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The Journal of Mind and Behavior
Winter 1993, Volume 14, Number 1
Pages 13–26
ISSN 0271–0137

CPU or Self-Reference: Discerning Between Cognitive Science and Quantum Functionalist Models of Mentation

Kim McCarthy

University of Oregon and Columbia College Chicago

and

Amit Goswami

University of Oregon

The quantum functionalist model of mentation provides an explanation of conscious and unconscious perception without the postulation of a central processing unit (CPU). Based on Goswami's (1989, 1990) idealist interpretation of quantum mechanics, the quantum model posits a dual quantum/classical system for the mind–brain with which consciousness is linked via self-reference. A comparative analysis of word-sense disambiguation data is conducted with a cognitive science model derived from the Posner and Snyder (1975b) facilitation and inhibition and the Rummelhart, McClelland, and PDP group's (1986) parallel–distributed–processing theories. A new line of experiments is proposed which distinguishes between the two models.

In a previous paper in this journal, one of us (Goswami, 1990) developed a mind–brain–consciousness model (called quantum functionalism) based on quantum measurement theory and the philosophy of monistic idealism. This model solves some of the difficult problems of the mind–body problem: the problem of mind–brain identity, the problem of cause-effect relation (free choice), and the problem of self-reference. In contrast, in classical function-

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Thanks are due to Dr. Michael Posner for many helpful comments and for attracting our attention to the work of his group. We also thank Dr. Richard Rankin for unwavering support for this work. Thanks are also due to Drs. Shawn Boles, Nora Cohen, and Henry Dizney for helpful discussions. Finally, we thank Maggie Goswami for a careful editing of the manuscript. Requests for reprints should be sent to either Amit Goswami, Ph.D., Institute of Theoretical Science, University of Oregon, Eugene, Oregon 97405; or Kim McCarthy, Ph.D., Department of Liberal Education, Columbia College Chicago, Chicago, Illinois 60605.

alism, the identity of classical computer states and mental states is postulated as a form of psychophysical parallelism, freedom of choice is denied any validity, and the problem of self-reference remains unsolved. Finally, the quantum model incorporates classical functionalism in the limit of conditioned stimuli (classical correspondence). Thus, the quantum model has demonstrated superiority.

Nevertheless, one can ask if there are experimental data that prove the superiority of the quantum model over cognitive science classical functionalist models (McCarthy, 1990). In this paper, we will first examine one class of word-sense disambiguation experiments by Marcel (1980) that seems to possess the power to distinguish between the classical and quantum models as an experimental question and which involves both conscious and unconscious perception events. Next we outline proposed future experiments that can amplify this distinction.

We will begin, however, with a brief review of the quantum model as it relates to the word-sense disambiguation experiments.

Review of Quantum Functionalism

Quantum functionalism is a generalization of the functionalist analogy of the mind–brain as a computer. But instead of a classical computer, it is proposed that the correct metaphor for the mind–brain is a dual quantum/classical system (Goswami, 1990). Crucial to this model is a consciousness-based interpretation of quantum mechanics that is founded on the following three premises: (a) quantum objects remain in potentia as formless ideas (akin to Platonic archetypes) that are mathematically described as wave functions, or coherent superpositions of probability-weighted possibility structures, until consciousness collapses the wave functions, leading to their manifestation in the world of appearance; this is basically an idealist ontology; (b) the collapse of the quantum wave function by consciousness is a discontinuous act of choice; and (c) a collapse, or quantum measurement, can be said to be complete only when mind–brain awareness, arising self-referentially, is present in the event of collapse.

Before we discuss how quantum functionalism can be applied to the understanding of the word-sense disambiguation data, it is important to see precisely how consciousness is looked upon in this quantum/idealistic view as compared to the cognitive science models. The word *consciousness* has three different connotations. First, by consciousness one often means a field of consciousness, sometimes referred to as the mind field or global workspace (Baars, 1988); in the quantum theory of consciousness, this is identified as awareness. Second, consciousness sometimes refers to what we will call objects in consciousness, such as thoughts and feelings, that arise and pass away in the field that we call awareness. An apt analogy is the movement of material objects in ordinary space. It is assumed that quantum mechanics applies to the movement of mental objects in awareness. Third, consciousness refers to the subject of consciousness, the experiencer and/or witness. In quantum functionalism, this is the self of self-reference that simultaneously arises with awareness in the event of a measurement (Goswami, 1990). Consequently, no central processing unit (CPU) is needed in acts of conscious awareness.

