 – L	-67.448	**.001**	-39.146	**.001**	-12.001	**.002**	-51.147	**.001**	55.447	**.001**	16.301	**.001**
O22 – H	-69.804	**.001**	-44.997	**.001**	-9.898	**.007**	-54.894	**.001**	59.906	**.001**	14.910	**.001**
O23 – L	-76.899	**.001**	-46.622	**.001**	-14.158	**.001**	-60.780	**.001**	62.741	**.001**	16.119	**.001**
O23 – H	-75.788	**.001**	-48.542	**.001**	-13.553	**.001**	-62.096	**.001**	62.235	**.001**	13.692	**.001**
O24 – L	-30.019	**.001**	-42.630	**.001**	8.028	**.036**	-34.601	**.001**	38.048	**.001**	-4.582	.227
O24 – H	-27.870	**.001**	-45.057	**.001**	9.566	**.012**	-35.491	**.001**	37.436	**.001**	-7.621	**.042**
O25 – L	-70.742	**.001**	1.127	.765	-46.568	**.001**	-45.441	**.001**	24.174	**.001**	25.301	**.001**
O25 – H	-63.998	**.001**	3.374	.406	-42.939	**.001**	-39.565	**.001**	21.059	**.001**	24.433	**.001**
O26 – L	-70.141	**.001**	-0.289	.942	-43.518	**.001**	-43.807	**.001**	26.623	**.001**	26.334	**.001**
O26 – H	-72.414	**.001**	-6.795	.075	-41.679	**.001**	-48.474	**.001**	30.734	**.001**	23.939	**.001**
O27 – L	-60.755	**.001**	0.273	.941	-36.363	**.001**	-36.091	**.001**	24.392	**.001**	24.665	**.001**
O27 – H	-61.982	**.001**	-7.825	**.038**	-34.081	**.001**	-41.906	**.001**	27.900	**.001**	20.076	**.001**
O28 – L	-76.582	**.001**	-43.327	**.001**	-16.552	**.001**	-59.879	**.001**	60.030	**.001**	16.703	**.001**
O28 – H	-75.080	**.001**	-48.574	**.001**	-15.554	**.001**	-64.128	**.001**	59.527	**.001**	10.953	**.002**

O44 – L	-72.301	**.001**	-42.584	**.001**	-16.105	**.001**	-58.689	**.001**	56.196	**.001**	13.612	**.001**
O44 – H	-69.860	**.001**	-44.705	**.001**	-13.538	**.001**	-58.243	**.001**	56.322	**.001**	11.616	**.002**
O45 – L	-67.109	**.001**	-49.734	**.001**	-6.576	.058	-56.309	**.001**	60.533	**.001**	10.799	**.002**
O45 – H	-60.902	**.001**	-51.351	**.001**	-1.795	.628	-53.146	**.001**	59.107	**.001**	7.756	**.036**
O46 – L	-66.488	**.001**	-18.068	**.001**	-28.796	**.001**	-46.864	**.001**	37.691	**.001**	19.624	**.001**
O46 – H	-64.605	**.001**	-25.385	**.001**	-23.184	**.001**	-48.569	**.001**	41.420	**.001**	16.035	**.001**
O47 – L	-69.715	**.001**	-58.287	**.001**	-4.363	.238	-62.650	**.001**	65.352	**.001**	7.065	.055
O47 – H	-60.643	**.001**	-57.988	**.001**	0.982	.799	-57.006	**.001**	61.626	**.001**	3.638	.342
O48 – L	-76.647	**.001**	-48.221	**.001**	-12.814	**.001**	-61.035	**.001**	63.833	**.001**	15.612	**.001**
O48 – H	-74.185	**.001**	-51.695	**.001**	-9.329	**.009**	-61.024	**.001**	64.856	**.001**	13.161	**.001**
O49 – L	-52.889	**.001**	-38.425	**.001**	-2.817	.450	-41.242	**.001**	50.071	**.001**	11.647	**.002**
O49 – H	-53.466	**.001**	-46.388	**.001**	-0.663	.843	-47.051	**.001**	52.803	**.001**	6.415	.054
O50 – L	-74.734	**.001**	-45.487	**.001**	-14.211	**.001**	-59.698	**.001**	60.523	**.001**	15.036	**.001**
O50 – H	-74.387	**.001**	-44.278	**.001**	-13.789	**.001**	-58.067	**.001**	60.598	**.001**	16.319	**.001**
O51 – L	-74.069	**.001**	-44.828	**.001**	-16.364	**.001**	-61.192	**.001**	57.705	**.001**	12.876	**.001**
O51 – H	-73.174	**.001**	-46.851	**.001**	-11.465	**.001**	-58.316	**.001**	61.709	**.001**	14.858	**.001**
O52 – L	-21.592	**.001**	-31.585	**.001**	5.315	.176	-26.270	**.001**	26.907	**.001**	-4.678	.231
O52 – H	-16.466	**.001**	-34.938	**.001**	12.727	**.002**	-22.211	**.001**	29.193	**.001**	-5.745	.163
O53 – L	-73.844	**.001**	-43.750	**.001**	-15.401	**.001**	-59.151	**.001**	58.442	**.001**	14.692	**.001**
O53 – H	-75.376	**.001**	-44.429	**.001**	-12.736	**.001**	-57.166	**.001**	62.639	**.001**	18.210	**.001**
O54 – L	-77.754	**.001**	-50.906	**.001**	-13.793	**.001**	-64.699	**.001**	63.960	**.001**	13.054	**.001**
O54 – H	-74.471	**.001**	-53.053	**.001**	-10.202	**.006**	-63.255	**.001**	64.270	**.001**	11.216	**.002**
O55 – L	-50.311	**.001**	-46.634	**.001**	-0.183	.961	-46.817	**.001**	50.311	**.001**	50.129	**.001**
O55 – H	-56.170	**.001**	49.472	**.001**	-1.180	.750	-50.652	**.001**	54.990	**.001**	5.517	.135
C1 – L	9.483	**.009**	-14.867	**.001**	12.924	**.001**	-1.943	.593	3.441	.334	-11.426	**.002**
C1 – H	12.394	**.001**	-11.395	**.001**	18.674	**.001**	7.279	**.039**	6.280	.069	-5.115	.141
C2 – L	28.172	**.001**	-2.620	.419	24.261	**.001**	21.641	**.001**	-3.911	.226	-6.531	**.045**
C2 – H	25.254	**.001**	-2.392	.474	19.132	**.001**	16.740	**.001**	-6.122	.066	-8.514	**.011**
C3 – L	22.757	**.001**	0.880	.788	17.138	**.001**	18.018	**.001**	-5.619	.086	-4.738	.150
C3 – H	24.678	**.001**	0.173	.959	16.369	**.001**	16.542	**.001**	-8.309	**.013**	-8.136	**.015**

C4 – L	27.362	**.001**	7.842	**.015**	16.966	**.001**	24.808	**.001**	-10.396	**.001**	-2.554	.428
C4 – H	31.504	**.001**	7.448	**.021**	17.402	**.001**	24.850	**.001**	-14.103	**.001**	-6.654	**.039**
C5 – L	27.235	**.001**	5.669	.087	15.556	**.001**	21.225	**.001**	-11.679	**.001**	-6.010	.071
C5 – H	21.134	**.001**	2.394	.470	16.808	**.001**	19.202	**.001**	-4.326	.190	-1.932	.561
C6 – L	28.775	**.001**	5.736	.087	18.313	**.001**	24.049	**.001**	-10.462	**.002**	-4.726	.159
C6 – H	27.587	**.001**	1.989	.546	17.494	**.001**	19.483	**.001**	-10.093	**.002**	-8.104	**.015**
C7 – L	9.713	**.006**	-1.606	.641	8.321	**.017**	6.715	.056	-1.392	.685	-2.998	.386
C7 – H	10.643	**.002**	-2.806	.402	10.514	**.002**	7.709	**.024**	-0.129	.969	-2.934	.382
C8 – L	18.986	**.001**	-3.220	.352	18.226	**.001**	15.006	**.001**	-0.760	.826	-3.980	.252
C8 – H	16.871	**.001**	-4.433	.189	14.802	**.001**	10.369	**.003**	-2.069	.538	-6.502	.055
C9 – L	20.697	**.001**	2.821	.405	13.291	**.001**	16.113	**.001**	-7.405	**.029**	-4.584	.178
C9 – H	28.646	**.001**	1.320	.675	16.515	**.001**	17.834	**.001**	-12.131	**.001**	-10.812	**.001**
C10 – L	21.121	**.001**	2.723	.388	14.909	**.001**	17.632	**.001**	-6.212	**.049**	-3.489	.270
C10 – H	22.118	**.001**	0.246	.942	16.450	**.001**	16.696	**.001**	-5.667	.093	-5.422	.110
C11 – L	-4.020	.266	-24.102	**.001**	11.537	**.001**	-12.565	**.001**	15.557	**.001**	-8.545	**.017**
C11 – H	-5.808	.097	-28.997	**.001**	13.750	**.001**	-15.247	**.001**	19.558	**.001**	-9.439	**.007**
C12 – L	15.626	**.001**	-3.091	.346	14.717	**.001**	11.626	**.001**	-0.909	.781	-4.000	.224
C12 – H	13.509	**.001**	-7.642	**.022**	14.095	**.001**	6.453	.057	0.586	.860	-7.055	**.035**
C13 – L	26.896	**.001**	5.612	.109	16.239	**.001**	21.851	**.001**	-10.657	**.002**	-5.045	.151
C13 – H	30.100	**.001**	1.809	.563	18.740	**.001**	20.549	**.001**	-11.360	**.001**	-9.551	**.003**
C14 – L	26.455	**.001**	1.673	.622	17.637	**.001**	19.309	**.001**	-8.819	**.010**	-7.146	**.036**
C14 – H	24.701	**.001**	-2.547	.427	17.043	**.001**	14.496	**.001**	-7.658	**.017**	-10.205	**.002**
C15 – L	19.947	**.001**	21.421	**.001**	1.285	.722	22.706	**.001**	-18.662	**.001**	2.759	.441
C15 – H	15.371	**.001**	15.478	**.001**	0.215	.950	15.692	**.001**	-15.157	**.001**	0.321	.925
C16 – L	12.817	**.001**	3.620	.295	7.030	**.045**	10.651	**.003**	-5.786	.094	-2.166	.532
C16 – H	15.208	**.001**	6.605	.052	8.383	**.015**	14.988	**.001**	-6.825	**.044**	-0.220	.948
C17 – L	24.620	**.001**	5.274	.102	13.538	**.001**	18.811	**.001**	-11.082	**.001**	-5.809	.073
C17 – H	18.754	**.001**	3.609	.279	9.670	**.004**	13.279	**.001**	-9.084	**.007**	-5.474	.102
C18 – L	17.820	**.001**	14.541	**.001**	4.369	.203	18.910	**.001**	-13.451	**.001**	1.090	.749
C18 – H	21.685	**.001**	12.826	**.001**	5.738	.087	18.564	**.001**	-15.947	**.001**	-3.121	.348

C19 – L	13.619	**.001**	-5.719	.091	13.303	**.001**	7.584	**.028**	-0.316	.925	-6.035	.076
C19 – H	15.642	**.001**	-5.482	.086	16.867	**.001**	11.384	**.001**	1.225	.699	-4.257	.183
C20 – L	24.753	**.001**	10.646	**.001**	11.276	**.001**	21.922	**.001**	-13.477	**.001**	-2.831	.380
C20 – H	28.692	**.001**	12.651	**.001**	13.068	**.001**	25.719	**.001**	-15.624	**.001**	-2.973	.367
C21 – L	-5.681	.124	-14.946	**.001**	7.102	.054	-7.844	**.034**	12.782	**.001**	-2.163	.553
C21 – H	2.873	.392	-15.627	**.001**	13.320	**.001**	-2.307	.493	10.448	**.002**	-5.179	.119
C22 – L	18.416	**.001**	-2.557	.440	16.263	**.001**	13.706	**.001**	-2.153	.514	-4.710	.157
C22 – H	21.309	**.001**	3.974	.229	13.151	**.001**	17.125	**.001**	-8.158	**.014**	-4.184	.207
C23 – L	8.926	**.013**	-10.561	**.003**	14.302	**.001**	3.741	.298	5.376	.127	-5.186	.144
C23 – H	16.562	**.001**	-13.008	**.001**	16.612	**.001**	3.604	.292	0.050	.988	-12.958	**.001**
C24 – L	10.686	**.003**	-14.492	**.001**	13.560	**.001**	-0.932	.798	2.875	.421	-11.618	**.001**
C24 – H	12.409	**.001**	-15.196	**.001**	19.413	**.001**	4.217	.219	7.005	**.038**	-8.191	**.016**
C25 – L	22.751	**.001**	0.861	.798	18.050	**.001**	18.911	**.001**	-4.701	.163	-3.840	.257
C25 – H	24.789	**.001**	-1.486	.654	17.002	**.001**	15.516	**.001**	-7.786	**.019**	-9.273	**.006**
C26 – L	15.979	**.001**	-4.970	.146	18.214	**.001**	13.244	**.001**	2.235	.512	-2.735	.425
C26 – H	11.291	**.001**	-8.655	**.012**	16.976	**.001**	8.321	**.018**	5.685	.098	-2.970	.390
C27 – L	10.937	**.004**	23.132	**.001**	-4.759	.203	18.372	**.001**	-15.697	**.001**	7.435	**.046**
C27 – H	13.713	**.001**	21.180	**.001**	-4.212	.245	16.968	**.001**	-17.924	**.001**	3.256	.365
C28 – L	16.089	**.001**	14.999	**.001**	2.405	.500	17.404	**.001**	-13.684	**.001**	1.315	.710
C28 – H	14.770	**.001**	15.362	**.001**	4.683	.177	20.045	**.001**	-10.086	**.003**	5.275	.126
C29 – L	26.395	**.001**	30.252	**.001**	2.975	.379	33.227	**.001**	-23.421	**.001**	6.832	**.042**
C29 – H	22.144	**.001**	25.958	**.001**	2.158	.536	28.116	**.001**	-19.986	**.001**	5.972	.085
C30 – L	11.531	**.001**	-17.600	**.001**	19.077	**.001**	1.477	.681	7.546	**.033**	-10.054	**.005**
C30 – H	10.298	**.005**	-20.146	**.001**	22.436	**.001**	2.290	.534	12.138	**.001**	-8.008	**.028**
C31 – L	8.493	**.017**	-18.697	**.001**	17.476	**.001**	-1.222	.731	8.982	**.010**	-9.715	**.006**
C31 – H	11.979	**.001**	-19.639	**.001**	24.123	**.001**	4.484	.225	12.144	**.001**	-7.495	**.040**
C32 – L	25.828	**.001**	-7.563	**.023**	21.376	**.001**	13.813	**.001**	-4.452	.179	-12.015	**.001**
C32 – H	28.228	**.001**	-7.785	**.024**	25.385	**.001**	17.600	**.001**	-2.843	.407	-10.628	**.002**
C33 – L	24.504	**.001**	5.254	.101	12.839	**.001**	18.093	**.001**	-11.665	**.001**	-6.411	**.047**
C33 – H	24.809	**.001**	8.507	**.007**	12.651	**.001**	21.158	**.001**	-12.158	**.001**	-3.651	.243

