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Varieties of volatility

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Abstract

This article explores the quantitative and qualitative dimensions of volatility and their implications for cultural analysis in a range of fields. From quantitative finance, it takes the notion of 'delta-hedging', the suspension or neutralization of directionality to get access to volatility, and applies this to qualitative areas such as surfing, dance, cinema, and language.

Keywords

Volatility, directionality, delta-hedging, Black-Scholes, rhetoric, metaphor, metonymy

Introduction

What is the relationship between the quantitative and qualitative aspects of volatility? How does a term that has a statistical definition as a standard deviation also apply to psychological processes? Despite its semantic variability, volatility now seems to be applied to changes of two broad classes of phenomena: those that can be measured, such as the weather or stock prices, and those that can't, such as affects and emotions. Often the relationship is seen as analogical, usually with the exactness of the quantitative grounding the imprecision of the qualitative, as in analogies between temperature and affects (the heat of anger, the coldness of disdain). However, Emanuel Derman, author of *My Life as a Quant* (2016) and *The Volatility Smile* (Derman and Miller, 2016), argues elsewhere for a more neutral stance: "Volatility is the propensity to continually change one's current state, irrespective of the direction of the change", which would apply to both to quantitative and qualitative dimensions of volatility (Derman, 2023: 1).

This article will explore this 'neutral stance' by examining whether the separation of directionality and volatility exists both in quantitative finance and qualitative activities such as surfing, dance, cinema, and language. The key idea behind delta-hedging is that in order to access volatility you have to suspend or neutralize directionality; as the volatility changes, you have to rebalance ('dynamic replication') at zero volatility in order to await the new changes. In the qualitative counterpart to 'delta-hedging', suspending or neutralizing directionality

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depends upon the traditional types of directionality that you are trying to neutralize; for example, postmodern dance suspends the vertical orientation of classical ballet or the inward turn of modern dance to access the randomness of contact improvisation. The key is to separate the difference between any actual directional change (a stock price goes up or down or anger diminishes) and the 'counterfactual alternatives' that could have happened but didn't (and in some sense influenced what did happen). In the case of dance, Merce Cunningham and John Cage consciously broke with tradition and experimented with randomness because they thought it was the source of a new type of creativity. Deborah Hay, a dancer and choreographer said of watching their choreography:

> It was like my mind was blown open. It was like taking drugs – and I wasn't – here was this dance going on, but I couldn't see the source of it. (Gustin, 1996: 1)

In quantitative finance, 'delta-hedging' is at the heart of the Black-Scholes model for pricing options. The following equation, whose relationship to the Black-Scholes equation will later be described, captures the tension between directionality (drift) and randomness that lie underneath both quantitative and qualitative perspectives on volatility: stock price changes (S_t) are the interaction between directional and random components.

$$(S_t) = \mu S_t \, dt + \sigma S_t \, dB_t$$

drift + random

The separation between drift and random components is not accidental; in derivative finance, the drift component can be handled by standard calculus because it is smooth, but the random portion has to be treated by stochastic calculus (the changes are jagged because there is a small chance that a large change might happen), which wasn't discovered until World War II. Before we examine examples of qualitative 'delta-hedging' in surfing, dance, cinema, and language, we will look at trading and market-making where the quantitative and qualitative dimensions of volatility interact. We will examine the notion of time, which in our contemporary thinking combines two contradictory notions of time: a mathematical and extensional notion of time that comes from Newton's 'absolute time' and an indexical and intensional notion of time, which is associated with Bergson's notion of duration: the experience of the flow of time from future to present and then to past. These perspectives lead to two models of subjectivity, decision-making under uncertainty (the binomial model for pricing options) and 'flow' models ('animal spirits'), as well as two notions of volatility, calendar-time and tic-time volatility, all of which interact in trading or market-making. These two models are already present in behavioral finance. Daniel Kahneman, in his book *Thinking, Fast and Slow* (2011), mentions Csikszentmihalyi's flow models as peak experiences for creativity, which require a modulation of affect and emotion. It will be suggested that these two models of subjectivity come from different notions of time; decision-making under uncertainty comes from game theory, where time is mathematical and flow comes the passage of time from future to present and past, where time is based on our experience of duration.

Time and volatility

Although Bergson was not thought of as a philosopher of volatility, he saw everything as inherently volatile. This passage from *Matter and Memory* shows that everything was vibrating

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and in motion and the philosophical challenge was to describe the transformation of this initial volatility to the stable images of perception and art:

> Matter thus resolves itself into numberless vibrations, all linked together in uninterrupted continuity, all bound up with each other, and traveling in every direction like shivers through an immense body. In short, try first to connect together the discontinuous objects of daily experience; then, resolve the motionless continuity of their qualities into vibrations on the spot, which are moving in place; finally, fix your attention on these movements, by abstracting from the divisible space which underlies them and considering only their mobility (that undivided act which our consciousness becomes aware of in our own movements); you will thus obtain a vision of matter fatiguing perhaps for your imagination, but pure, and freed from all that the exigencies of life compel you to add to in external perception. Now bring back consciousness, and with it the exigencies of life: at long, very long, intervals, and by as many leaps over enormous periods of the inner history of things, quasi-instantaneous views will be taken, view which this time are bound to be pictorial, and of which the more vivid colours will condense an infinity of elementary repetitions and changes. In just the same way the multitudinous successive positions of a runner are contracted into a single symbolic attitude, which our eyes perceive, which art reproduces, and which becomes for us all the image of a man running. (Bergson, 1911: 276-77)

The key section is the separation from the directionality of space ("abstracting divisible space") from "these movements" and then consider only their volatility or "mobility". With this separation of directionality from volatility, the volatility will be discovered to be the basis for perception and art ("which art reproduces"). Bergson saw the quantitative and qualitative aspects of time and volatility as irreconcilable, but the reason was the interaction of psychological processes with duration. Anything measurable had to presuppose numbers and he thought any denumerable collection of objects presupposed space. Mathematics, along with language and cinema, spatialized and objectified time and movement.

What was at stake for Bergson is our understanding of freedom and creativity. Kant argued that freedom was transcendental and presupposed the concepts of time, space, and causality. The Kantian notion of time came from the formalization of time by Newton; it was infinitely divisible and it was the framework in which all events took place. For Bergson, freedom and creativity came from our experience of duration, which presupposed the moment of perception from which memory and other psychological processes were derived. For Newton, on the other hand, time was mathematical and duration was psychological. Instead of freedom being transcendental, Bergson saw its roots in memory and learning. Since even simple organisms such as paramecia could learn and thus freedom and creativity were coeval with life, which Bergson called *élan vital* (vital force).

For Bergson, both volatility and time had quantitative and qualitative dimensions, which in analytic philosophy has been sharpened into the distinction between extensional and intensional contexts, which derives from Frege's analysis of sense and reference. Extensional contexts are those in which intersubstitutability of co-referential terms preserves truth value; in science and mathematics, 2+2, 2^2, and 4, can be substituted for one another because they refer to the same number. Intensional contexts are those in which such substitutions fail and include intentionality, modality, and indexicality; for example, the sentence *Oedipus wanted to marry Jocasta* is false even though *Jocasta=Oedipus's mother.* Mathematics and science are extensional; Bergson gave an alternative explanation to Frege's notion of intensionality by showing how subjectivity and his version of modality (his concept of the 'virtual') interacted with the indexicality of time.

