

## *Original Paper*

# Computational Mindfulness

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### ***Abstract***

*We take a computational approach to investigating highly abstract concepts including mindfulness, brain waves, and quantum mechanics. Using Langerian non-meditative mindfulness, defined as the active process of noticing new things, we find that when tested on the authors as subjects in two different ways, induced mindfulness is consistently distinguishable from induced mindlessness, and results in a calmer time series of brain waves as measured on an electroencephalogram. Additional results include a statistical Granger causality analysis of scholarly mindfulness research showing that Langerian mindfulness research causes future mindfulness research but not vice versa, and preliminary results from another study showing substantial differences in responses among subjects induced to view their own faces either mindfully or mindlessly.*

### ***Keywords***

*mindfulness, EEG, quantum, computational, Langerian*

## **1. Introduction**

Widely known as the “mother of mindfulness,” Ellen Langer has defined mindfulness (Langer, 1978; 1989; 2000) as the “very simple process of actively noticing new things.” Langerian mindfulness requires no meditation or training, and can be achieved instantly by virtually anyone, yet the benefits are enormous, including reductions in chronic pain, depression, anxiety, addiction, and stress, and improvements in immune system response, working memory, inter-personal relationships, vision, longevity, youthfulness, and well-being.

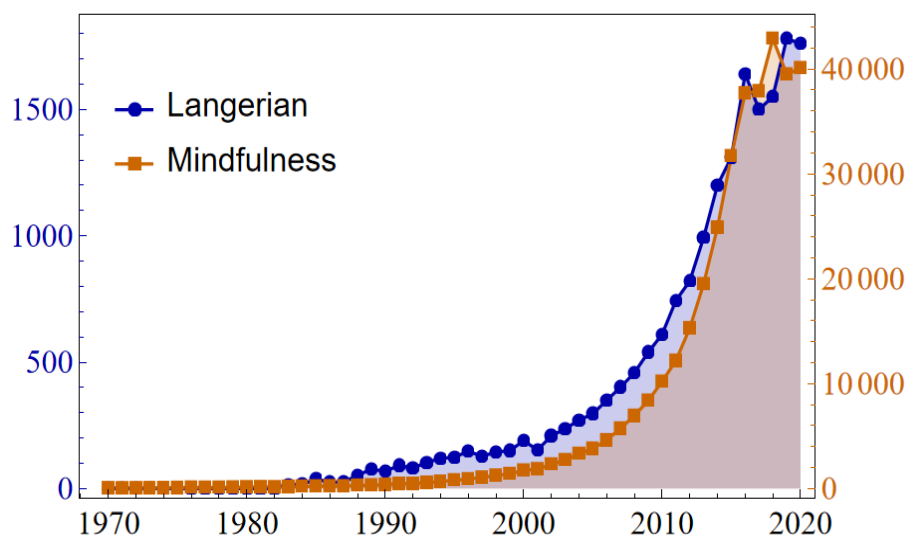
Here we seek to induce Langerian mindfulness using a vision task and exposure to quantum fluctuations and evaluate the resulting brainwaves as measured by an electroencephalograph (EEG) machine.

### 1.1 History of Mindfulness Research

Mindfulness has grown exponentially over time and has now become a household word. There are even mindful hamburgers and mindful pizzas. To chart the growth of this concept in the academic arena, we query Google Scholar for a search term (either “mindfulness” or “Langer mindfulness”) and a date range to track scholarly research output over time.

Figure 1 shows the results. The plot of both Langerian mindfulness research and overall mindfulness research reveals a common trend.

How do we know which one causes the other? We can perform a Granger causality test in both directions. Table 1 summarizes these results. The highly significant p-value of less than 0.01% means that we can definitively reject the null hypothesis of no causality in favor of the alternative hypothesis that Langerian mindfulness research causes all mindfulness research. In addition, the reverse test is highly non-significant, with a p-value greater than 90%. Hence, we can conclude that Langerian mindfulness research causes all future mindfulness research.