C34 – L	9.944	**.004**	4.065	.226	8.103	**.017**	12.167	**.001**	-1.841	.581	2.224	.508
C34 – H	5.287	.116	7.112	**.033**	1.153	.731	8.265	**.015**	-4.134	.211	2.978	.371
C35 – L	2.567	.470	26.090	**.001**	-12.852	**.001**	13.238	**.001**	-15.419	**.001**	10.671	**.003**
C35 – H	-3.129	.364	20.679	**.001**	-14.714	**.001**	5.966	.085	-11.585	**.001**	9.094	**.008**
C36 – L	27.398	**.001**	2.939	.354	17.257	**.001**	20.196	**.001**	-10.141	**.001**	-7.202	**.024**
C36 – H	26.601	**.001**	-0.560	.863	17.917	**.001**	17.357	**.001**	-8.684	**.008**	-9.244	**.005**
C37 – L	8.973	**.009**	3.684	.278	6.629	.054	10.313	**.003**	-2.344	.488	1.340	.694
C37 – H	10.974	**.002**	-1.829	.594	6.672	.055	4.843	.165	-4.302	.208	-6.130	.075
C38 – L	8.439	**.021**	-17.799	**.001**	17.885	**.001**	0.087	.981	9.447	**.009**	-8.352	**.021**
C38 – H	12.828	**.001**	-13.625	**.001**	20.301	**.001**	6.676	.069	7.473	**.038**	-6.152	.090
C39 – L	25.359	**.001**	-2.500	.441	18.073	**.001**	15.573	**.001**	-7.286	**.025**	-9.786	**.003**
C39 – H	27.094	**.001**	-3.820	.261	22.025	**.001**	18.205	**.001**	-5.069	.135	-8.889	**.010**
C40 – L	31.216	**.001**	9.586	**.004**	17.328	**.001**	26.914	**.001**	-13.888	**.001**	-4.302	.194
C40 – H	35.652	**.001**	12.601	**.001**	16.684	**.001**	29.286	**.001**	-18.968	**.001**	-6.366	.054
C41 – L	24.811	**.001**	4.086	.242	17.387	**.001**	21.473	**.001**	-7.424	**.033**	-3.338	.341
C41 – H	25.225	**.001**	2.100	.510	16.512	**.001**	18.611	**.001**	-8.714	**.006**	-6.614	**.039**
C42 – L	29.520	**.001**	16.059	**.001**	12.103	**.001**	28.162	**.001**	-17.417	**.001**	-1.358	.688
C42 – H	28.209	**.001**	11.059	**.001**	16.180	**.001**	27.239	**.001**	-12.029	**.001**	-0.970	.765
C43 – L	11.780	**.001**	-6.599	.057	13.602	**.001**	7.003	**.047**	1.822	.597	-4.777	.168
C43 – H	23.614	**.001**	-7.012	**.031**	21.712	**.001**	14.700	**.001**	-1.902	.557	-8.914	**.007**
C44 – L	26.138	**.001**	9.610	**.003**	13.168	**.001**	22.778	**.001**	-13.150	**.001**	-3.540	.272
C44 – H	31.705	**.001**	1.204	.693	20.059	**.001**	21.263	**.001**	-11.647	**.001**	-10.443	**.001**
C45 – L	11.211	**.002**	-1.858	.592	6.576	.061	4.717	.182	-4.636	.181	-6.494	.063
C45 – H	8.778	**.012**	-2.940	.391	8.281	**.017**	5.341	.126	-0.497	.884	-3.437	.318
C46 – L	22.193	**.001**	-1.707	.620	16.410	**.001**	14.703	**.001**	-5.783	.092	-7.490	**.031**
C46 – H	21.951	**.001**	-8.643	**.011**	20.690	**.001**	12.046	**.001**	-1.261	.708	-9.905	**.004**
C47 – L	22.998	**.001**	-3.475	.296	19.653	**.001**	16.178	**.001**	-3.345	.313	-6.819	**.042**
C47 – H	24.972	**.001**	-5.987	.089	20.459	**.001**	14.472	**.001**	-4.513	.198	-10.500	**.003**
C48 – L	24.171	**.001**	12.610	**.001**	10.390	**.002**	23.000	**.001**	-13.781	**.001**	-1.171	.724
C48 – H	26.406	**.001**	11.471	**.001**	12.108	**.001**	23.578	**.001**	-14.298	**.001**	-2.827	.402

C49 – L	37.577	**.001**	27.645	**.001**	10.174	**.005**	37.819	**.001**	-27.404	**.001**	0.241	.946
C49 – H	39.314	**.001**	25.414	**.001**	12.984	**.001**	38.398	**.001**	-26.329	**.001**	-0.915	.784
C50 – L	16.885	**.001**	13.256	**.001**	8.660	**.012**	21.916	**.001**	-8.225	**.016**	5.031	.141
C50 – H	21.134	**.001**	10.628	**.001**	9.824	**.003**	20.452	**.001**	-11.310	**.001**	-0.682	.833
C51 – L	1.849	.606	13.567	**.001**	-4.102	.252	9.465	**.009**	-5.951	.092	7.616	**.033**
C51 – H	5.001	.161	13.612	**.001**	-4.519	.204	9.094	**.011**	-9.519	**.007**	4.093	.246
C52 – L	-5.822	.095	-13.826	**.001**	7.928	**.023**	-5.898	.092	13.749	**.001**	-0.076	.982
C52 – H	5.195	.124	-11.991	**.001**	10.552	**.002**	-1.438	.670	5.357	.106	-6.634	**.047**
C53 – L	12.759	**.001**	-7.948	**.022**	16.115	**.001**	8.167	**.021**	3.356	.332	-4.592	.187
C53 – H	17.757	**.001**	-9.655	**.004**	19.580	**.001**	9.925	**.004**	1.823	.588	-7.832	**.021**
C54 – L	24.571	**.001**	9.101	**.006**	13.896	**.001**	22.997	**.001**	-10.675	**.001**	-1.574	.634
C54 – H	27.284	**.001**	9.065	**.004**	14.837	**.001**	23.902	**.001**	-12.447	**.001**	-3.381	.284
C55 – L	13.135	**.001**	4.576	.201	8.896	**.014**	13.472	**.001**	-4.238	.235	0.338	.925
C55 – H	14.197	**.001**	4.237	.201	9.377	**.005**	13.613	**.001**	-4.821	.145	-0.584	.860
P1 – L	30.995	**.001**	22.053	**.001**	7.133	**.033**	29.186	**.001**	-23.862	**.001**	-1.809	.585
P1 – H	34.633	**.001**	14.098	**.001**	15.216	**.001**	29.314	**.001**	-19.417	**.001**	-5.319	.085
P2 – L	50.011	**.001**	36.986	**.001**	10.426	**.004**	47.412	**.001**	-39.585	**.001**	-2.599	.461
P2 – H	48.595	**.001**	33.956	**.001**	12.143	**.001**	46.099	**.001**	-36.452	**.001**	-2.496	.488
P3 – L	37.252	**.001**	25.117	**.001**	10.694	**.001**	35.812	**.001**	-26.558	**.001**	-1.441	.662
P3 – H	37.823	**.001**	23.927	**.001**	12.155	**.001**	36.082	**.001**	-25.668	**.001**	-1.741	.583
P4 – L	39.530	**.001**	23.959	**.001**	12.767	**.001**	36.726	**.001**	-26.762	**.001**	-2.804	.395
P4 – H	39.131	**.001**	21.841	**.001**	13.769	**.001**	35.609	**.001**	-25.362	**.001**	-3.521	.309
P5 – L	32.177	**.001**	26.097	**.001**	6.491	.075	32.588	**.001**	-25.686	**.001**	0.411	.909
P5 – H	36.381	**.001**	22.816	**.001**	11.084	**.002**	33.899	**.001**	-25.297	**.001**	-2.481	.481
P6 – L	23.798	**.001**	17.335	**.001**	8.969	**.010**	26.303	**.001**	-14.830	**.001**	2.505	.465
P6 – H	28.355	**.001**	17.847	**.001**	11.515	**.001**	29.363	**.001**	-16.839	**.001**	1.008	.762
P7 – L	-2.001	.609	8.987	**.021**	5.256	.179	14.243	**.001**	7.256	.060	16.244	**.001**
P7 – H	6.615	.082	0.544	.884	9.596	**.012**	10.141	**.008**	2.981	.424	3.526	.348
P8 – L	-14.966	**.001**	-32.038	**.001**	10.460	**.006**	-21.578	**.001**	25.427	**.001**	-6.611	.076
P8 – H	-18.515	**.001**	-39.764	**.001**	13.315	**.001**	-26.448	**.001**	31.831	**.001**	-7.933	**.043**

P9 – L	-36.257	**.001**	-16.980	**.001**	-8.655	**.024**	-25.636	**.001**	27.602	**.001**	10.622	**.005**
P9 – H	-40.005	**.001**	-18.952	**.001**	-5.792	.111	-24.744	**.001**	34.213	**.001**	15.261	**.001**
P10 – L	-39.234	**.001**	-35.208	**.001**	-1.480	.680	-36.688	**.001**	37.754	**.001**	2.546	.476
P10 – H	-33.742	**.001**	-40.594	**.001**	2.367	.523	-38.227	**.001**	36.109	**.001**	-4.485	.223
P11 – L	38.094	**.001**	31.703	**.001**	9.399	**.005**	41.102	**.001**	-28.695	**.001**	3.007	.362
P11 – H	40.550	**.001**	20.998	**.001**	13.110	**.001**	34.108	**.001**	-27.440	**.001**	-6.442	.056
P12 – L	29.935	**.001**	15.854	**.001**	11.783	**.001**	27.637	**.001**	-18.152	**.001**	-2.298	.505
P12 – H	34.530	**.001**	8.346	**.011**	20.306	**.001**	28.653	**.001**	-14.224	**.001**	-5.877	.075
P13 – L	40.591	**.001**	29.725	**.001**	9.654	**.005**	39.379	**.001**	-30.937	**.001**	-1.212	.719
P13 – H	38.898	**.001**	27.294	**.001**	10.345	**.003**	37.639	**.001**	-28.553	**.001**	-1.259	.711
P14 – L	35.375	**.001**	26.491	**.001**	9.534	**.006**	36.025	**.001**	-25.841	**.001**	0.650	.849
P14 – H	37.396	**.001**	26.811	**.001**	7.700	**.027**	34.511	**.001**	-29.696	**.001**	-2.885	.403
P15 – L	30.128	**.001**	5.755	.070	19.249	**.001**	25.004	**.001**	-10.879	**.001**	-5.124	.108
P15 – H	30.615	**.001**	3.115	.330	20.006	**.001**	23.121	**.001**	-10.609	**.001**	-7.494	**.020**
P16 – L	31.308	**.001**	21.398	**.001**	11.026	**.001**	32.424	**.001**	-20.282	**.001**	1.116	.729
P16 – H	32.493	**.001**	19.183	**.001**	11.218	**.001**	30.401	**.001**	-21.274	**.001**	-2.092	.514
P17 – L	37.754	**.001**	31.054	**.001**	7.076	**.043**	38.129	**.001**	-30.678	**.001**	0.376	.913
P17 – H	39.594	**.001**	27.362	**.001**	8.612	**.012**	35.974	**.001**	-30.981	**.001**	-3.619	.284
P18 – L	27.140	**.001**	-7.189	**.034**	24.819	**.001**	17.630	**.001**	-2.321	.491	-9.510	**.005**
P18 – H	20.636	**.001**	-10.257	**.003**	22.453	**.001**	12.197	**.001**	1.817	.591	-8.439	**.014**
P19 – L	32.635	**.001**	25.292	**.001**	6.247	.070	31.539	**.001**	-26.387	**.001**	-1.096	.749
P19 – H	32.746	**.001**	21.441	**.001**	10.957	**.002**	32.397	**.001**	-21.790	**.001**	-0.349	.920
P20 – L	29.093	**.001**	13.350	**.001**	13.874	**.001**	27.224	**.001**	-15.219	**.001**	-1.869	.574
P20 – H	32.618	**.001**	6.580	**.046**	18.746	**.001**	25.326	**.001**	-13.872	**.001**	-7.292	**.027**
P21 – L	33.964	**.001**	24.176	**.001**	10.430	**.001**	34.606	**.001**	-23.534	**.001**	0.642	.842
P21 – H	33.130	**.001**	25.053	**.001**	9.203	**.005**	34.256	**.001**	-23.927	**.001**	1.125	.730
P22 – L	35.454	**.001**	20.571	**.001**	11.021	**.001**	31.592	**.001**	-24.433	**.001**	-3.862	.248
P22 – H	29.651	**.001**	19.346	**.001**	7.843	**.015**	27.188	**.001**	-21.809	**.001**	-2.463	.439
P23 – L	-39.800	**.001**	0.491	.897	-25.562	**.001**	-25.072	**.001**	14.238	**.001**	14.729	**.001**
P23 – H	-44.605	**.001**	-5.013	.190	-25.486	**.001**	-30.499	**.001**	19.118	**.001**	14.105	**.001**