The modern notion of time, derived from Newton's 'absolute time', is of an infinitely divisible framework for all events, which flows from the future to the present and to the past. Absolute time is a framework for all events, whereas the flow of time is a function of events, such as linguistic tense, which presupposes the present moment of speaking. As Newton noted, our conception of time is contradictory: mathematical time has nothing to do with our experience of duration, the flow of time; duration was psychological whereas time was mathematical.

In contemporary philosophy, the mathematical notion of time is extensional: *two hours* and *one hundred and twenty minutes* refer to the same amount of time, and like 2+2 and 4, they can be substituted for one another without the truth value being affected. Logic, mathematics, and science are *extensional* (co-referential terms can be substituted for one another without reference shift) whereas psychological processes, modality (necessity and possibility), and indexicality (for example, deictics and linguistic tense) are *intensional* because they introduce a reference shift. Bergson also touched upon modality and indexicality (his notion of the "virtual" is an alternative to modal analyses of 'possible worlds', and linguistic tense is indexical), so the extensional/intensional distinction overlaps with Bergson's contrast between quantitative and qualitative dimensions of both time and volatility.

Bergson's famous debate with Einstein about time and relativity can be seen as a debate between quantitative and extensional notions of time and our qualitative and intensional experience of duration. This should not be surprising, as indexicality and intentionality are both intensional; linguistic tense is indexical and our verbs of feeling, thinking, and speaking are intentional and intensional. Newton and Einstein argued for a notion of time that was mathematical and extensional; Bergson's duration was indexical and intensional and the source of our subjectivity.

The quantitative and extensional perspective on volatility treats it as statistical. Quantitative volatility measures the spread or dispersion, and not the direction of changes, over time. It is calculated by measuring changes of intensity over time, such as the daily temperature at noon for a month. First one calculates a mean and then you subtract that mean from every measurement. The differences will be positive, negative, or zero. Then square the differences – so that positive and negative differences won't cancel each other out (you're trying to measure the spread or dispersion, ignoring the direction), then sum the squared differences and divide by the number of measurements. The result is the variance. The standard measurement of volatility is the standard deviation, which is the square root of the variance; quantitative finance thinks of volatility as the standard deviation.

Bergson didn't talk about finance, and he saw the quantitative and qualitative aspects of volatility as quite separate. However, in economics, Keynes (1936) saw stock prices as both statistical and subject to 'animal spirits'. Although Keynes was a part of the Bloomsbury group, many of which were admirers of Bergson, he never wrote about duration and 'animal spirits' or affects and emotions. It would not be until the advent of behavioral economics that economists might even entertain non-rational decision-making behavior.

Dance, affect, volatility

Randy Martin would have agreed with Keynes and disagreed with Bergson that the quantitative and qualitative dimensions of volatility should be kept separate. Randy saw an internal connection between the quantitative volatility of derivatives and the qualitative volatility of movement-based cultural activities such as postmodern dance, so he didn't agree with Bergson on not mixing quantitative and qualitative perspectives on 'multiplicity' or 'volatility'. Martin (2015) introduced technical financial vocabulary ('arbitrage', 'hedging', 'random walk', 'volatility') into cultural analysis, especially dance criticism. As a good Marxist, he understood finance capitalism had changed with derivatives and he sought a framework

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that would include both finance and culture. Randy honed in on a term that is the foundation for modern finance and has both quantitative and qualitative dimensions: risk. The comparison between dance and derivatives was, for Randy, stronger than an analogy as the following passage about the postmodern refinement of release technique:

> The formalism of release technique resonates with other technical practices like the mathematical modeling of derivatives. The expansion of research capacity, the dissemination of arbitrage as an orientation to a field of difference, the scanning and rapid processing of information, the search for means to generate flow, constitute a kinesthetic alignment between dancers and financiers. So too, the exploration of the relation between risk and uncertainty, the seizing of moment of stability whose consequence is a generative instability or volatility which become productive of further instruments of value. (Martin, 2015: 184)

We won't talk about dance right now, which Randy masterfully did in 'Toward a Decentered Social Kinesthetic' (Martin, 2010), but instead talk about something that he also mentioned in that essay, i.e., surfing. Market-makers describe themselves as 'surfing the volatility wave', as in the following description of trading by Elie Ayache (2008). Ayache was a market-maker and author of *The Blank Swan* (2010) and *The Medium of Contingency* (2015); his first day of market-making was 'Black Monday', when global markets dropped twenty percent, which gave him a special sensitivity to 'animal spirits'.

> Through the dynamic delta-hedging and the anxiety that it generates (Will I execute it right? When to rebalance it, etc.), the market-maker penetrated the market. He penetrated its volatility and he could now feel it in his guts. In a word, he became a dynamic trader. He now understood – not conceptually, but through his senses, through his body – the inexorability of time decay, the pains and joys of convexity. (Ayache, 2008: 37)

The paragraph still makes sense if you substitute *dynamic surfer* for *dynamic trader*. Randy often suggested that 'arbitrage' also applied to dance; we will suggest that a financial technique called 'delta-hedging' also describes how surfers handle the volatility of a wave. We will look at a ride at Teahupoo in Tahiti by Laird Hamilton, which so resonated among professional surfers in its combination of volatility and creativity that it revolutionized surfing. Delta-hedging is also the key to the Black-Scholes model for pricing options and why Black-Scholes catalyzed the expansion of derivative finance; it tells you how to make new derivatives out of old ones by telling you how to make something creative out of volatility and risk.

Derivatives and Black-Scholes

Options are financial derivatives that give their purchasers their right to buy or sell a stock at a given price (the 'strike price') at a given time (the 'expiration date') in the future. For example, a call (put) option would get his holder the right to purchase (sell) 100 shares of Apple stock at \$100 six months in the future. If Apple stock reaches \$110, he makes \$1000 minus the price of the call option. If it reaches \$90 at six months, he decides not to exercise the option and he loses the cost of the call. The option depends on the performance of the underlying stock. The Black-Scholes model prices the option from the performance of the underlying stock, which depends upon the stock price, the expiration date, the strike price, the volatility (not the expected return) of the stock, and the risk-free interest rate (treasury bonds); the only parameter that is unknown is the volatility of the stock. The most popular model for option pricing is binomial trees, which are equivalent to Black-Scholes when the time interval between choices approaches zero. Binomial trees are decision-trees in which the stock price goes up or down with a random fifty-fifty chance (think of flipping coins); the reiteration of this initial tree forms a binomial distribution, which Brownian movement and stock prices follow and approximates a normal distribution.