**Figure 1. Langerian Mindfulness Research vs. All Mindfulness Research**

**Table 1. Granger Causality Tests of Scholarly Research Output over Time**

The p-values represent the probability of the given results under the null hypothesis of no causality.

	p-value
Langerian Mindfulness Research Causes Mindfulness Research	< 0.01%
Mindfulness Research Causes Langerian Mindfulness Research	91.82%

## 2. Method

### 2.1 Inducing Mindfulness

If mindfulness involves noticing new things, how can we induce such a state in participants? One possibility is to directly instruct them to notice three new things and specify what they noticed. In ongoing research, Kiruluta, Maymin, Dhawan, Johnson, and Langer (2021) asked 1,021 people to either notice three new things about their own face or to simply use three words to describe their face. All participants did both tasks, in random order.

The mindful responses were twice the length of the mindless ones, on average. Figure 2 shows the word cloud of responses for each condition, without stopwords.

We can train a Markov machine learning model on 80% of the sample and test the model on the remaining 20%. Table 2 shows the confusion matrix of the results.



**Figure 2. Response Word Clouds in Mindless (left) and Mindful (right) Conditions in Facial Task**

**Table 2. Confusion Matrix of the Machine Learning Model on the Facial Task**

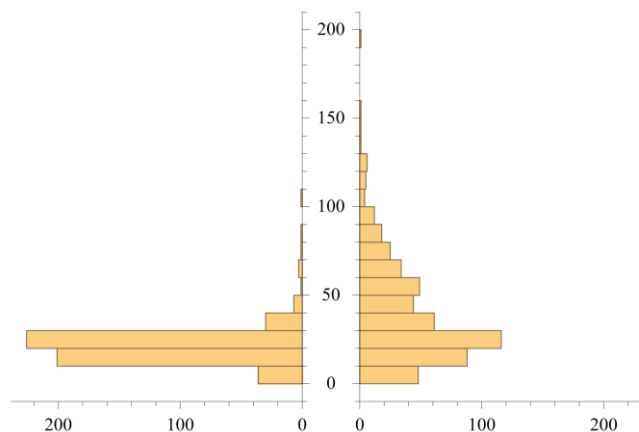
	Predicted: Mindless	Predicted: Mindful
Actual: Mindless	78	23
Actual: Mindful	25	78

The Markov classifier was able to achieve approximately a 77% accuracy in predicting whether a response was likely from the mindful or the mindless condition, relative to a baseline accuracy of 50%. Table 3 lists some of the best predicted examples and some of the worst predicted examples. The examples appear to largely distinguish based on string length. As noted above, the mindful responses were, on average, twice as long as the mindless responses.

**Table 3. Best and Worst Predicted Examples of the Machine Learning Model on the Facial Task**

		Predicted	Actual
Best 1	1) How tired I look. 2) That one of my eyebrows is slightly higher than the other. 3) I have a new spot on my forehead.	Mindful	Mindful
Best 2	I've got quite a tall forehead, I'm got quite a prominent lip crease thingy between the nose and lip (don't know the name), and my lips are quite pronounced	Mindful	Mindful
Best 3	Wonky mouth! Difficult to say if anything else that I'd think of as new - looking very tired. Possibly a little bit of an extra chin!	Mindful	Mindful
Worst 1	I noticed the screen, I noticed my face and I noticed that I looked very serious.	Mindful	Mindless
Worst 2	i dont know - have i missed a bit	Mindless	Mindful
Worst 3	Hairy, Shaped, Sad	Mindless	Mindful

However, the model appears to do even better than a naive classification based only on string length. Consider the histogram of mindless and mindful text lengths shown in Figure 3. Almost all texts longer than 40 characters are mindful: only 14 mindless responses, and 199 mindful ones, had 40 or more characters. If we naively classify text responses longer than 40 characters as mindful, then we will achieve an accuracy of  $199/213 = 93.4\%$  on those, and fifty-fifty on the remaining 808, for a net accuracy of 59%, still almost twenty percentage points lower than the machine learning model. In other words, the machine learning model must be picking up information from the content of the responses as well since it is able to substantially outperform a naive classification based on the lengths of the responses.