P24 – L	38.371	**.001**	29.538	**.001**	7.494	**.035**	37.032	**.001**	-30.877	**.001**	-1.339	.703
P24 – H	41.662	**.001**	28.956	**.001**	11.447	**.001**	40.403	**.001**	-30.215	**.001**	-1.259	.711
P25 – L	30.940	**.001**	19.413	**.001**	11.835	**.001**	31.248	**.001**	-19.105	**.001**	0.308	.926
P25 – H	24.299	**.001**	14.985	**.001**	9.359	**.006**	24.344	**.001**	-14.940	**.001**	0.045	.989
P26 – L	28.349	**.001**	8.447	**.011**	17.136	**.001**	25.582	**.001**	-11.214	**.001**	-2.767	.404
P26 – H	24.083	**.001**	10.519	**.002**	12.531	**.001**	23.050	**.001**	-11.552	**.001**	-1.033	.762
P27 – L	40.942	**.001**	31.968	**.001**	9.438	**.006**	41.406	**.001**	-31.504	**.001**	0.464	.890
P27 – H	38.370	**.001**	23.798	**.001**	12.187	**.001**	35.984	**.001**	-26.183	**.001**	-2.385	.457
P28 – L	33.943	**.001**	21.840	**.001**	9.404	**.005**	31.243	**.001**	-24.539	**.001**	-2.700	.418
P28 – H	37.725	**.001**	20.322	**.001**	13.856	**.001**	34.178	**.001**	-23.869	**.001**	-3.547	.274
P29 – L	-25.175	**.001**	-8.334	**.018**	-9.346	**.008**	-17.680	**.001**	15.829	**.001**	7.495	**.033**
P29 – H	-19.475	**.001**	-9.314	**.009**	-1.307	.717	-10.621	**.004**	18.168	**.001**	8.854	**.014**
P30 – L	22.708	**.001**	12.954	**.001**	10.738	**.001**	23.692	**.001**	-11.971	**.001**	0.983	.766
P30 – H	20.134	**.001**	10.250	**.003**	8.355	**.015**	18.606	**.001**	-11.959	**.001**	-1.709	.615
P31 – L	42.675	**.001**	30.035	**.001**	10.889	**.002**	40.923	**.001**	-31.787	**.001**	-1.752	.609
P31 – H	39.993	**.001**	23.566	**.001**	14.833	**.001**	38.398	**.001**	-25.161	**.001**	-1.595	.644
P32 – L	23.713	**.001**	-0.347	.917	17.043	**.001**	16.696	**.001**	-6.671	**.045**	-7.018	**.036**
P32 – H	22.669	**.001**	0.299	.930	17.910	**.001**	18.208	**.001**	-4.759	.158	-4.461	.189
P33 – L	-21.884	**.001**	-24.474	**.001**	1.679	.638	-22.795	**.001**	23.563	**.001**	-0.911	.797
P33 – H	-17.303	**.001**	-27.294	**.001**	9.244	**.011**	-18.050	**.001**	26.546	**.001**	-0.747	.836
P34 – L	35.526	**.001**	22.705	**.001**	10.935	**.001**	33.640	**.001**	-24.591	**.001**	-1.886	.554
P34 – H	34.872	**.001**	18.732	**.001**	13.274	**.001**	32.006	**.001**	-21.598	**.001**	-2.866	.387
P35 – L	3.320	.390	-13.640	**.001**	13.820	**.001**	0.180	.963	10.500	**.006**	-3.140	.411
P35 – H	9.613	**.007**	-27.352	**.001**	25.925	**.001**	-1.428	.687	16.312	**.001**	-11.040	**.002**
P36 – L	-62.377	**.001**	-72.367	**.001**	3.837	.324	-68.530	**.001**	66.214	**.001**	-6.153	.112
P36 – H	-63.338	**.001**	-72.199	**.001**	5.339	.195	-66.861	**.001**	68.677	**.001**	-3.522	.389
P37 – L	13.819	**.001**	38.081	**.001**	-12.905	**.002**	25.176	**.001**	-26.724	**.001**	11.357	**.006**
P37 – H	8.809	**.030**	31.345	**.001**	-10.440	**.010**	20.905	**.001**	-19.249	**.001**	12.096	**.003**
P38 – L	37.381	**.001**	23.984	**.001**	14.376	**.001**	38.359	**.001**	-23.005	**.001**	0.979	.775
P38 – H	40.415	**.001**	23.745	**.001**	13.574	**.001**	37.319	**.001**	-26.841	**.001**	-3.096	.356

P39 – L	39.692	**.001**	34.935	**.001**	5.468	.111	40.403	**.001**	-34.225	**.001**	0.711	.834
P39 – H	39.008	**.001**	28.994	**.001**	9.176	**.012**	38.169	**.001**	-29.833	**.001**	-0.839	.817
P40 – L	36.918	**.001**	24.597	**.001**	12.571	**.001**	37.168	**.001**	-24.347	**.001**	0.250	.944
P40 – H	37.840	**.001**	20.608	**.001**	13.777	**.001**	34.385	**.001**	-24.063	**.001**	-3.455	.296
P41 – L	37.064	**.001**	22.966	**.001**	9.962	**.005**	32.929	**.001**	-27.102	**.001**	-4.135	.232
P41 – H	36.163	**.001**	19.429	**.001**	14.938	**.001**	34.367	**.001**	-21.225	**.001**	-1.796	.600
P42 – L	38.780	**.001**	21.040	**.001**	15.056	**.001**	36.096	**.001**	-23.724	**.001**	-2.684	.433
P42 – H	40.104	**.001**	16.269	**.001**	19.050	**.001**	35.319	**.001**	-21.054	**.001**	-4.785	.138
P43 – L	37.554	**.001**	28.809	**.001**	9.109	**.005**	37.918	**.001**	-28.445	**.001**	0.364	.910
P43 – H	41.363	**.001**	20.541	**.001**	14.426	**.001**	34.966	**.001**	-26.938	**.001**	-6.397	.070
P44 – L	33.289	**.001**	18.735	**.001**	13.545	**.001**	32.280	**.001**	-19.744	**.001**	-1.009	.761
P44 – H	37.311	**.001**	18.538	**.001**	17.085	**.001**	35.623	**.001**	-20.226	**.001**	-1.688	.589
P45 – L	36.094	**.001**	25.764	**.001**	9.204	**.009**	34.968	**.001**	-26.890	**.001**	-1.126	.746
P45 – H	36.904	**.001**	17.837	**.001**	14.787	**.001**	32.623	**.001**	-22.117	**.001**	-4.280	.193
P46 – L	34.217	**.001**	23.579	**.001**	7.602	**.026**	31.182	**.001**	-26.615	**.001**	-3.035	.368
P46 – H	33.608	**.001**	19.151	**.001**	10.231	**.003**	29.382	**.001**	-23.377	**.001**	-4.226	.219
P47 – L	25.528	**.001**	2.506	.451	16.765	**.001**	19.271	**.001**	-8.763	**.009**	-6.257	.062
P47 – H	24.346	**.001**	-4.255	.213	20.274	**.001**	16.019	**.001**	-4.072	.232	-8.326	**.016**
P48 – L	44.563	**.001**	34.458	**.001**	8.120	**.020**	42.578	**.001**	-36.443	**.001**	-1.985	.565
P48 – H	41.096	**.001**	27.242	**.001**	12.924	**.001**	40.167	**.001**	-28.172	**.001**	-0.930	.793
P49 – L	34.582	**.001**	23.592	**.001**	8.500	**.012**	32.092	**.001**	-26.082	**.001**	-2.490	.455
P49 – H	31.155	**.001**	23.160	**.001**	11.438	**.001**	34.598	**.001**	-19.717	**.001**	3.443	.321
P50 – L	0.091	.979	-9.644	**.006**	10.593	**.003**	0.949	.788	10.502	**.003**	0.858	.806
P50 – H	5.043	.146	-14.211	**.001**	17.654	**.001**	3.443	.322	12.611	**.001**	-1.600	.640
P51 – L	-2.021	.569	-4.653	.184	3.867	.274	-0.786	.825	5.888	.092	1.235	.725
P51 – H	0.376	.914	-5.823	.089	6.026	.082	0.203	.954	5.650	.098	-0.174	.960
P52 – L	39.161	**.001**	28.324	**.001**	9.461	**.007**	37.786	**.001**	-29.699	**.001**	-1.375	.693
P52 – H	42.659	**.001**	23.250	**.001**	13.653	**.001**	36.904	**.001**	-29.005	**.001**	-5.755	.093
P53 – L	-51.113	**.002**	-26.573	**.001**	-10.633	**.001**	-37.206	**.001**	40.480	**.001**	13.907	**.001**
P53 – H	-51.171	**.019**	-30.442	**.001**	-8.071	**.001**	-38.513	**.001**	43.100	**.001**	12.658	**.001**

P54 – L	17.133	**.001**	-16.696	**.001**	20.667	**.001**	3.971	.269	3.534	.316	-13.162	**.001**
P54 – H	16.319	**.001**	-17.236	**.001**	22.968	**.001**	5.732	.105	6.649	.055	-10.586	**.003**
P55 – L	-5.277	.157	-17.704	**.001**	10.097	**.007**	-7.607	**.042**	15.374	**.001**	-2.330	.527
P55 – H	-1.641	.654	-20.089	**.001**	12.719	**.001**	-7.371	**.045**	14.360	**.001**	-5.729	.114
P56 – L	43.091	**.001**	31.865	**.001**	9.921	**.006**	41.786	**.001**	-33.170	**.001**	-1.305	.711
P56 – H	43.412	**.001**	33.283	**.001**	10.436	**.003**	43.719	**.001**	-32.975	**.001**	0.308	.929
P57 – L	9.507	**.008**	-4.437	.210	9.986	**.006**	5.549	.124	0.479	.892	-3.958	.265
P57 – H	13.617	**.001**	-10.869	**.001**	15.131	**.001**	4.262	.213	1.514	.651	-9.355	**.006**
P58 – L	13.733	**.001**	-8.788	**.011**	18.116	**.001**	9.327	**.008**	4.382	.204	-4.406	.204
P58 – H	15.994	**.001**	-12.518	**.001**	21.460	**.001**	8.942	**.009**	5.466	.102	-7.052	**.036**
P59 – L	20.021	**.001**	-3.559	.310	17.179	**.001**	13.619	**.001**	-2.842	.416	-6.402	.069
P59 – H	19.997	**.001**	-3.788	.253	17.142	**.001**	13.354	**.001**	-2.855	.387	-6.643	**.046**
P60 – L	30.018	**.001**	17.884	**.001**	13.760	**.001**	31.644	**.001**	-16.259	**.001**	1.626	.617
P60 – H	31.776	**.001**	12.166	**.001**	16.708	**.001**	28.873	**.001**	-15.069	**.001**	-2.903	.387
P61 – L	34.829	**.001**	37.199	**.001**	1.705	.625	38.903	**.001**	-33.124	**.001**	4.074	.239
P61 – H	37.592	**.001**	28.046	**.001**	6.227	.088	34.273	**.001**	-31.265	**.001**	-3.319	.358
P62 – L	31.906	**.001**	23.741	**.001**	9.481	**.008**	33.222	**.001**	-22.425	**.001**	1.316	.709
P62 – H	37.127	**.001**	24.142	**.001**	11.235	**.001**	35.377	**.001**	-25.892	**.001**	-1.751	.605
P63 – L	-17.197	**.001**	-3.904	.269	-4.916	.169	-8.820	**.015**	12.282	**.001**	8.377	**.019**
P63 – H	-8.104	**.017**	-2.792	.403	0.083	.980	-2.709	.425	8.187	**.014**	5.395	.108
P64 – L	31.932	**.001**	9.288	**.004**	17.527	**.001**	26.815	**.001**	-14.406	**.001**	-5.117	.112
P64 – H	30.934	**.001**	7.480	**.024**	19.763	**.001**	27.243	**.001**	-11.171	**.001**	-3.691	.264
P65 – L	36.162	**.001**	22.069	**.001**	11.924	**.001**	33.993	**.001**	-24.238	**.001**	-2.169	.521
P65 – H	35.379	**.001**	13.757	**.001**	15.821	**.001**	29.578	**.001**	-19.558	**.001**	-5.801	.081
P66 – L	38.214	**.001**	16.494	**.001**	13.832	**.001**	30.326	**.001**	-24.382	**.001**	-7.888	**.021**
P66 – H	35.571	**.001**	14.748	**.001**	15.393	**.001**	30.141	**.001**	-20.178	**.001**	-5.430	.105
P67 – L	18.375	**.001**	-1.966	.545	19.398	**.001**	17.432	**.001**	1.023	.752	-0.943	.772
P67 – H	23.755	**.001**	-4.094	**.001**	20.071	**.001**	15.977	**.001**	-3.684	**.001**	-7.778	**.001**
P68 – L	38.502	**.001**	24.062	**.001**	10.616	**.001**	34.678	**.001**	-27.886	**.001**	-3.824	.245
P68 – H	35.947	**.001**	20.881	**.001**	10.776	**.001**	31.657	**.001**	-25.171	**.001**	-4.291	.181