Brownian motion has many interesting properties; it is both a martingale and fractal. A martingale is a stochastic process in which future behavior is dependent only on the present state and not previous states; martingale processes have no memory (which contrasts with Bergson's duration in which the past influences the present through memory). A fractal is 'self-similar' at different scales; examples of fractals include snowflakes, crystals, coastlines, blood vessels, and ocean waves. Brownian motion originally described the erratic 'dance' of pollen particles suspended in water – it also applies to smoke diffusing in air or heat transfer. The efficient market hypothesis explains the random behavior of stock prices. Although every trade is done for a variety of psychological reasons, generally information about companies arrives randomly on the market. Since traders are to process and react to new information, its random arrival is reflected in stock prices both at the company specific level and the market as a whole. The fractal structure is such that each path looks like each other potential path and a small sequence of prices will be similar to a larger sequence.

Each possible future price will be associated with a certain probability, with large losses or gains being less frequent and in the thinner 'tails' of the distribution. The question is how does one calculate the price of the option given the performance of the underlying stock? Most stocks don't have a perfectly random distribution; in the long run, the stock market goes up. In Brownian motion or smoke diffusion, there are currents in the water or air, and they give directionality to Brownian motion. In order to capture the 'drift', the equation for stock price changes consists of a directional portion and a random or Brownian portion, where μ = mean and σ = standard deviation, and dB_t = a Brownian component.

$$(S_t) = \mu S_t \, dt + \sigma S_t \, dB_t$$

drift + random

The drift component is linear, smooth (non-jagged) and continuous, the Brownian portion is jagged and is not integrable by standard calculus and requires stochastic calculus (usually Ito's calculus) that can handle its non-smooth behavior.

Since an option is a function on the underlying stock (its graph would ideally match point-to-point the underlier), the option function will also have drift and random components. If you take the stock price function S_t where t = time, a call function (C) would look like:

$$dC(S,t) = \{\mu S_t \, \partial C/\partial S + \partial C/\partial t + 1/2 \, \sigma^2 S^2 (\partial^2 C)/(\partial S^2)\} \, dt + \sigma S^t \, \partial C/\partial S \, dB_t$$

drift + random

The Black-Scholes equation for a call option can be derived in which the only unknown parameter is the volatility of stock, where C = the option price; σ = the volatility of the stock, and S = the stock price:

$$\partial C/\partial t + 1/2 \, \sigma^2 S^2 (\partial^2 C)/(\partial S^2) + rS \, \partial C/\partial S - rC = 0$$

As Wilmott (2009: 130-31) explains, the equation contains four terms: (1) a term for time decay, i.e., how much the option value changes if the stock price doesn't change; (2) a convexity term, for how much a hedged position makes on average when the stock changes;

(3) a drift term allowing for growth in the stock at the risk-free rate; and (4) a discounting term, since the payoff is received at expiration but you are valuing the option now.

Delta-hedging

The key term here is (2), the convexity term, which refers to a 'hedged position' that is the fundamental breakthrough of derivative pricing and contains the ideas of delta hedging and dynamic replication. Fischer Black explains 'delta hedging' and why it is so important:

> Suppose there is a formula that tells how the value of a call option depends on the price of the underlying stock, the exercise price and the maturity of the option, and the interest rate.
>
> Such a formula will tell us, among other things, how much the option value changes when the stock price changes by a small amount within a short time. Suppose that the option goes up about $.50 when the stock goes down $1.00. Then you can create a hedged position by going short two option contracts and long one round lot of stock.
>
> Such a position will be close to riskless. For small moves in the stock in the short run, your losses on one side will be mostly offset by gains on the other side. If the stock goes up, you will lose on the option but make it up on the stock. If the stock goes down, you will lose on the stock but make it up on the option.
>
> At first, you create a hedged position by going short two options and long one stock. As the stock price changes, and as the option approaches maturity, the ratio of option to stock needed to maintain a close-to-riskless hedge will change. To maintain a neutral hedge, you will have to change your position in the stock, your position in the option, or both.
>
> As the hedged position will be close to riskless, it should return an amount equal to the short-term interest rate on close-to-riskless securities. This one principle gives us the option formula. It turns out that there is only one formula for the value of an option that has the property that the return on hedged position of option and stock is always equal to short-term interest rate. (Black, 1989: 4)

What you want to maintain is a proportion between being long the stock and short the option so that the portfolio is risk-free; that proportion is the 'delta hedge'. The risk-free interest rate, where volatility is zero, is the balance point that you try to reduplicate every time the stock price changes. Since every time the stock price changes the delta-hedge will change. You then buy or sell the option to maintain the portfolio as riskless; a riskless portfolio will earn the risk-free interest rate, which is usually given by U.S. Treasury bills. Since you can calculate the value of the hedged position by discounting to the present by the riskless rate, and since the hedged portfolio consists of the stock and a delta-hedge of the option, you can calculate the value of the option. Every time there is a directional change in the stock price (it goes up or down) you set the delta-hedge to the risk-free rate and prepare for the next change.

Surfing the volatility wave

It is common lore that traders are risk-takers and the rise of *Texas hold 'em* parallels the rise of derivative markets. However, we will examine the relationship between 'delta-hedging' in options trading and surfing as market-makers often describe themselves as 'surfing the volatility wave' when they are trading. They view the ubiquitous Bloomberg machines in which stock and option prices are rolling by them like waves and are determining when to 'cut in' and make a trade. Option prices are displayed in implied volatilities not in dollars and cents and

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the financial calculations use extensional mathematics and operate in calendar time, which is also extensional.[1] However, those prices are also mediated by the social and psychological processes that make up trading, which Ayache describes as anxiety, inexorability, pain, and joy – a repertoire of Keynes's 'animal spirits'. What they are seeing on the screen are implied volatilities of accomplished trades, which are inflected by affect and emotion. If the efficient market hypothesis is correct, then there is a random portion of a stock's behavior and any stock's return will be a combination of drift and randomness. But the surfing also plays with directional risk and volatility. Surfers are trying to track the movement of the underlying wave through the movement of their feet, which is similar to a way an option tracks the volatility of the underlying stock through delta-hedging and dynamic replication; keeping their balance is a counterpart to delta-hedging and by concentrating on how the wave will break, they are constantly 'discounting' the future volatility to the present.

Big waves are fractal in which segments of the wave are self-similar to the whole wave. The biggest waves, some approaching one hundred feet tall, are directional. However, perhaps the most famous ride in surfing came on August 17, 2000, when Laird Hamilton rode the most 'massive' wave ever; instead of a directional ride (the tallest wave), it was 'shooting the tube' where the volatility enclosed Hamilton. Hamilton is the first person caught surfing such a massive wave; if he slips, he would probably be killed because the break is very shallow on coral. But what makes the ride amazing is how he creatively harnesses the volatility of the wave to navigate through its convexity. Breaking left, you normally use your left hand to steer. But instead, Hamilton instinctively puts his right hand back into the face of the wave to steer, which turned him into the convexity of the wave to balance against its force – as a fellow surfing professional Sam George described it:

> Normally, surfers are dragging this [left] hand along the face. Laird had to drag his right, his back hand on the opposite side of the board to keep himself from getting sucked up in that hydraulic. In the middle of that maelstrom, how did his mind say this is what I have to do. No one has ever ridden as Laird rode on that wave before. So it was the imagination of dealing with that unimaginable energy and coming up with the plan spontaneously. (Aloha Traveler, 2008: 3:22-3:51)

With a backwards flip of his hand, Hamilton opened surfing to a new appreciation of volatility by neutralizing or 'delta-hedging' out directional risk and then stepping into the liquid as he shoots the tube.