The key point is that in the idealist interpretation of quantum mechanics, consciousness is regarded as the ground of being for objects, both mental and physical, and it manifests as the self/subject co-dependently with the objects. It is a monistic view of reality based on consciousness as opposed to the monistic view of material realism (on which cognitive science models are based) in which reality is based on matter.

In this way, a conscious event in the quantum model is defined by the discontinuous event of collapse (by consciousness) of the state of an object in the presence of awareness. If there is no awareness, the event is unconscious. Thus there is a clear distinction between conscious and unconscious perception of an object.

The primary purpose of this paper is to show that with this distinction achieved in quantum theory between conscious and unconscious perception events, we can find a better explanation for the Marcel (1980) data than can the cognitive classical functionalist model which needs the gratuitous postulate of a central processing unit in the brain to accommodate the same data. Secondly, we will discuss a new line of possible cognitive experiments that will enable us to discern the quantum model from the cognitive model from an empirical point of view.

In the following section, we will review the Marcel data and discuss how existing cognitive models and the present model deal with that data.

Word-sense Disambiguation Experiments: The Marcel Data

The Marcel (1980) data involve measuring the recognition time for the last word in strings of three words such as HAND–PALM–WRIST and TREE–PALM–WRIST where the middle ambiguous word is sometimes pattern-masked so that it can be perceived only unconsciously. The effect of pattern-masking seems to be to remove the congruent (as in the case of HAND above) or incongruent (as in the case of TREE above) effect of the first (priming) word on the recognition time.

The no-mask condition, where the subjects are aware of the second word, supports what is called the selective theory of the effect of prior context in word recognition (Selfridge and Neisser, 1968). In the congruent case, the "hand" meaning of the unmasked polysemous word PALM is facilitated by the associated meaning of the prime word HAND, while the "tree" meaning of PALM is inhibited. Therefore, the response time to WRIST receives facilitation and no inhibition. The opposite is true for the incongruent case: the "tree" meaning of PALM is selected, which has no association with WRIST, and hence the response time for WRIST is increased. If the mind–brain is looked upon as a classical computer, as in classical functionalism, then the computer seems to operate in a serial, top-down, linear, and unidirectional fashion in this kind of situation.

However, when the polysemous word is pattern-masked, both its meanings seem to be available in the subsequent processing of information, since the congruent and incongruent conditions take similar recognition times. Marcel noted that a "nonselective" theory must apply to the unconscious identification. It appears that such a nonselective theory can be based on parallel processing, in which multiple units of information are simultaneously processed with feedback included (technically, this is called parallel distributed processing with delta rule—abbreviated as PDP–D). Parallel processing models are an example of the bottom-up "connectionist" approach to artificial intelligence machines in which the connections among the various components play a dominant role. During the first phase, the input is presented and moved forward through the network to compute the output value for each associative or connecting unit. During the second phase, a backward pass through the network takes place and appropriate weight changes are made for each of the associative or connecting units. The two-phase procedure iterates until the system settles into a "best fit" solution defined as the simultaneous satisfaction of multiple constraints (Rumelhart, McClelland, and the PDP Research Group, 1986).

To summarize, classical functionalist models that are linear and selective have no difficulty in explaining the effect of biasing the context in cases where no masks are used, but these models cannot explain the change that occurs in the unconscious perception experiments with pattern masking. The PDP–D nonselective theory may fit the case of unconscious awareness, but cannot explain both sets of data in a coherent fashion.

A cognitive solution put forth by Michael Posner (Posner, 1973, 1978; Posner and Boies, 1971; Posner and Klein, 1973; Posner and Snyder, 1975a, 1975b) invokes attention as the crucial ingredient for distinction between conscious and unconscious perception. Attention comes with selectivity; thus, according to Posner, we act as a serial processing computer and select one of two meanings when we are attentive, as in conscious perception of the ambiguous word in the Marcel experiment. However, when we are not attentive, there is no selection; the mind–brain's computer acts in the parallel processing (PDP–D) mode. Thus both meanings of an ambiguous word are perceived, as in the unconscious perception of pattern-masked words in the Marcel experiment.