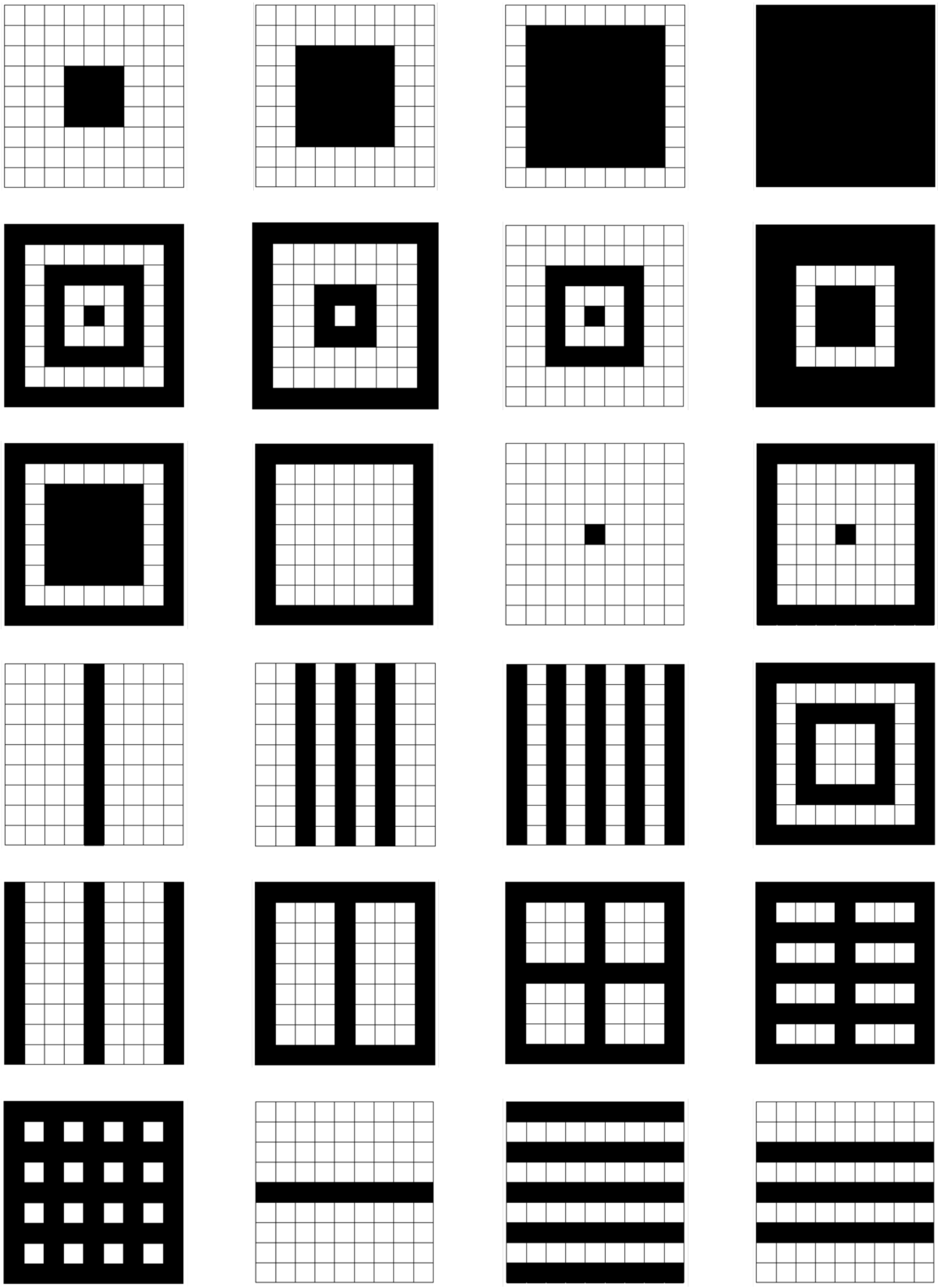
P69 – L	37.064	**.001**	31.586	**.001**	8.702	**.015**	40.288	**.001**	-28.362	**.001**	3.225	.364
P69 – H	36.618	**.001**	24.723	**.001**	11.366	**.001**	36.089	**.001**	-25.252	**.001**	-0.528	.874
P70 – L	33.268	**.001**	9.957	**.005**	18.229	**.001**	28.187	**.001**	-15.038	**.001**	-5.081	.152
P70 – H	26.430	**.001**	11.281	**.001**	15.443	**.001**	26.723	**.001**	-10.987	**.002**	0.294	.932

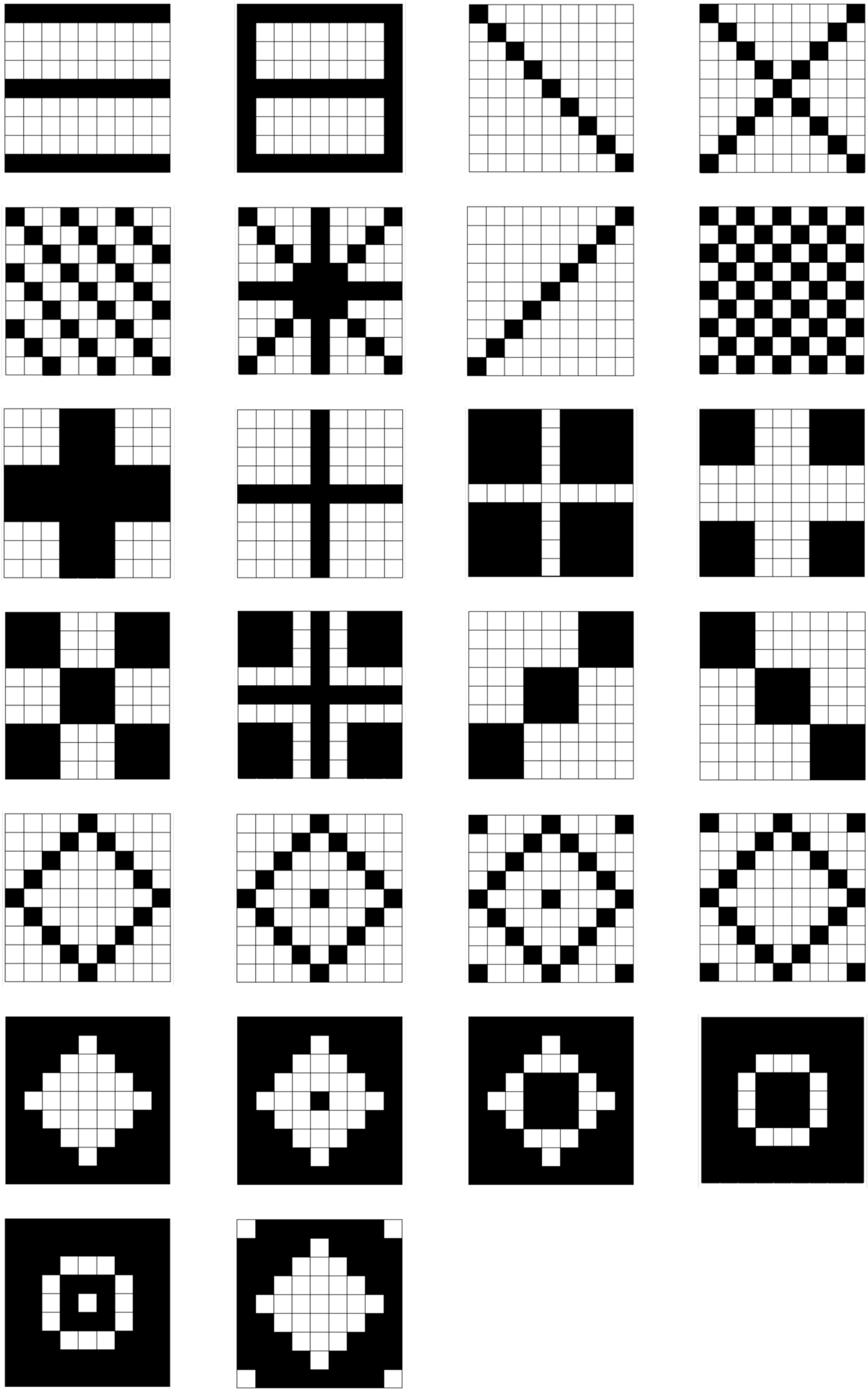
Note. The first part of the labels, which includes a letter (i.e., O, C, or P) and a number, is only for identification. R = Randomness, NR = Non-Randomness, C = Complexity, S = Simplicity, L = Low, and H = High. In bold, *p*-values < .05.

Appendix C – Stimuli for Studies 2A-6

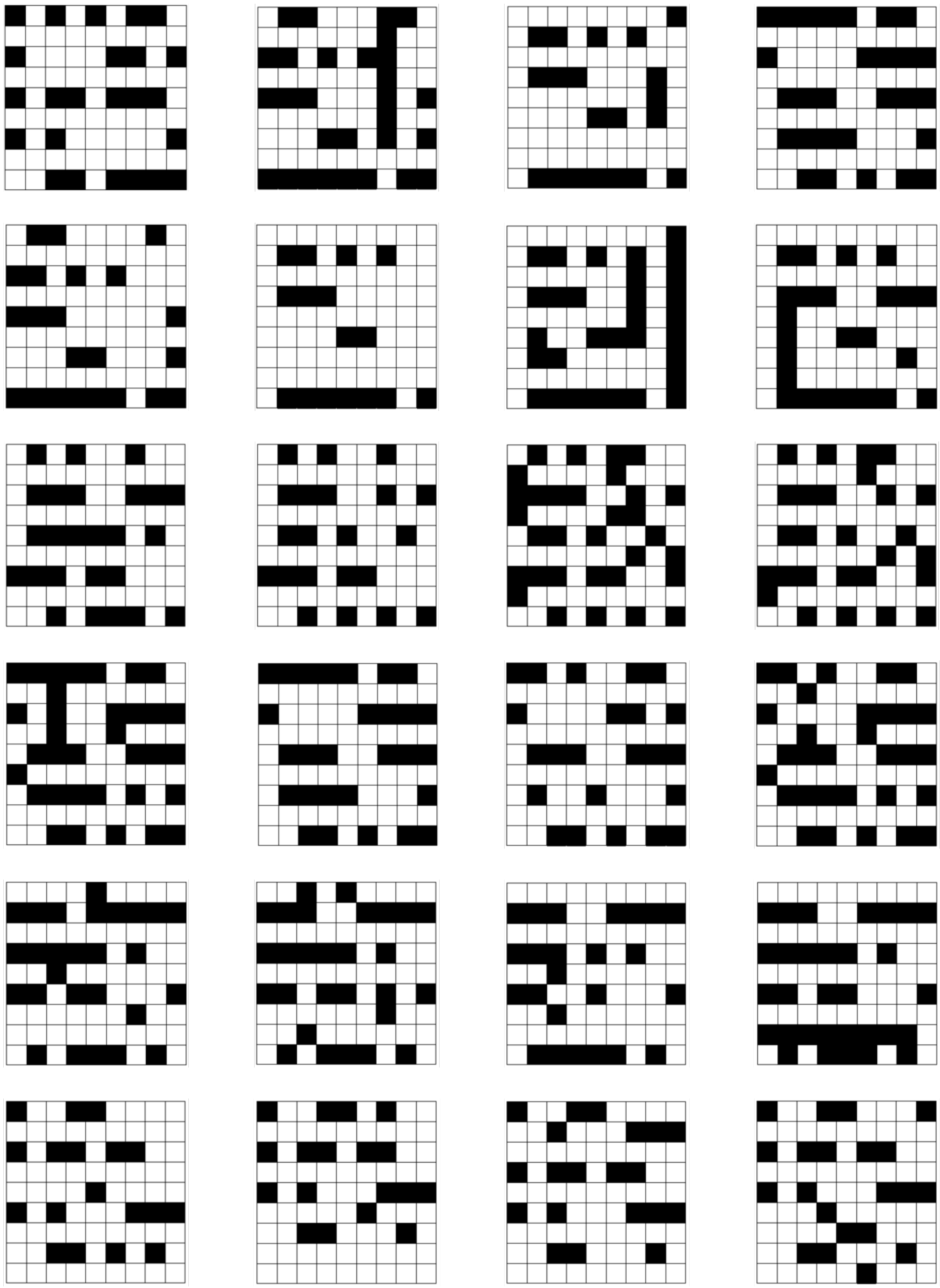
Figure C1
Stimuli for the Low and High Levels of the Randomness Factor (Studies 2A and 2B)