What makes his ride an exemplary case of what Randy Martin (2015) called 'risking together' is both its role in the surfing community and how he distinguished the directionality of risk from its volatility. Big wave surfing has always searched for what might be called the peak experience of pure directional plays – the tallest and the fastest. The Teahupoo wave was unique in its convexity, forming an almost perfect tube in which the volatility of what is forthcoming is foregrounded and its directionality backgrounded, especially when compared to riding the tallest waves. It showed that there was an alternative intensity whose cultivation required new techniques to access, which is why it had such an impact on the surfing community as it 'risks together'. Hamilton's amazing steering gesture effectively 'hedges out' directionality by turning his board into a wave that is breaking over and around him, counteracting its thrust. Hedging out directional risk creates a small space of 'buffered volatility' that constantly moves forward as he harvests its momentum to 'shoot the curl'. From then on, it's Laird Hamilton dynamically replicating the interplay between implied (what he thinks the wave will do) and realized (what the wave does) volatilities, as with a flick of his wrist and a twist of his board he hedges the unfolding volatility he feels underfoot.

But how do we fit together these two notions of quantitative and qualitative volatility? Both market-makers and Laird Hamilton have motions of decision-making: when to trade and when to cut into the wave. Surfing also involves its form of 'discounting to the present'; surfers look ahead as the wave breaks in front of them and adjust their feet and body accordingly. But both involve a time of tracking where decision-making isn't part of it and of course the riding of the wave doesn't involve conscious decision-making but adjusting to the volatility of the wave and making the appropriate bodily movements; the 'delta-hedging' against the directionality of the wave isn't conscious but embodied. As Ayache indicates, there is a huge dimension of affect in market-making where each aspect of the quantitative parameters of Black-Scholes has its appropriate qualitative affect: delta-hedging and anxiety, time-decay with inexorability, and convexity with pains and joys.

All financial pricing models in finance presuppose calendar time, which is the infinitely divisible extensional time in which all events take place. Not surprisingly, it is the scientific and mathematical notion of time (both Newtonian and Einsteinian time has no direction – it is reversible) and volatility (standard deviations) and decision-making under uncertainty are assumed to operate in calendar time. However, Derman (2002), introduces another way of calculating volatility based upon the intensity of trading or what he calls "tic-time" or "intrinsic time". All the financial calculations and the models of decision-making underlying trading operate in calendar time. Most pricing models assume that decision-makers follow the dictates of expected utility theory, maximizing utility. It's only with the work of Daniel Kahneman and Amos Tversky that people systematically investigated why people didn't follow expected utility theory, leading to a variety of local but systematic explanations (prospect theory, anchoring, affective biases). But none of these behavioral economic explanations point to the issue of time as a variable; they all assume that time is calendar time.

Tic-time

But what if there was some other time? Derman (2002) proposes that trading may presuppose an event-based or indexical time instead of the abstract calendar time presupposed by finance and Black-Scholes. He calls it "tic-time", which is based upon the frequency of trading – in periods of intense trading, traders try to keep up with one another, noting the "action" around them; traders count "tics", i.e., trading opportunities, and the expected return is measured in units of tic-time, the amount of expected return per tic (not per second, as might be the case for calendar time). Tic-time is tied to trading events as they unfold in indexical time; it's this 'flow' that traders experience as they surf the volatility wave. Derman (2002: 288) captures this move to the indexical and the intentional by readjusting the time differential in the equation for stock price changes:

$$dS_i/S_i = \mu_i\, dt + \sigma_i\, dZ_i$$

drift + random

Calendar time

$$dS_i/S_i = M_i\, d\tau_i + \Sigma_i\, dW_i$$

drift + random

Tic-time

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The first formula says that a small change in the price of a stock is the sum of drift and Brownian components measured in calendar time. The second formula adjusts *dt* to a tic-time differential $d\tau_i$. $d\tau_i$ represents an infinitesimal increment in intrinsic time τ_i, which measures the rate at which trading opportunities for stock_i pass; it counts the intensity of indexical trading events. The symbol M_i represents the expected return of stock_i per unit of its intrinsic time and Σ_i denotes the stock's volatility measured in intrinsic time, as given by the square root of the variance of the stock's returns per unit of intrinsic time.

The stock's trading frequency is the number of intrinsic time ticks for a given stock per calendar second – the trading frequency is a translation of tic-time, which is dimensionless, into ratio-scaled calendar time. For people who trade in intrinsic time, the calendar time between ticks is irrelevant and the only thing that matters is the number of ticks that pass by and the risk and return per tick. Derman (2002: 291) hypothesizes "that short-term stock speculators expect returns proportional to the *temperature* of a stock, where temperature is defined as the product of the stock's traditional volatility and the square root of its trading frequency". The stock's temperature, which is the product of the volatility of the stock in calendar time and its trading frequency in tic-time, "provides a measure of the perceived speculative riskiness of the stock in terms of how it influences expected return" (Derman, 2002: 291). Replacing calendar time with intrinsic or tic-time, Derman derives the traditional Sharpe Capital Asset Pricing Model (CAPM), suggesting that it's possible to rethink much of finance in terms of intrinsic rather than calendar time and then uses tic-time volatility to derive Black-Scholes.

Whereas calendar time is a universal, stock-independent measure, tic time is tied to the frequency of trading; it measures the indexical intensity of trading in real time. Derman then constructs two different expected return and volatility measures, one based on calendar time and the other intrinsic time, and then uses the latter to explain the evolution of market bubbles. When there is intense trading as in speculative booms and busts, traders operate in tic-time, the time of trading as it unfolds.[2] Instead of price changes being calculated over some interval of time (most stock statistics are updated at the end of trading, i.e., a 24-hour interval except for weekends and holidays), the price changes are recorded with each 'tick' or moment of trading. Whereas calendar time is the homogenous, empty time of science and mathematics (derived from Newton's infinitesimal calculus), tic-time is tied to the indexical event of trading. Derman suggests that volatility can be calculated both in calendar and tic-time but that tic-time volatilities will lead to better explanations of the behavior of stock prices in the short-term trading characteristic of the intense trading in booms and busts, where market-makers are trying to keep up with what other traders are doing.

Instead of the homogenous, empty time of Newton, we have the flow of time from the future through the present and to the past, which Bergson (1911) called 'duration'. Duration is the time of affect and emotion, tied to context – it's not a time of punctual decision-making but also caught up in Csikszentmihalyi's (1996) descriptions of 'flow' and peak experiences where you are so absorbed in the task at hand that you lose sense of time.