**Figure 3. Histogram of Response Lengths for Mindless (left) and Mindful (right) Conditions**

## 2.2 Spot the Differences

If mindfulness is the simple act of noticing new things, can we induce mindfulness with a spot-the-difference challenge? Drawing on Maymin (2019), we use pairs of pictures with differences that are either easy or difficult to spot. Figure 4 shows an example of an easy one.



**Figure 4. Spot-the-Difference between These Two Pictures**

As you look across these two images trying to spot the difference, you may not even realize that you are becoming more mindful.

Mindfulness need not be difficult, time-consuming, expensive, or obvious. In a series of studies on hotel chambermaids, Crum and Langer (2007) found that, first of all, none of them considered their daily jobs to be a form of exercise at all, and, second, when half of them were shown how their work was indeed a form of exercise and what muscle groups each activity targeted, that group experienced a decrease in weight, waist-to-hip ratio, and body-mass index over the subsequent month compared to the control group, despite the fact that neither group changed their diet or gym attendance. It was simply the change in mindset that resulted in such amazing improvements.

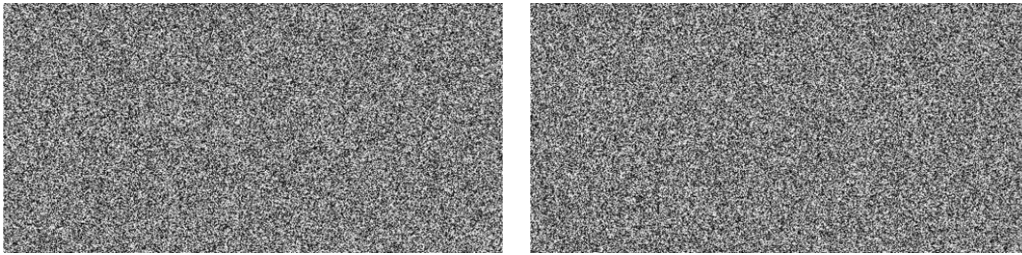
Similarly, as you notice changes in the images, you begin to realize that there are things you do not know. This causes you to pay attention and be mindful. This approach was later used as part of the process of inducing mindfulness to reduce behavioral biases in Maymin and Langer (2021).

## 2.3 Quantum Randomness

Mindfulness results from noticing “new” things. The results of quantum measurements are in a sense entirely physically “new” in a way that pseudorandom measurements are not. Ongoing research by Maymin (2021) in this area tests the hypothesis with subjects online. For this study, only the authors of the present work were used as subjects.

### 2.3.1 Pseudorandomness

We generate pseudorandomness using the Rule 30 cellular automaton of Wolfram (2002). Randomness will be generated in hexadecimal. We define a function for generating pseudorandom hexadecimal numbers and display a grayscale array plot of a sample 256x512 result. The left panel of figure 5 shows an example of such a pseudorandom image.



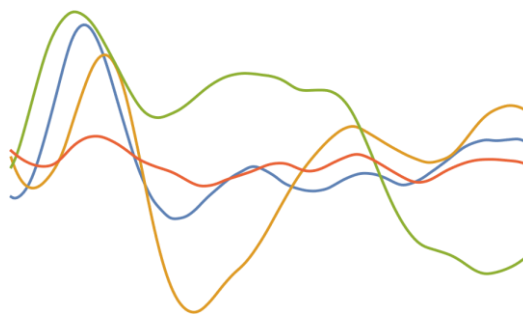
**Figure 5. Example of a Pseudorandom (left) and Quantum Random (right) Image**

### 2.3.2 Quantum Randomness

Generating quantum randomness requires quantum effects. The quantum random number generator at Australian National University offers a live API implementing Symul et al. (2011) and Haw et al. (2015). The right panel of figure 5 shows an example of such a quantum random image.

### 2.3.3 Electroencephalogram

An EEG (electroencephalogram) measures brain waves, the electrical activity in the brain, using small metal discs placed on the head via a headband. The device records the frequency and patterns of brain waves in different areas of your brain. We used the BrainBit device available on BrainBit.com. Figure 6 shows some example EEG patterns measured from wearing the device for a short period of time.