Low Randomness





High Randomness



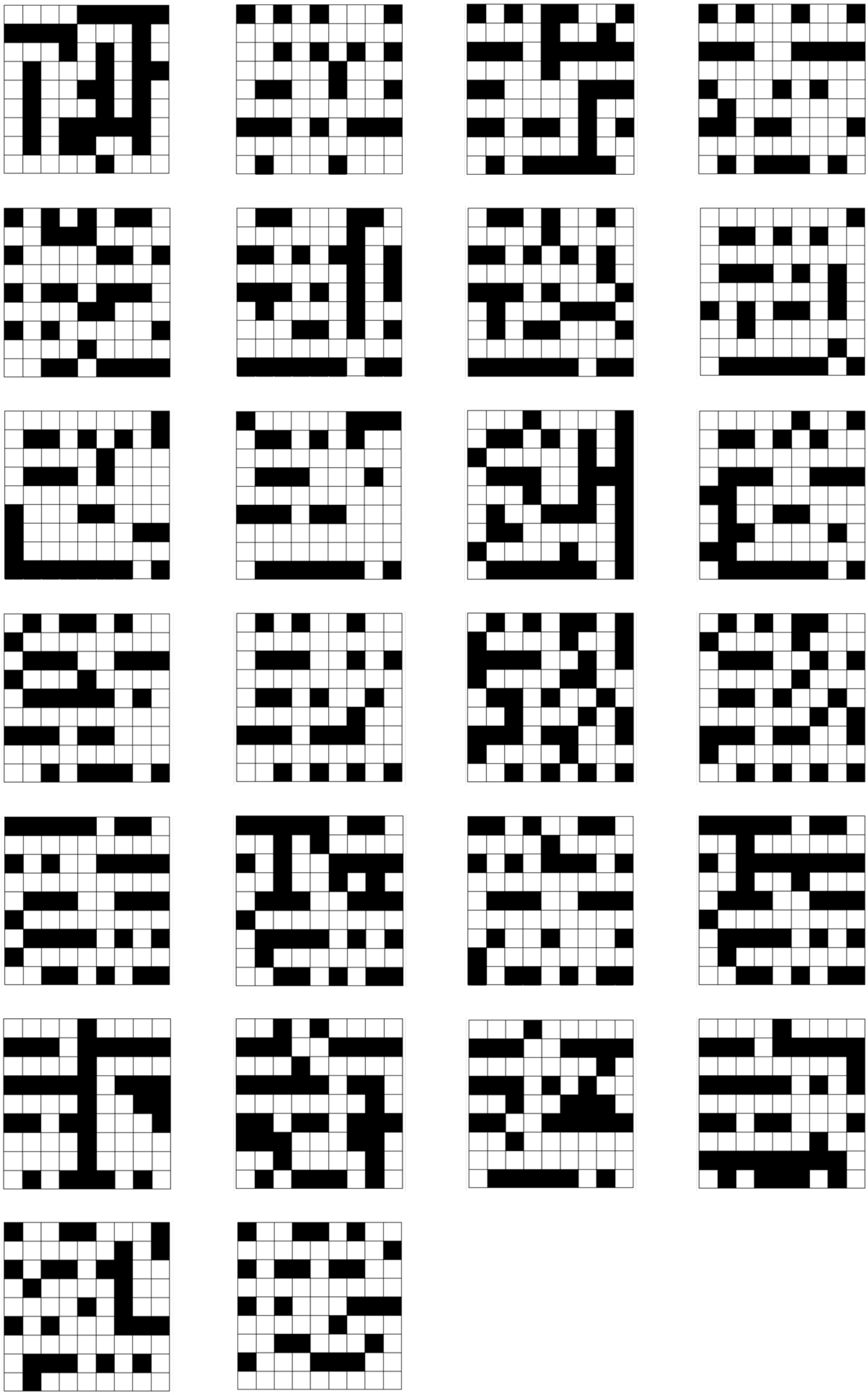
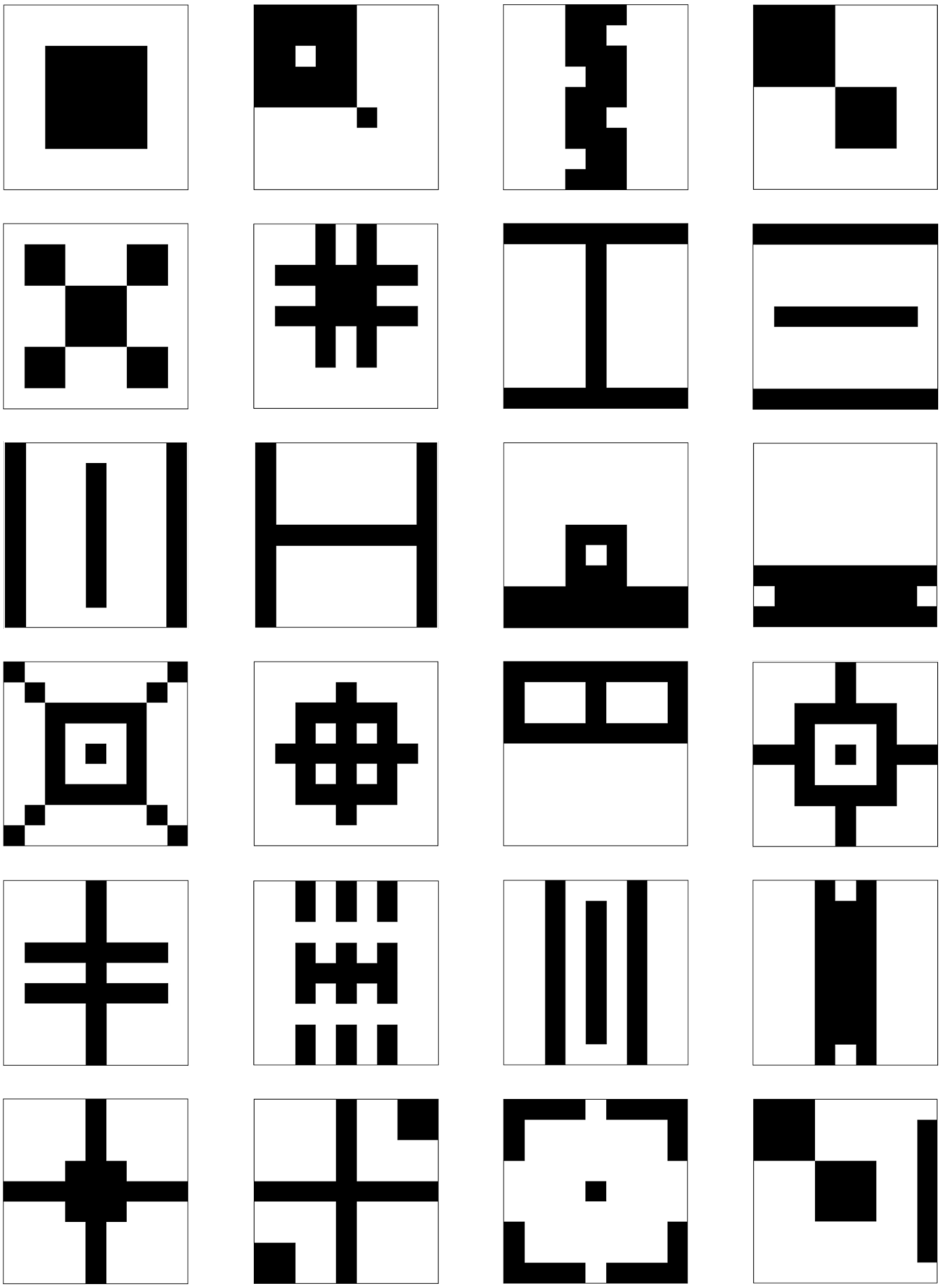
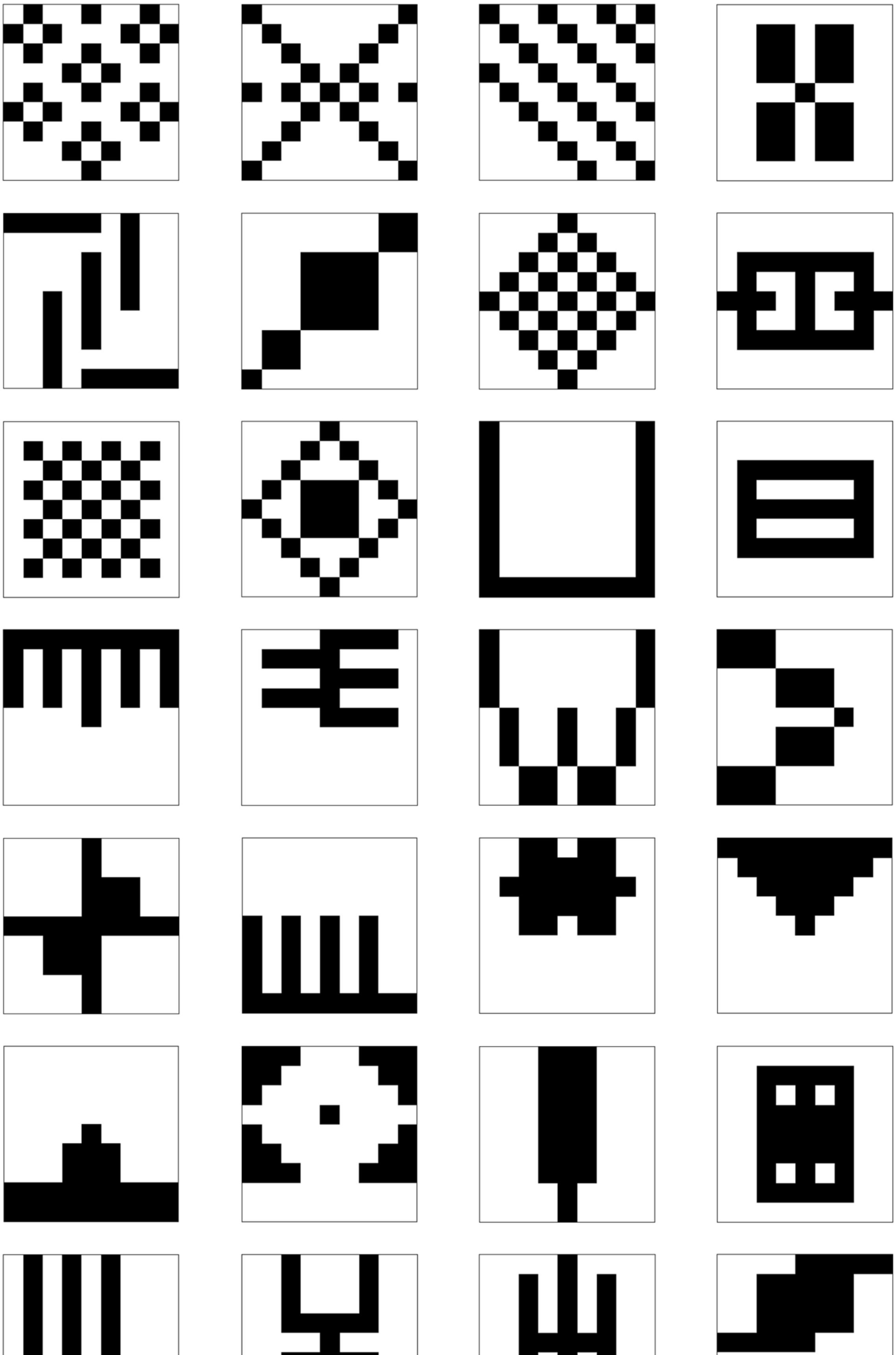


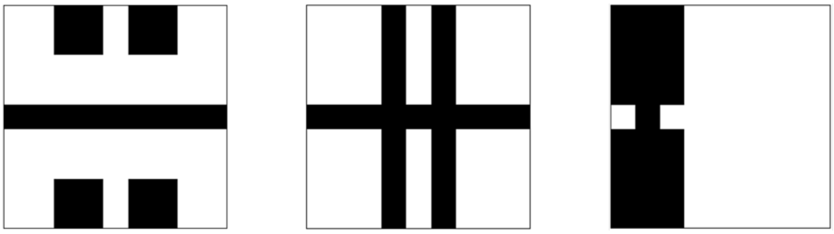
Figure C2

Stimuli for the Low and High Levels of the Randomness Factor (Studies 3A, 3B, and 4)