> Traders speak of their best trading moments in ways that make them sound like mystical engagements. They need to abandon self-consciousness to gain full access to the market's interior and use discipline to block outside contexts from their conscious thoughts and to enhance their abilities to read, interpret, and ultimately merge with the market. Traders often speak of being "in the zone" or of a "flow" experience. In the zone, economic judgments and actions seem to come without effort from the instincts of the trader. The market and the trader merge, giving him special access to the natural rhythms of financial fluctuations. (Zaloom, 2006: 135)

The "time" that Zaloom is talking about is not decision-making under uncertainty but explicitly a flow model in which the trader matches the volatility of the market. The natural rhythms of financial fluctuations are in tic-time, not calendar time. As Derman describes, calendar time is dominant in normal trading when decision-making models are prominent; in intensive trading characteristic of booms and busts, 'flow models' move in tic-time, the time of affect and emotion. The feeling associated with volatility is present in normal trading, as Ayache describes, but becomes the dominant feeling when the market veers off in one direction, which traders describe as 'surfing the volatility wave'.

Decision-making and flow models of subjectivity

Bergson thought that different notions of time were associated with quantitative and qualitative multiplicities (volatilities). He would not have been surprised about the distinction between calendar and tic-time and that financial models of subjectivity operated in extensional time; in *Time and Free Will*, he has an explicit critique of the decision-making model even drawing a tree diagram to illustrate where it goes wrong! Most economic and financial models are derived from Von Neumann and Morgenstern's axiomatization of expected utility and game-theory and use decision-making under uncertainty as their model of subjectivity. However, Keynes suggested another model of subjectivity, using the term 'animal spirits' to explain stock market gyrations, but for fifty years expected utility and game theory dominated finance. The development of behavioral economics by Daniel Kahneman and Amos Tversky began to explain why people didn't follow the dictates of expected utility theory. Although most of the behavioral economic explanations (anchoring, prospect theory) are local forms of everyday reasoning, there is a large affective component. In the beginning of *Thinking, Fast and Slow*, Kahneman uses 'flow' to distinguish two types of thinking; by the end he is talking about "experienced utility" and "experiencing and remembering selves" (Kahneman, 2011: 14).

Trading is clearly a form of decision-making but also involves an affective component ('surfing the volatility wave'); the two kinds of time and volatility interweave in 'market-making' as they do in surfing: there is the decision to pick a certain wave, but the decision is flanked by a tracking and riding of the wave that do not involve decision-making but 'following the flow'. If we think of market-makers sitting in a trading room watching on their Bloomberg machines (often two or three will be on their desks) the cascades of option prices as they decide when to open a trade, we see a Bergsonian interaction between their 'experiencing selves' in the present moment and their 'remembering selves' (their previous trading experiences and the previous prices) as they surf the volatility wave.

The affectual component of trading (and volatility itself) operates in the flow of time given by our experience of the future, present, and past, contrasted to decision-making under uncertainty that operates in 'homogenous empty time' of clocks and calendars in which all events take place; 'flow' phenomena follow the contours of the unfolding of events. Of course, Laird Hamilton's ride was a peak experience after which he sat down, put his head in his hands, and meditated. Flow experiences are periods of maximal creativity when people are so absorbed in a task that they lose sense of time. Flow requires the requisite balance of abilities and goals; too high a goal or aspirations and people get discouraged; not enough challenge, people get bored. Flow is the 'sweet spot' that is described as 'auto-telic' or self-motivating and suggests a different model of subjectivity than decision-making under uncertainty, which is a means-end model.

Perhaps trading and 'surfing the volatility wave' can be seen as the prototype for the interaction of the quantitative and qualitative aspects of volatility. Trading involves two models of subjectivity: an extensional decision-making model and an indexically based intensional flow model. Trading involves both the quantitative and qualitative aspects of volatility; the pricing models and Black-Scholes presuppose decision-making whereas the 'animal spirits' and affect presuppose flow models. The implied volatilities that flash on the Bloomberg machines are mathematically calculated and the volatilities are in calendar time. It's extensional time all the way down. However, decisions to trade are based on 'tracking' the implied volatilities on Bloomberg screens; tracking is closer to a flow model than decision-making – it is like a surfer tracking the waves and then finally deciding which one to cut into. However, the affect that Ayache describes in trading follows the flow of tic time; technical terms like 'delta-hedging' are associated with specific affects such as anxiety. Every act of trading is an interaction between decision-making and flow models; decision-making models have an affective component, especially in times of intense trading. However, the resulting prices are used to calculate implied volatilities that appear on the Bloomberg machines, which are used to calculate the new delta-hedge and expose the trader to the new volatility; the trader waits to 'cut into' the volatility wave, which introduces a new moment of affective mediation until the next trade. Trading is always trying to catch up with itself.

Dance and the turn to randomness

But what happens when one is not trying to duplicate extrinsic movements or changes but instead sample or creatively use directionality and volatility? Randy Martin examines the history of dance, in which postmodern dance might be said to overcome directionality and discover randomness and volatility. For example, in ballet everything was oriented towards the vertical dimension (ballet began in the court of Louis XIV) indexing the king and God. Modern dance, epitomized by Martha Graham, emphasized an inward turn (the contraction) and horizontal movement; postmodern dance, especially in contact improvisation, replaces directional intent with the volatility of contact; "a point of contact between two bodies is what moves the particular dancers, rather than the dancers beginning with intent, an idea that is translated into a gesture, form, or fixed movement vocabulary" (Martin, 2010: 173). The discovery of volatility and randomness in postmodern dance led to questioning how one would control it: in the next step, how much volatility did one play with at the expense of directionality? It is quantitatively expressed in the equation $d(S_t) = \mu S_t dt + \sigma S_t dB_t$ where (S_t) could express the next step: how much of the next step is random or directional? Does art balance directionality versus randomness?

Dance always had to deal with the volatility of movement, but for example in classical ballet, volatility was subservient to a directional vertical orientation, appropriate for the royal court in which the king was a representative of God. Martha Graham, reflecting the modernist turn inward toward subjectivity, created a choreography based upon contraction and release. In the late 1940s and 1950s a former Graham dancer, Merce Cunningham, began collaborating with the composer John Cage to explore a 'choreography by chance' in which random dance sequences that were determined by flipping coins or rolling dice. By creating the narrative sequence out of randomness, they focused on the step or the time-interval out of which dance sequences are built.

Two Cunningham dancers, Joan Skinner and Steve Paxton, refined Cunningham's focus on randomness to invent 'release technique' and 'contact improvisation', which embedded the time-interval with almost ontological significance. As Graham can be considered to have created a new philosophy of dance based upon the inward turn, Skinner and Paxton

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discovered a similar philosophy but focused on randomness and volatility especially at the point of contact.