**Figure 6. Sample EEG Patterns**

### 2.3.4 Hypotheses

Hypothesis 1: The EEGs for difficult spot-the-differences should be different from the EEGs for easy spot-the-differences. We will assume that the difficult ones are the “mindful” state and the easy ones are the “mindless” state.

Hypothesis 2: Quantum random numbers will induce more mindfulness than pseudo random numbers, in the same way that the hard spot-the-differences differed from easy spot-the-differences.

## 3. Results

Figure 7 compares the graphs of the resulting EEG measurements for the two co-authors under the spot-the-difference and the pseudo-vs-quantum-randomness conditions. The thicker green lines

represent what is intended to be the mindful condition (difficult spot-the-difference or quantum-randomness), and the thinner blue lines represent the mindless condition (easy spot-the-difference or pseudorandomness). Both subjects were blind to the treatment they experienced, and both experienced them in a random order.

Both Stella's and Philip's mindful EEGs were substantially calmer than their mindless EEGs, in both spot-the-difference and pseudo-vs-quantum-randomness conditions. Thus, both hypotheses were confirmed. Needless to say, these results are for  $n = 2$ , a very small sample.

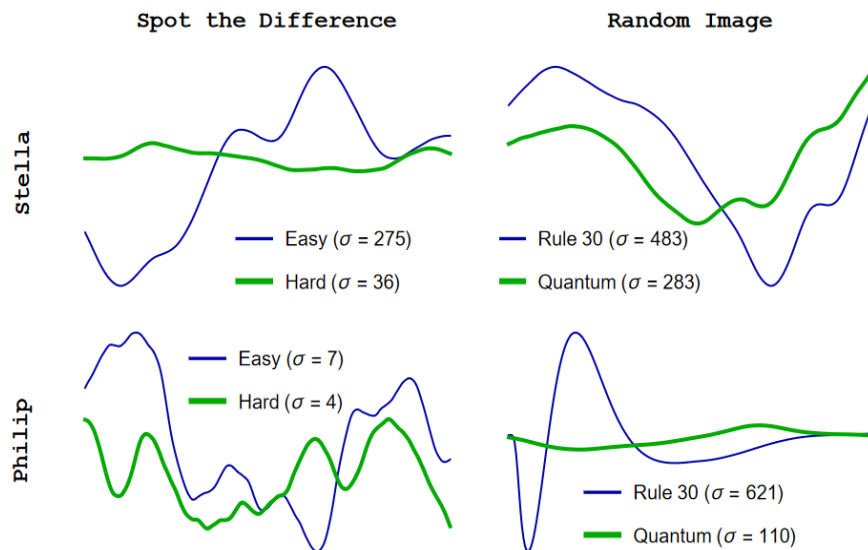


Figure 7. EEG Measurements under Both Conditions

#### 4. Conclusion and Discussion

Mindfulness may sound like an undefinable concept like consciousness, but Langer's long-standing definition provides a clear way to operationalize it: "Mindfulness is the simple process of actively noticing new things."

Under this definition, two completely different ways of inducing mindfulness present themselves.

One is to show pairs of pictures with computationally generated differences between them, making the differences either easy to spot or difficult. In this approach, subjects search for differences, finding things that are new to them.

The other is to show grayscale plots that were generated either from pseudorandom or quantum random number generators. While both pseudo and quantum random numbers are "new" to the subjects simply by virtue of never having been seen before, quantum random numbers are by definition physically "new" information in the sense that observers of the quantum information become entangled with the generating process in a way that observers of pseudorandom information do not.

Under both approaches, the brainwaves measured under the mindful condition were substantially different than those measured under the mindless condition, for both authors. Furthermore, the mindful

EEG's were always calmer than the mindless ones.

This paper offers support for a computational approach to studying arguably some of the most abstract concepts ever devised by humanity, including mindfulness, brain waves, and quantum mechanics.

Future research includes extending these experiments to a wider subject pool and presenting the pseudo vs. quantum randomness in a variety of presentations beyond grayscale plots.

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