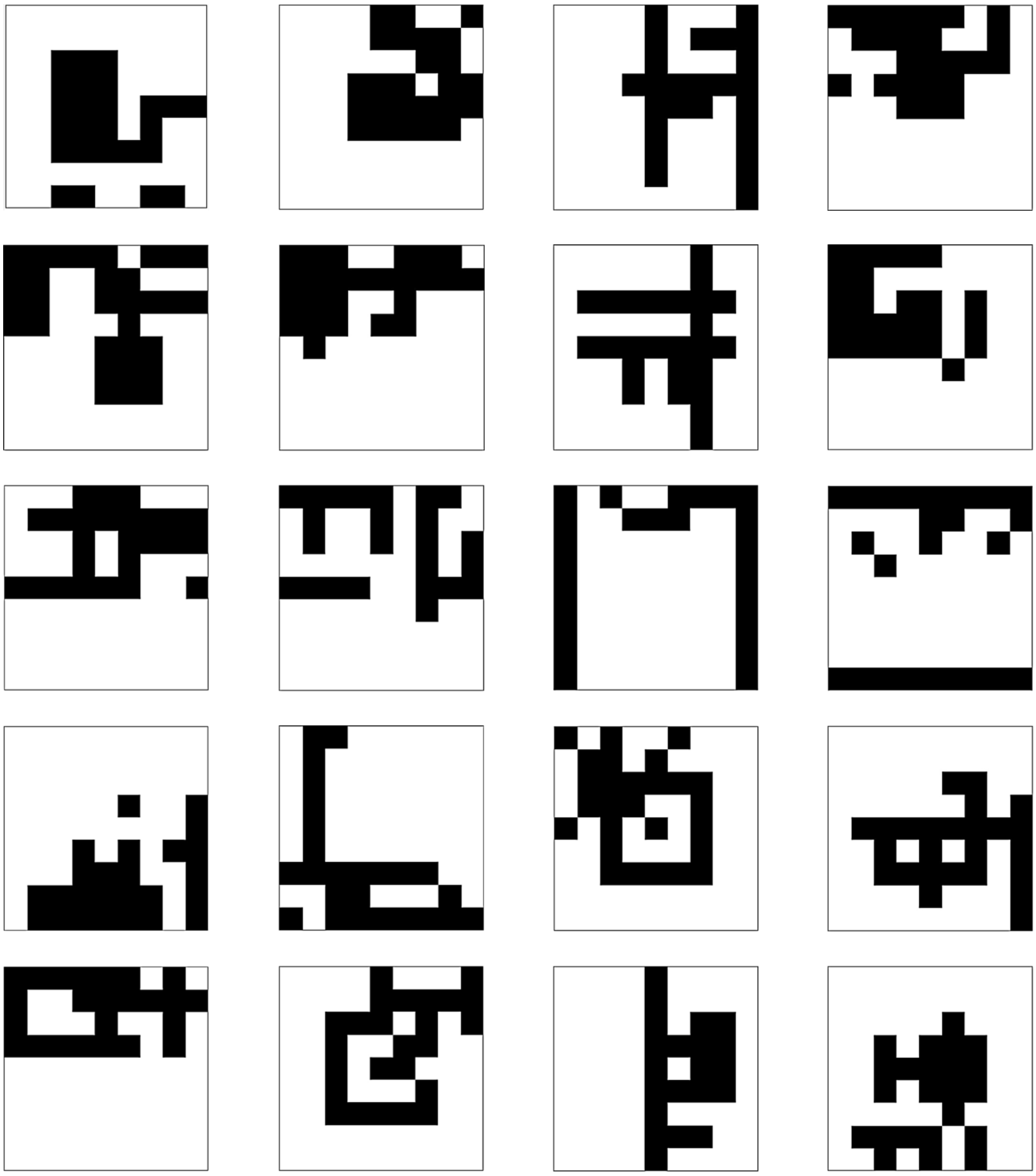
Low Randomness

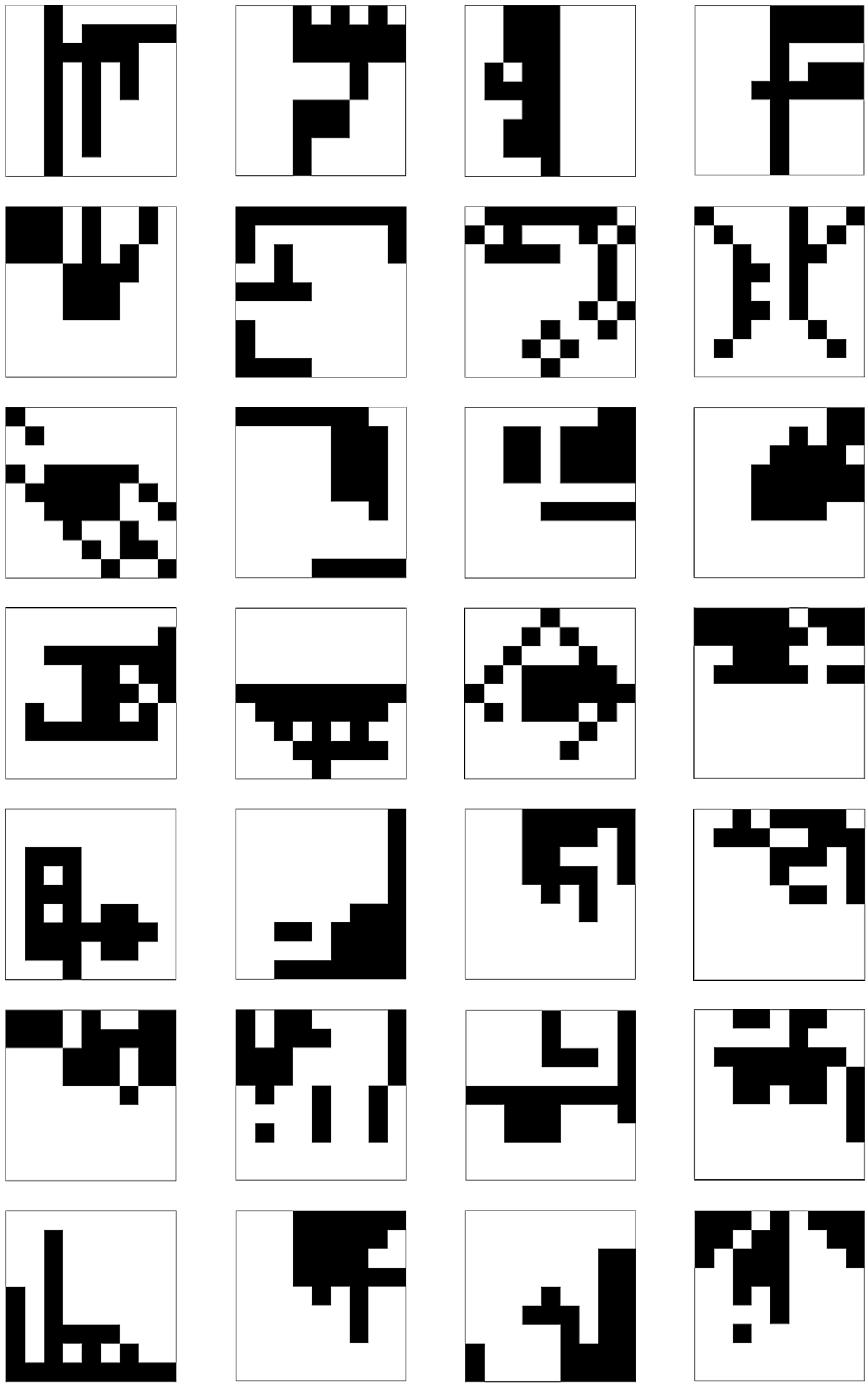






High Randomness





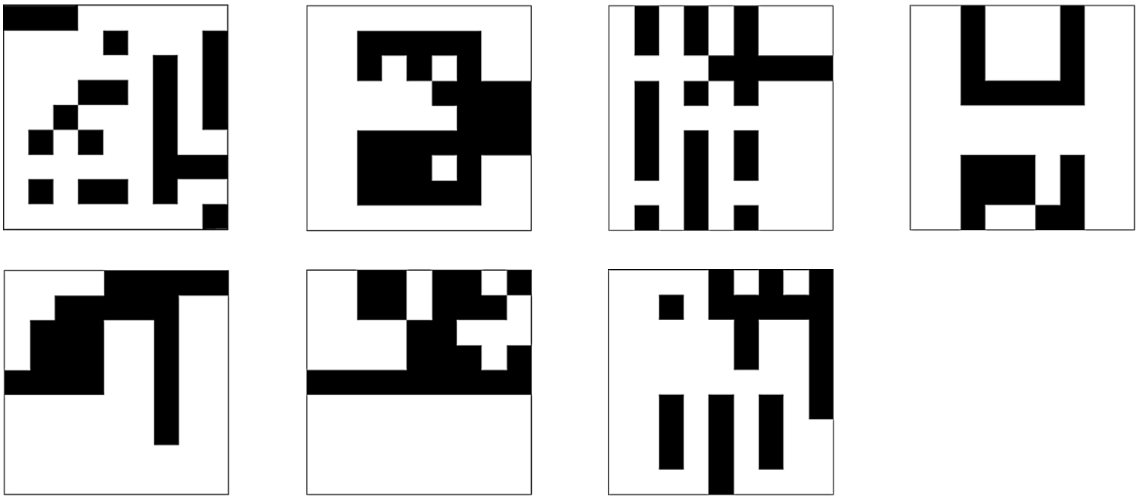
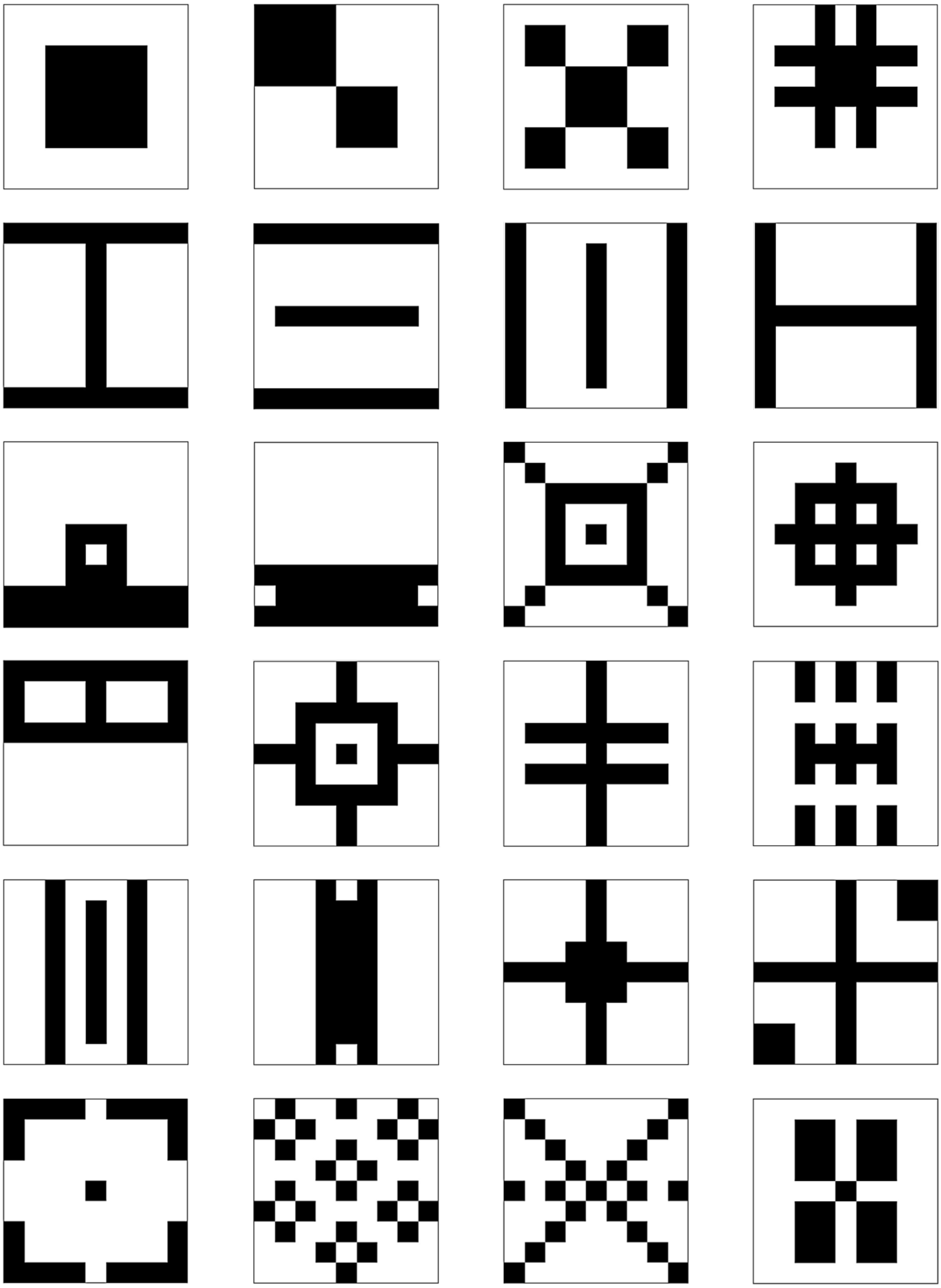
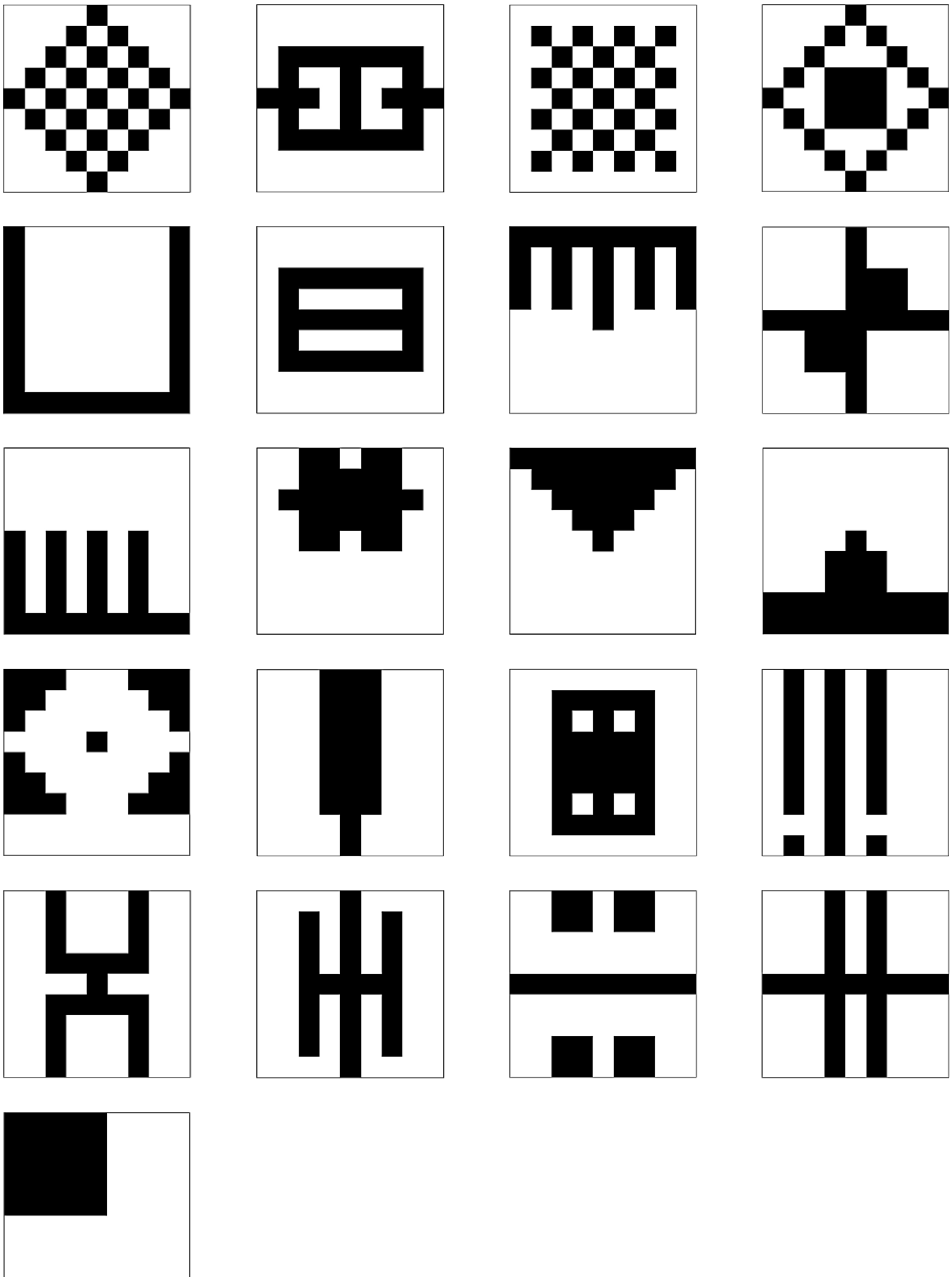