Perhaps the iconic moment where postmodern dance jettisons directionality is Trisha Brown's famous *Man Walking Down the Side of a Building*, in which her husband, wearing a harness, walks down the side of their apartment building in Soho. Elizabeth Streb repeated the performance walking down the side of the Whitney Museum and said she was completely unprepared for the effects of eliminating traditional directionality:

> There's something Trisha noticed about the dance world, and movement, and what's possible in terms of forces, the use of gravity, where your ground is, what your base of support is, and how you behave when you get into a completely foreign physical situation, spatially. I thought I understood exactly how it was going to feel, so I went to the gym and started doing all these sit-ups, and back extensions and all that, so I thought that's how it's going to feel, like just to stay on the wall, with my feet, just perfectly horizontal to the ground, once I tipped over the top edge of the building, walk down. This was not like that, I mean, at all. The first time I walked down, my balance was so precarious that I was on the head of a pin, and everything I did dislodged that balance. Every time you lift a foot, you're changing your center. So I started to swing: one way, then the other way, which isn't good, because when the rope gets longer and longer, your pendulum gets more and more extreme, you know, side to side, but it was also going in and out when I got a certain distance down. So I had all of this ambient motion, that I was trying to not have occur. (Whitney Museum of American Art, 2010: 1:38-2:22)

The neutralization of the normal effect of gravity leads to a new type of volatility, which appropriately visualizes a "spread": the pendulum movement from "side to side".

In an interesting interview with Slavoj Žižek, Phillipe Petit describes the "negative space" or "void" that he walked on a wire suspended between the Twin Towers of August 7, 1974. Like Elizabeth Streb (who he mentions in the interview), the playing with directionality leads to a new appreciation of the tactile nature of volatility underfoot just as the surfer feels the wave underneath him:

> What attracted me between the towers were not the towers was the negative space I'm talking of a painter that the two man-made buildings created and I wanted to life to that space … The void is sustaining me. Those clouds upon which I walk upon have the density of granite … we think void is nothing and fifty-five years of walking in the void I can tell you the void is filled, filled with power, filled with magic, filled with miracles, filled with God. (Belinski, 2018: 26:05-27:12)

As Deleuze indicated in his book on Francis Bacon, artists make invisible forces visible:

> It is in this way that music must render non-sonorous forces sonorous, and painting must render invisible forces visible. Sometimes these are the same thing: Time, which is nonsonorous and invisible, how can time be painted, how can time be heard? (Deleuze, 2003: 48)

In order to make time visible, you have to capture the bimodal nature of time:

> There is the force of changing time, through the allotropic variation of bodies, "down to the tenth of a second", which involves deformation. And then there is the force of eternal time, the eternity of time … a pure light. (Deleuze, 2003: 54)

Cinema and volatility

Deleuze describes a similar discovery of the volatility of time in cinema except it concerns the film shot and not the dance step. By freeing the step from the directionality of the traditional

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dance narrative, postmodern dancers explored the interval as containing other potentials for development that directional narratives had obscured or covered over. The same problem developed in cinema, especially the standard narrative films that Hollywood created after World War II when the United States was in ascendance but Europe lay in ruins. Deleuze describes the post-war development of a new cinematic image of time. In his *Cinema* books, he traces the development of the movement-image to the time-image, an example of which is the appropriately named ‘crystal-image’. Deleuze reveals how the crystal-image suspended the directionality of the movement-image, leading us to focus on the newly revealed temporal dimensions of the cinematic image when it is not narratively or spatially tied to the past or the future as in directional action. Deleuze says:

> movement can tend to zero … But this is not what important, because movement may also be exaggerated, be incessant, become a world movement, a Brownian movement, a trampling a to-and-fro, a multiplicity of movements on different scales. What is important is that the anomalies of movement become the essential point instead of being accidental or contingent. (Deleuze, 1985: 128)

A Brownian movement, which presents randomness and volatility, is also fractal, self-similar “on different scales”. The time-image suspended the directionality of the movement-image and replaced the fractal volatility as the framework of the cinematic image. A particular type of time-image was the embodiment of the self-similar structure of fractals – the crystal-image, with its mirror images of time. The fractal nature of the time-image means that the smallest movement contains a microcosm of the whole. Yet the regularities of volatility and what they inspire can’t be seen except by removing the directionality of movement. The suspension of traditional narrative directionality also suspends means-end decision-making rationality:

> Having lost its sensory motor connections, concrete space ceases to be organized according to tensions and resolutions of tension, according to goals, obstacles, means, or even detours. (Deleuze, 1989: 128-29)

In the crystal-image, “there are direct presentations of time” because “we no longer have an indirect image of time which derives from movement, but a direct time-image from which movement drives” (Deleuze, 1989: 129). Deleuze knew that his association with the time-image and Brownian motion installed randomness and volatility as the frameworks for cinematic analysis. Deleuze followed Benoit Mandelbrot’s lectures in Paris; Mandelbrot was the discoverer of fractal geometry and his lectures about fractals and stock price movements were very famous in Paris (he was also a PhD advisor to Eugene Fama, the discoverer of the efficient market hypothesis); Deleuze wrote the penultimate chapter of *A Thousand Plateaus* about fractals and Mandelbrot (Deleuze and Guattari, 1988). Brownian motion was the model for stock price movements in the Black-Scholes equation; the efficient market hypothesis assumed that stock price movements were volatile because of the random arrival of information on the stock market.

Both dance and cinema eliminate directionality to discover volatility and randomness. Bergson sees mathematics (number), language (semantic structure), and cinema (the shot) as spatializing and objectifying movement. However, Deleuze disagreed with Bergson about cinema and devotes two volumes to development of the movement-image to time-image; when the narrative directionality of the movement-image is neutralized, the time-image reveals the fractal structure of Brownian movement in the appropriately named ‘crystal-image’ (crystals are fractal). In the case of surfing, large waves, especially the ‘fingers’ where the waves break, are fractal, and postmodern dance experimented with ‘hedging’ to discover the creativity of randomness.

Rhetoric and volatility

Bergson antedated the linguistic turn brought about by Claude Levi-Strauss and structuralism. However, he didn't talk about language in detail and never wrote about the linguistic representation of time; although he followed developments in physics and biology, he never mentions the work of Ferdinand de Saussure or other structural linguists. In his essay in this volume, Ackbar Abbas (2023) argues that Paul De Man is the premier literary theorist of volatility and that his work on rhetoric fills the linguistic gap. Unlike Bergson, De Man used the insights of structural linguistics to analyze the relations between language and rhetoric.

In Western philosophy, rhetoric has been the handmaiden to grammar and logic. Grammar produces the sentences that logic evaluates as true or false. Rhetoric is the use-value of language and the art of persuasion. De Man opposes the place of rhetoric in the trivium arguing that is the process by which "signs give birth to other signs" (De Man, 1979: 9). Although De Man is often viewed as a 'deconstructionist', Abbas suggests that he was the discoverer of volatility in literary criticism. In one of the most famous essays in deconstructionist literature, 'Semiology and Rhetoric' (also the first chapter of *Allegories of Reading*), he revises the role of rhetoric in the Western trivium; his argument installs the qualitative counterpart to volatility in grammar and then shows how the qualitative counterpart to delta-hedging produces the undecidability of rhetorical interpretation.

Black-Scholes can be divided into three parts. First, volatility replaces the directionality of expected return as the unknown parameter. The actual directional trade (the stock price goes up, down, or remains constant) is a particular actualization of the volatility spread. The second step is 'delta-hedging'. In order to price the option, one needs to set up a delta-hedge against the direction of the price change, which then balances the 'replicating portfolio' at the risk-free interest rate. The final step is 'dynamic replication'. For each price change, one rebalances the delta-hedge so that one can be exposed to the ensuing volatility until the option expires.