Figure C3

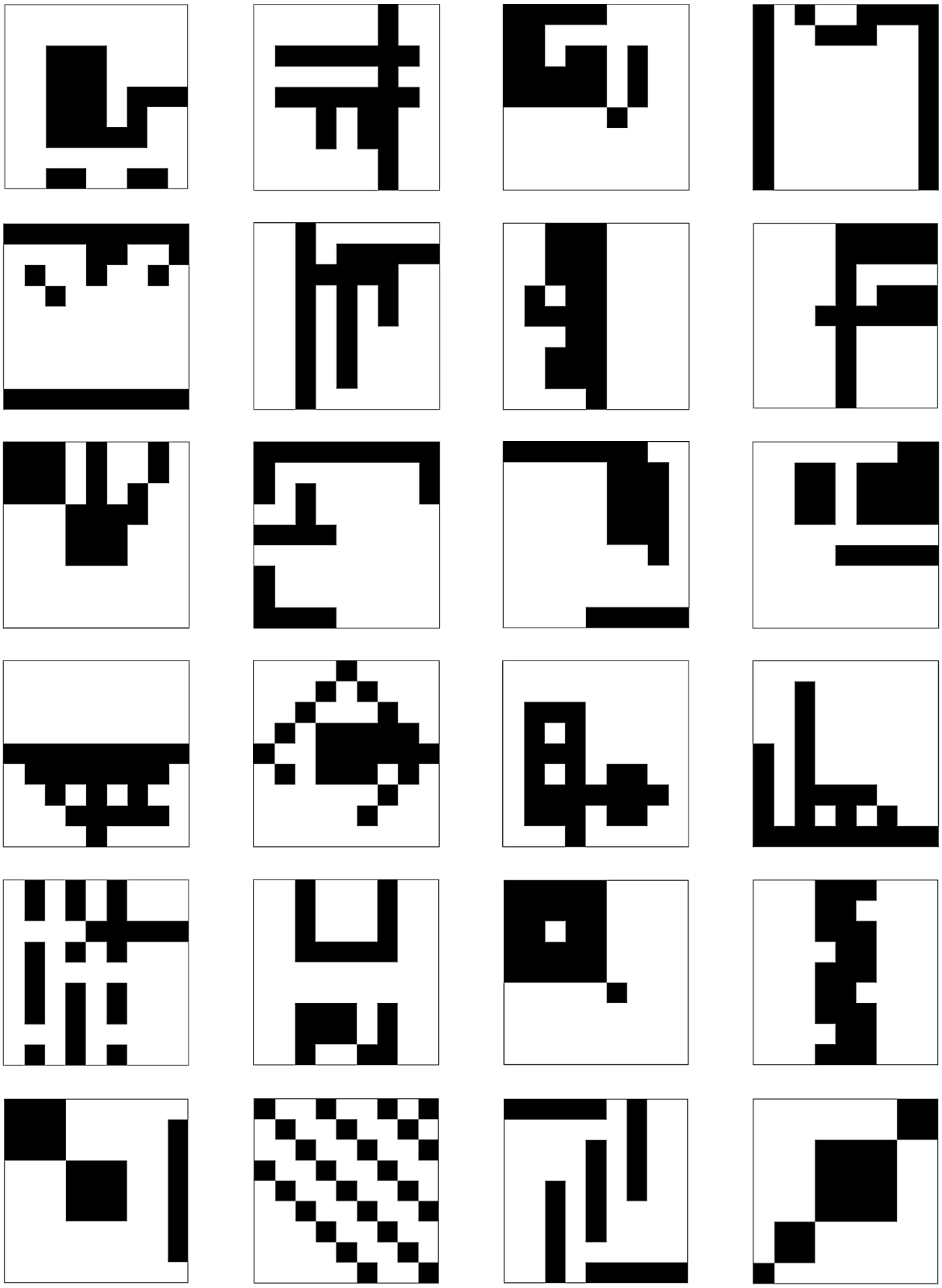
Stimuli for the Low, Medium, High, and Very High Levels of the Randomness Factor (Studies 5A and 5B)