De Man's argument in 'Semiology and Rhetoric' also comes in three parts. The first step is realigning grammar and rhetoric and installing semantic volatility into language. De Man explicitly uses Roman Jakobson to establish that rhetoric aligns with grammar and is not marginal to it; it places rhetoric's indirection in the heart of language and the ensuing 'semantic volatility' makes linguistic ambiguity and creativity possible.

The second part of the argument is more speculative but goes to the heart of the deconstructionist reading of rhetoric and its role in the trivium. It concerns the 'metafigural' and is taken from Jakobson's comments about metalanguage and Tarski's semantic definition of truth, which introduced meta and object languages into philosophical and linguistic discourses. De Man (1979: 17) argues that in these metafigural functions (the "rhetorization of grammar" and the "grammatization of rhetoric") directional rhetorical readings cancel each other out and end up in "suspended ignorance". The final step is that the resulting undecidability is a feature of rhetorical interpretation of language itself. Each subsequent rhetorical interpretation will end up in the same "suspended ignorance" and the 'delta-hedging' of rhetorical interpretations confirms the fundamental undecidability of language.

Linguistic argument for the volatility of rhetoric

Installing semantic volatility into sign and grammar

In the classic Western tradition, rhetoric is the art of persuasion that uses the volatility of affect to achieve directional ends; a common example is of demagogues using oratory to incite

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the passions (volatility) in crowds (directionality) for untoward ends. A classic example is Marc Antony's speech inciting the mob against Brutus and his co-conspirators in Shakespeare's *Julius Caesar.* De Man objected to seeing rhetoric as the art of persuasion and secondary to grammar and logic. He insisted that rhetoric operated through deflection/indirection and used structural linguistics to show that rhetoric was at the heart of grammar rather than playing an ancillary role. The volatility of rhetoric was not in inciting passions but rather creating the 'undecidability' of interpretation.

In traditional theories of the trivium, if grammar works with logic and is transparent to it, then there is no volatility in semantic meaning. There are no ambiguous sentences because every linguistic sign has a fixed referential meaning. De Man argues that logic and grammar do not work together and against standard theories of the linguistic sign that saw a direct route from the signifier to the signified, from word to denotation. Instead, he invoked Peirce's "unfathomable definition of the sign" where rhetoric is the generative principle in which "one sign gives birth to another" and thus "radically suspends logic and opens up vertiginous possibilities of referential aberration" (De Man, 1979: 10); semantic volatility is built into semiosis and the structure of language. No longer is there a direct dyadic route from signifier to signified but a triadic relationship in which every sign conveys its object to another sign in a potentially infinite semiosis.

If rhetoric is central to grammar, then indirection, ambiguity, and referential aberration are built into language; the linguist Edward Sapir said that unlike mathematics, in natural languages "all grammars leak" and leakage is responsible for the creativity of language:

> The fact of grammar, a universal trait of language, is simply a generalized expression of the feeling that analogous concepts and relations are most conveniently symbolized in analogous forms. Were a language ever completely "grammatical", it would be a perfect engine of conceptual expression. Unfortunately, or luckily, no language is tyrannically consistent. All grammars leak. (Sapir, 1921: 38-39)

In order to divorce the volatility of interpretation from the volatility of affect, De Man turns to linguistic analyses of the linguistic sign and grammar. In 'Semiology and Rhetoric', he relies upon Jakobson's two classical articles about aphasia and the functions of communication where Jakobson places rhetoric at the heart of Saussure's account of the linguistics sign. In his analysis of the linguistic sign, Saussure suspended the directionality of speech (or 'parole') and focused on the systematic properties of language much as Deleuze did for the cinematic image. By suspending traditional narrative directionality, he reveals the systematic time structure of the crystal-image, which is fractal.

Saussure, peering into the structure of the linguistic sign free from the directionality of parole, saw it as embedded in a grammatical language, which systematically correlated differences in sound with differences in meaning. Grammar combines a 'paradigmatic' axis of selection with a syntagmatic axis of combination. For example, in the initial context of '_at', in English one can substitute c, b, s, m, and f and get the words *cat, bat*, *sat*, *mat*, and *fat*. The context allows similar sounds (they are phonemes in English) to be associated with different words in the initial context of a-t. *Cat*, *bat*, *sat*, *mat*, and *fat* make up the paradigmatic axis or axis of selection whereas the words combine the different letters into a grammatical utterance; the axis of combination, or the syntagmatic axis, is what is actually uttered, while the axis of selection is virtual, like the counterfactual alternatives in a volatility spread. Since metaphors compare things to one another and speech is the indexical unfolding of the syntagm, the two axes of the linguistic sign and grammar are metaphorical and metonymic. Rhetoric is built into the nation of the linguistic sign and grammar. In his discussion of the poetic function, Jakobson summarized:

> … we must recall the two basic modes of arrangement used in verbal behavior, selection and combination. If "child" is the topic of the message, the speaker selects one among the extant, more or less similar, nouns like child, kid, youngster, tot, all of them equal in a certain respect, and then, to comment on this topic, he may select one of the semantically cognate verbs-sleeps, dozes, nods, naps. Both chosen words combine in the speech chain. The selection is produced on the base of equivalence, similarity and dissimilarity, synonymity and antonymity, while the combination, the build up of the sequence, is based on contiguity. The poetic function projects the principle of equivalence from the axis of selection into the axis of combination. (Jakobson, 1951: 358)

The axis of selection will be the basis for metaphor (similarity or equivalence) and the axis of combination will be the basis for metonymy (indexicality). Although metaphors are assumed equivalences, Jakobson suggests that a continuum extends to its opposites, "dissimilarity" and "antonymity". For example, in poetry meter creates equivalences among syntagms; the poetic function thus introduces a metaphorical dimension (equivalence) into metonymic grammatical structures by seeing parallelisms (including "dissimilarity", and "antonymity") across syntagms, which can be of different lengths ranging from single words to verses to whole poems and "projects the principle of equivalence from the axis of selection into the axis of combination".

De Man, building upon Jakobson, sees rhetoric (metaphor and metonymy) within the linguistic sign and grammar, not external to it. Although De Man doesn't mention grammatical analogy, Jakobson wrote extensively about Sapir and Whorf, who thought that grammatical analogies were responsible for our conceptions of time and space. Grammatical analogy is made possible by "leakage"; if there was a grammatical distinction that applied to two different types of meaning, there would be the possibility of a grammatical analogy between those two types of meaning. The importance of grammatical analogy is that it extends rhetoric beyond tropes or figures of speech but maintains "indirection" or deflection as the defining feature of rhetoric.

The metafigural: Suspending directionality

De Man (1979) builds upon Jakobson's discussion of the metalingual and poetic functions by formulating two 'metafigural' functions of rhetoric. He extends Jakobson's identification of metaphor with the paradigmatic axis and metonymy with the syntagmatic unfolding of discourse. However, the 'metafigural' is a translation of Jakobson's metalingual function to apply to tropes and figures of speech; Jakobson's metalingual function is the reflexive use of language to talk about language and De Man's 'metafigural' is the use of language to talk about tropes or figures of speech. For a logical language in which all sentences were either true or false, a semantic contradiction would imply that anything could be deduced and not only infect the particular sentence but all of language itself. Tarski's answer was to give a semantic definition of truth in a metalanguage that took the original language as an object language. Jakobson pointed out that all natural languages had a metalingual function: every language has speech about speech and contains glossing or giving definitional equivalences: *An optometrist is an eye doctor*. There is an unending hierarchy of object and metalanguages, which is duplicated in that any metapragmatic statement has its own pragmatics; any speech act of glossing has its own pragmatics and any metafigural discussion of tropes will have its own rhetorical pragmatics. The recursion of metalanguages that focused on reference (metasemantics) was very important for decompositional and generative semantics as they analyzed complex concepts as the logical function of simpler ones.

De Man's (1979: 16) analysis of the metafigural starts with the case where a syntagm has multiple rhetorical interpretations, which he calls the "rhetorization of grammar". His example is the famous last line of Yeats's poem 'Among School Children': "How can we know the dancer from the dance?", which can be read as a literal or rhetorical question and either interpretation will be supported by the syntagmatic unfolding of the poem. By controlling the syntagmatic dimension, the focus can be the play of similarity and dissimilarity among alternates on the axis of selection. Since the two readings have similar backing throughout the whole poem, neither reading "can be given priority over the other" since neither can exist in the other's absence"; we seem to end up "in a suspended ignorance" between the readings (De Man, 1979: 17).

The other metafigural function is the 'grammatization' of rhetoric, which describes how tropes interact in the syntagmatic unfolding of the text. His example is taken from Proust's *Swann's Way*, in which the focus is on the interplay between tropes as the syntagmatic axis is unfolding. The passage is about the superiority of metaphor over metonymy but "the assertion of the mastery of metaphor over metonymy owes its persuasive power to the use of metonymic structure" (De Man, 1979: 15), which applies Jakobson's words about metaphor and metonymy to an argument about freedom and creativity:

> By passing from a paradigmatic structure based on substitution, such as metaphor, to a syntagmatic structure based on contingent association such as metonymy, the mechanical, repetitive aspect of grammatical forms is shown to be operative in a passage that seemed at first sight to celebrate the self-willed and autonomous inventiveness of a subject … Yet, our reading of the Proust passage shows that precisely when the highest claims are being made for the unifying power of metaphor, these very images rely in fact on the deceptive of semi-automatic grammatical patterns. (De Man, 1979: 15-16)

Although the text asserts the superiority of metaphor over metonymy and rhetoric over grammar, it also shows how that assertion is deconstructed by the syntagmatic structures of grammar. At first glance, the grammatization of rhetoric ends up in a negative certainty, which would be an affirmation of deconstructive readings. De Man (1979: 17) then follows his deconstruction of metaphor in Proust with perhaps his most controversial statement that deconstructionism will become "the task of literary criticism in the following years".

Replicating undecidability

What is not recognized by many interpreters of De Man's statement is that it was meant to be ironical and not a prediction of things to become. De Man uses the mutual influence of metaphor and metonym as the basis for criticizing overzealous and perhaps naive acolytes of deconstructionism who are convinced too early by a deconstructionist reading. The argument draws upon Tarski's work on defining truth, which Jakobson's references in 'Closing Statement: Linguistics and Poetics'. After we have deconstructed the assertion that metaphor is superior to metonymy and we then ask the further metafigural question, "whether the rhetorical mode of the text in question is metaphor or metonymy", it is "impossible to give an answer" (De Man, 1979: 18) because the narrator is a combination of a grammatical person (often the third person) and a rhetorical voice, and that combination is responsible for whatever is said or narrated. It is the metafigural counterpart to asking whether a sentence is true or false, which is a metasemantic question. The assertion of the superiority of metaphor is deconstructed by the metonymic structures of grammar but that metonymic structure "has as its subject a voice whose relationship to this clause is again metaphorical" (De Man, 1979: 18); the narrator who deconstructs metaphor by metonymy is itself a metaphor (has a voice). What results is not a simple assertion of the superiority of deconstructionism but an unending succession of readings that end up in suspended ignorance – it's the rhetorical counterpart to the self-reflexivity of the liar's paradox and leads to the same suspended ignorance that the rhetorization of grammar ends up in:

> We end up therefore, in the case of the rhetorical grammatization of semiology, just as in the grammatical rhetorization of illocutionary phrases, in the same state of suspended ignorance. Any question about the rhetorical mode of a literary text is always a rhetorical question which does not even know whether it is really questioning... Literature as well as criticism – the difference between them being delusive – is condemned (or privileged) to be forever the most rigorous and, consequently, the most unreliable language in terms of which man names and transforms himself. (De Man, 1979: 19)

The grammatization of rhetoric ends up in the same suspended ignorance or indeterminacy as the rhetorization of grammar. Both metafigural functions involve directional interpretations (rhetorical versus literal, metaphor versus metonymy) but they hedge each other out, leaving us in suspended ignorance to the next moment of interpretation as the undecidability dynamically replicates through language.

Conclusion

Volatility is always present in movement but all we actually see is a mixture of directionality and randomness in which directionality often dominates. However, in the twentieth century, mathematicians and artists discovered randomness as independent from directionality and in each area it takes its own development, as the reaction is against traditional forms of movement in order to discover volatility. By suspending traditional narrative movement, the interval or step is restructured and reconfigured and these discoveries are dynamically replicated as new sources of volatility.

From these historical examples, we saw that Black-Scholes abandoned the directionality of expected return and turned to volatility when pricing options. The dynamic replication of delta-hedging established a risk-free point of balance from which options could be priced. Surfing went from a focus on directionality to exploring volatility, only because Laird Hamilton 'delta-hedged' the volatility of the wave and was able to maintain his balance. Postmodern dance eschewed traditional forms of directionality in classical ballet and modern dance, even explicitly experimenting with randomness and contact improvisation. Cinema's time-image suspended the narrative directionality of the movement-image to discover the fractal structure of Brownian movement. In our most elaborate example, when rhetoric displaced the primacy of logic for grammar, semantic volatility was introduced as not a feature of the use of language but at the heart of language. The suspension of directionality installs volatility at the heart of movement and asks how to create a new narrative out of that volatility. In derivative finance, dynamic replication consists of repeating delta-hedging to allow the trader to face volatility afresh. In surfing, it consists of counteracting the directionality of the wave as you 'shoot the tube'. In dance, it is suspending the vertical or inward turn as you discover the volatility in the next step. In cinema, it is suspending the narrative coordination of space and time in the movement-image to uncover the volatility of time in the crystal-image. And in language, it is suspending the directionality of reference to allow rhetoric to install semantic volatility and undecidability in the heart of language.

Notes

1. Implied volatilities are discovered by inserting the traded option price in an inverted Black-Scholes equation and calculating the underlying stock's volatility; it is a form of post-hoc calibration that calculates the stock volatility from the option price because the option price is known because it has been traded.
2. For example, if you are driving on a highway and there is a sudden thunderstorm, the changing intensity of the drops on the windshield ('tic-time') causes you to slow down.

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