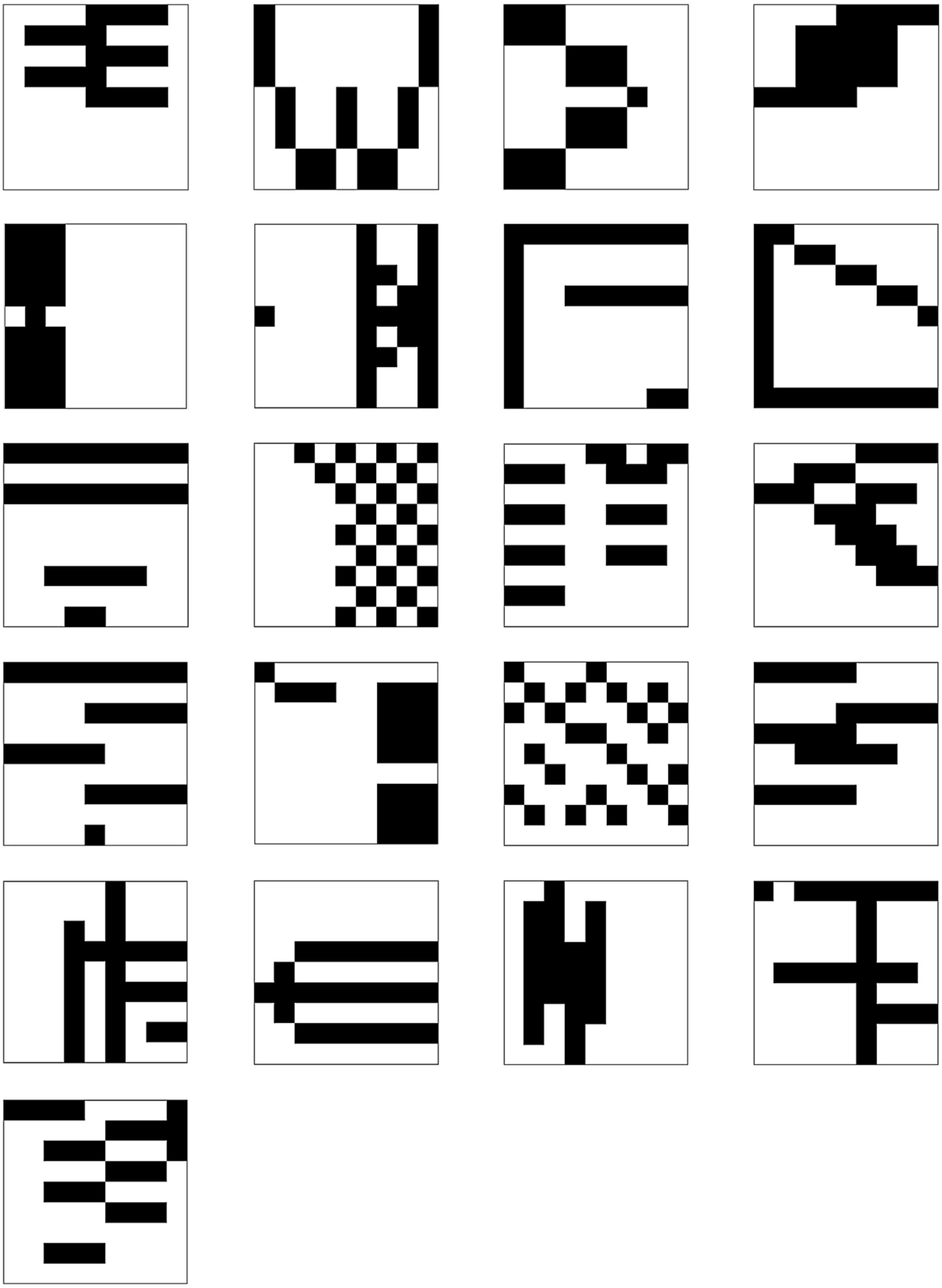
Low Randomness



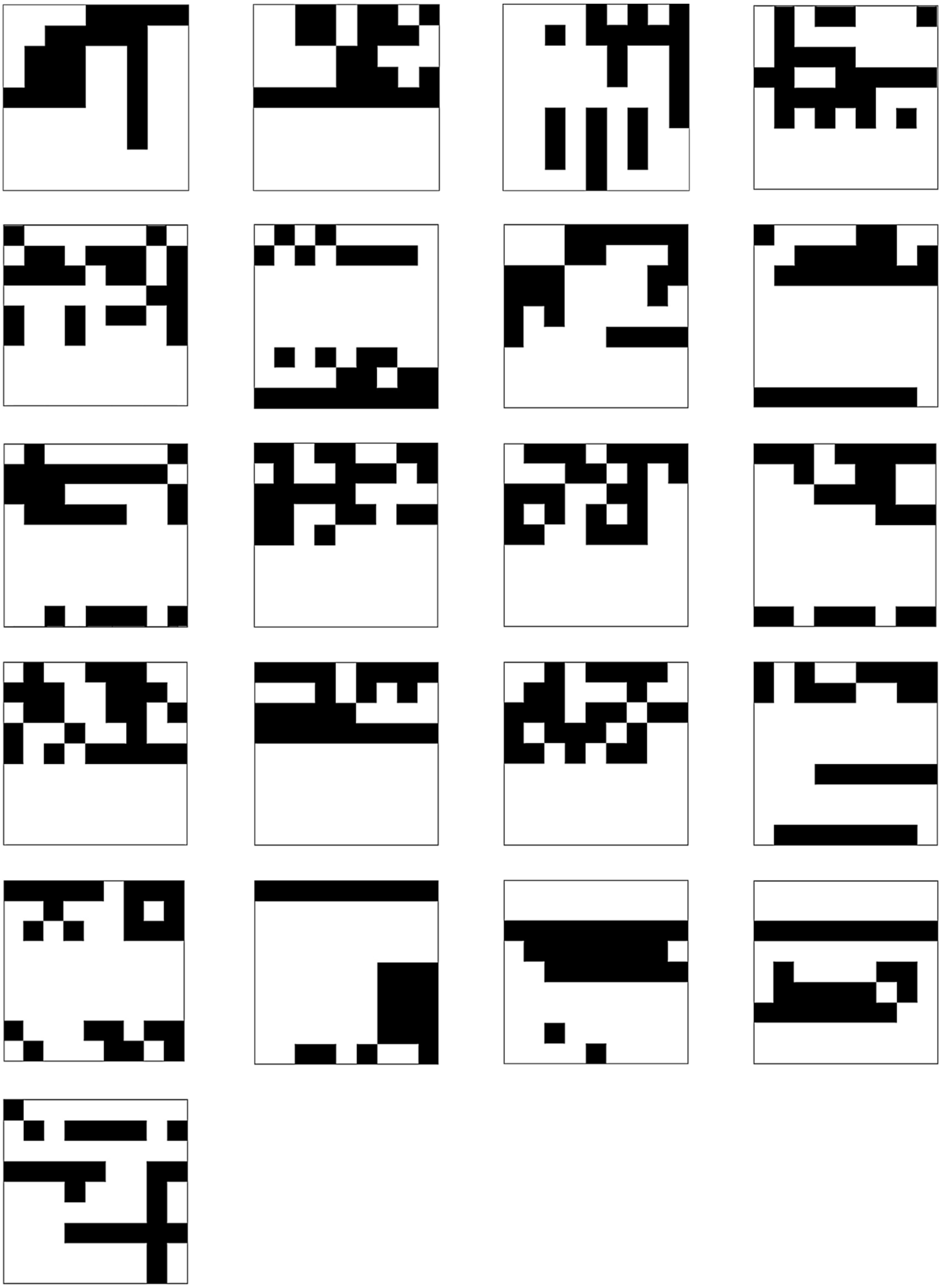


Medium Randomness

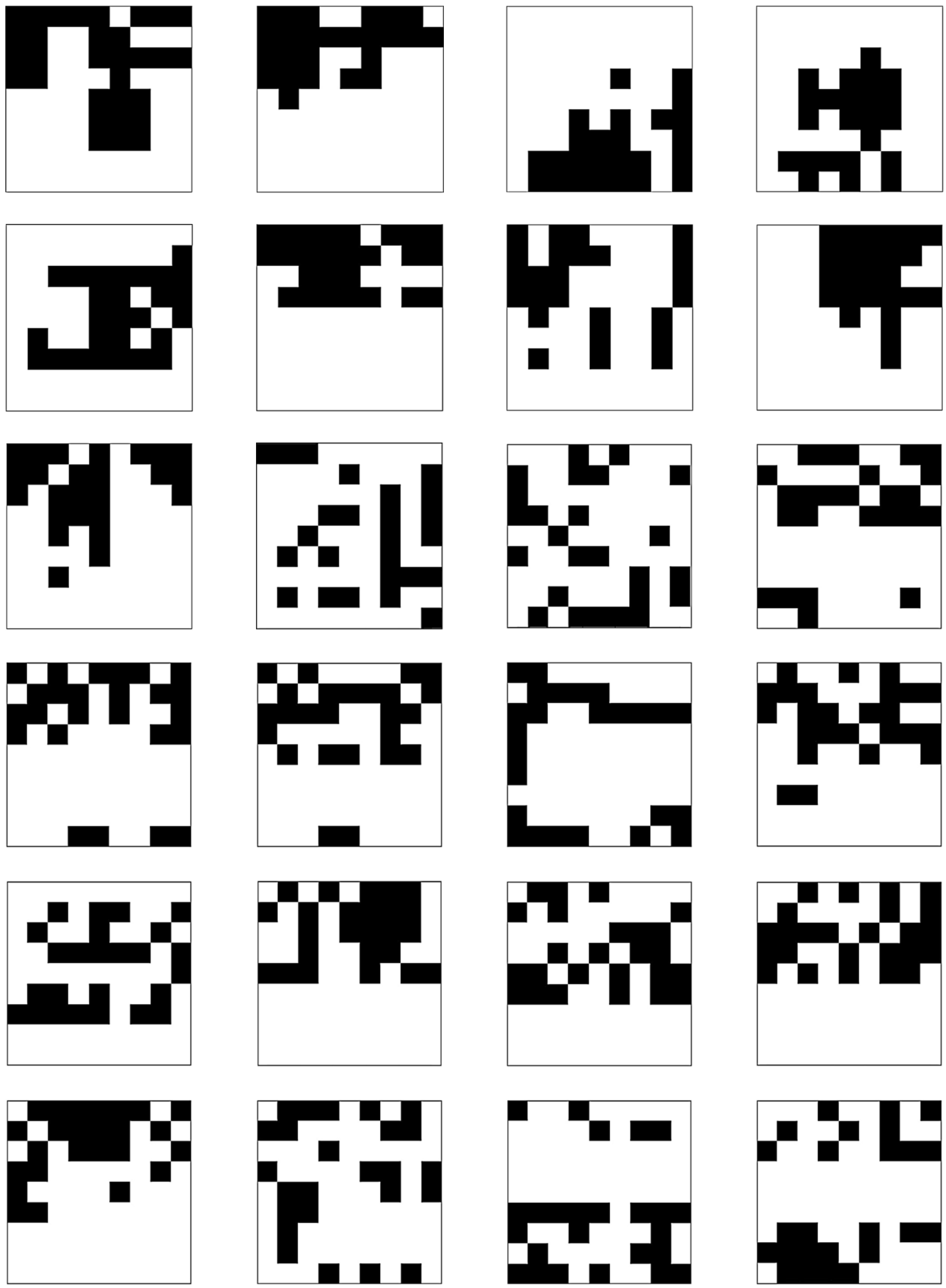




High Randomness



Very High Randomness



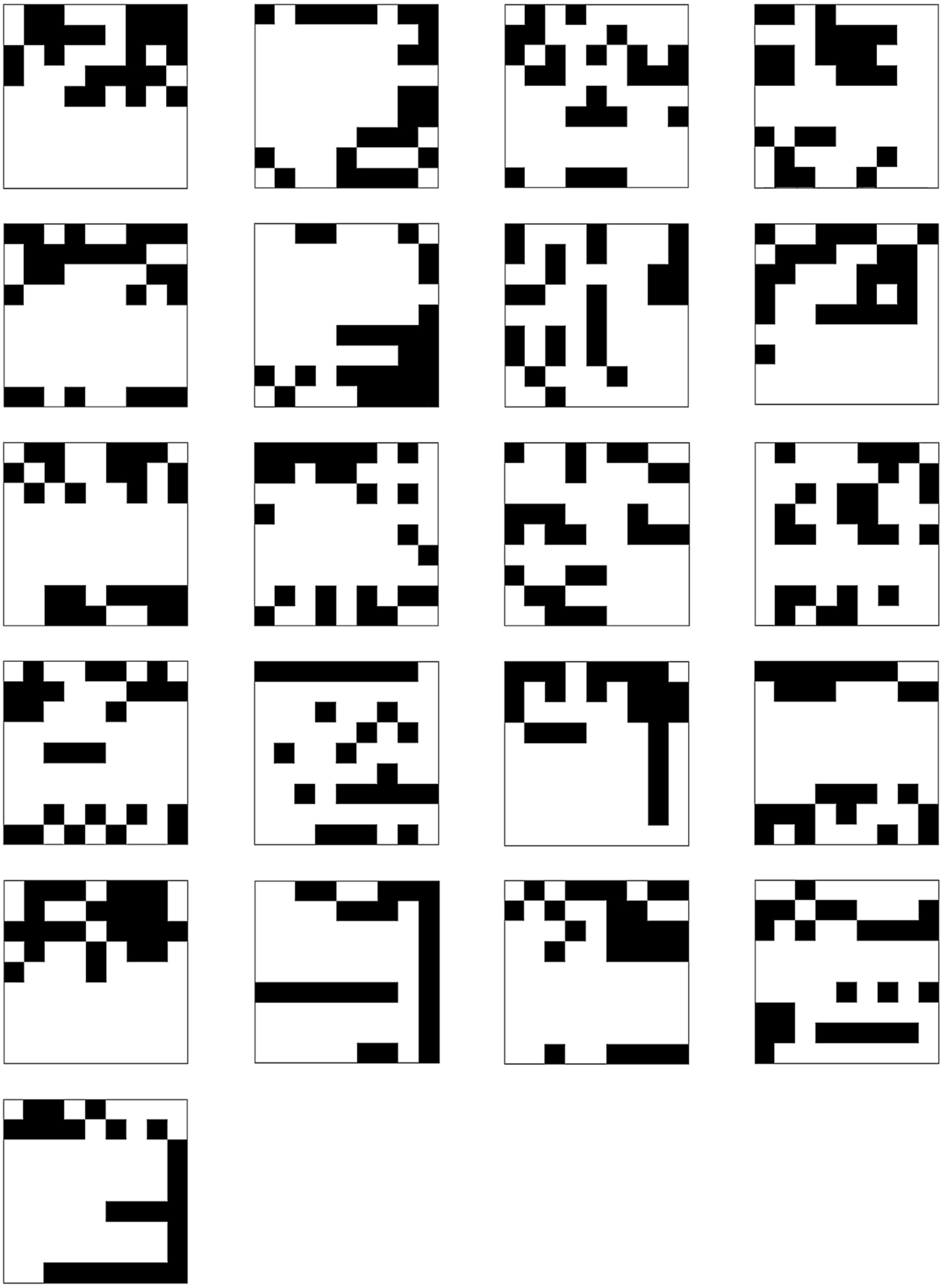
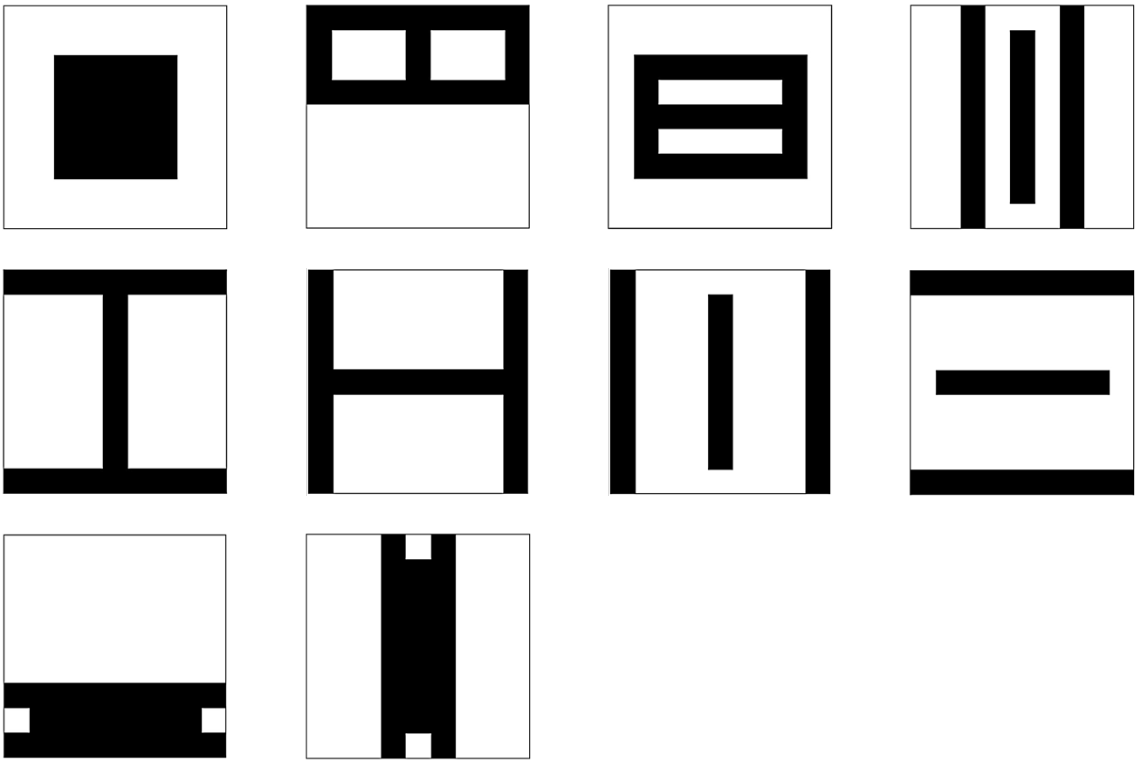


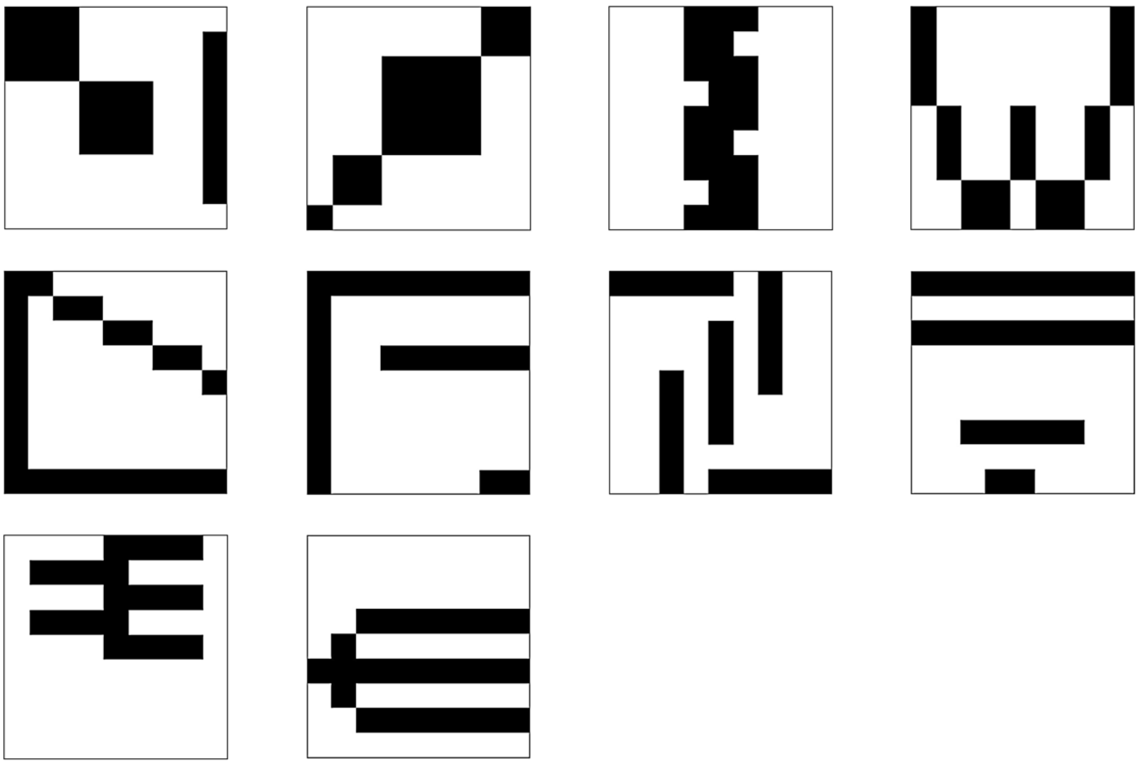
Figure C4

Stimuli for the Low and High Levels of the Randomness Factor, and the Low and High Levels of the Range Factor (Study 6)

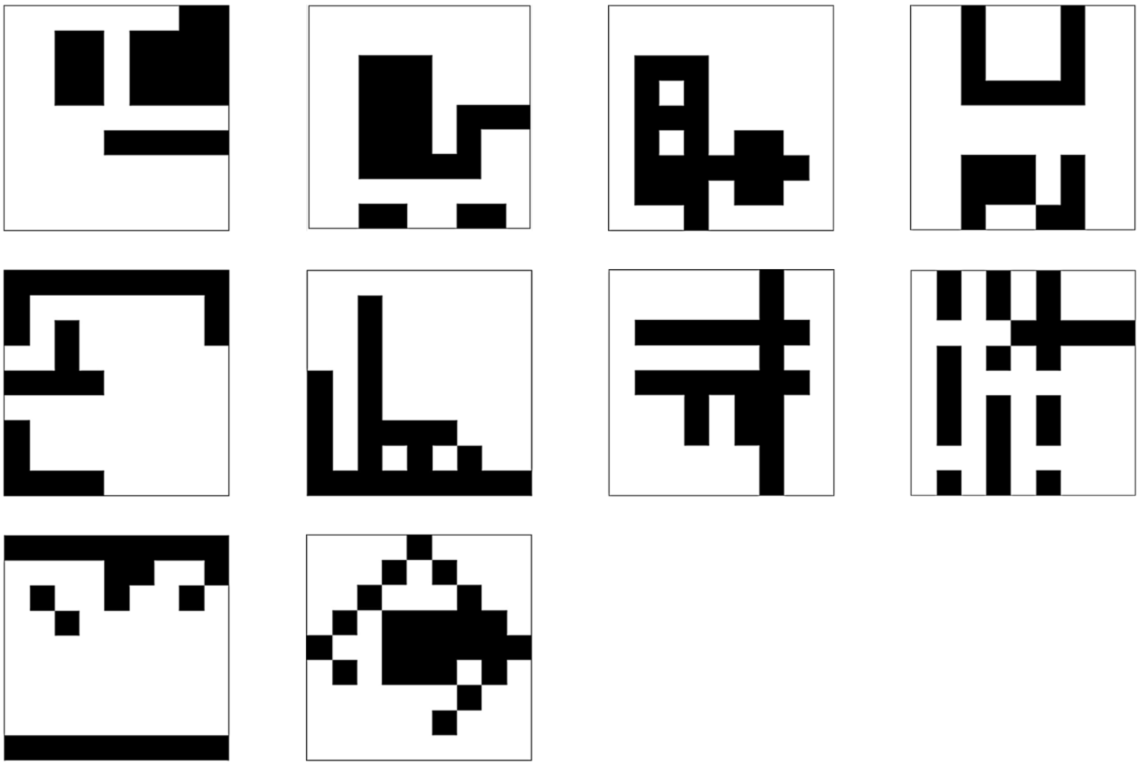
Low Randomness, Low Range



Low Randomness, High Range



High Randomness, Low Range



High Randomness, High Range