According to Posner, a central processing unit switches attention on or off (Posner and Klein, 1973). By invoking a central processing unit to switch attention on or off, Posner can invoke either selective serial processing or nonselective parallel processing.

But nobody has ever found a central processing unit in the mind–brain. Moreover, a central processing unit raises the specter of the homunculus inside the brain. Francis Crick (1978) alludes to the problem in the following anecdote:

> Recently I was trying to explain to an intelligent woman the problem of understanding how it is we perçeive anything at all, and I was not having any success. She could not see why there was a problem. Finally in despair I asked her how she herself thought she saw the world. She replied that she probably had somewhere in her head something like a television set. "So who," I asked, "is looking at it?" She now saw this problem immediately. (p. 224)

We may as well face it! There is no local homunculus, or central processing unit, sitting in the brain that switches attention, that interprets and ascribes meaning to all the actions of the mental conglomerates, tuning the channels from a control room. Suppose, on the other hand, that when somebody sees a pattern-masked word that has two possible meanings, the mind–brain becomes a quantum coherent superposition of two states, each state carrying one of the two meanings of the word. This assumption can explain both sets of Marcel data—both conscious and unconscious perception—without invoking a central processing unit.

The quantum mechanical interpretation of the unmasked congruent case is that the contextual word HAND projects out of the dichotomic word PALM (a coherent superposition) the state corresponding to the "hand" meaning (that is, the wave function collapses with the choice of "hand" meaning only). Since this state has a large overlap (positive associations are expressed in quantum mechanics as large overlaps of meaning between two states) with the state corresponding to the final word WRIST, the recognition of WRIST is facilitated.

Similarly, in the quantum model description of the unmasked incongruent case, the contextual word TREE projects out the state with the "tree" meaning of the coherent superposition state PALM, the overlap of meaning between TREE and WRIST is small, hence the inhibition. However, in the pattern-masked case, both congruent and incongruent, PALM is unconsciously perceived and therefore there is no projection of any particular meaning, no collapse of the coherent superposition, and hence equal recognition times.

Notice that in this model, awareness plays a role similar to the role of attention in the Posner model. But a central processing unit is not needed since in conscious perception, awareness of the collapsed object arises simultaneously and self-referentially with the conscious choice of one meaning.

Estimates of Probabilities Predicted by the Different Models

We will now quantitatively compare the predictions of the Posner and quantum models with the Marcel data and show that the quantum model better fits the data. Note that in the Posner model, the serial mode applies for conscious perception events and the PDP–D mode applies for unconscious perception.

Posner Model in the Serial Mode (Conscious Perception)

In the serial model the total probability of recognition of the final word for any three-word string is the product of two probabilities P(first→second) x P(second→third). The serial model operates unidirectionally and therefore the probability of a latter event can depend upon a former event but not vice versa. The probability for each event depends on whether the word association is positive or negative; the probability is enhanced in the former case (P_+) and inhibited (P_-) in the latter case.

In the unmasked condition of the congruent case (HAND–PALM–WRIST) of the serial model, the probability of recognizing the "hand" meaning of PALM is enhanced [P_+] due to its association with the priming word HAND; the probability of recognizing WRIST receives triple enhancement [P_{+++}] from the associations between HAND and PALM, HAND and WRIST, and PALM and WRIST. The total probability is the product $P_+(\text{Hand}\rightarrow\text{palm})$ x $P_{+++}(\text{Palm}\rightarrow\text{wrist})$. Because of the enhancement of the probabilities, the response time is facilitated.

In the unmasked incongruent case (TREE–PALM–WRIST), the serial model notes that the probability of recognizing the "tree" meaning of PALM is enhanced [P_+] due to its association with the priming word TREE; and the probability of recognizing WRIST is inhibited [P_-] in that it is not associated with the "tree" meaning of PALM. The total probability is thus $P_+ P_-$, and the response time is vastly inhibited. The serial model thus predicts vastly different probabilities and recognition times for the congruent and incongruent cases in agreement with the Marcel data.

Posner Model in the PDP–D Mode (Unconscious Perception)

In the PDP–D model the probability of each event depends nonlinearly and recursively on all events. In addition, unlike the serial model, the initial information is perceived with equal emphasis—it is only through iteration that differences in emphasis between individual units occur in the PDP–D model (Rummelhart et al., 1986). Thus in the PDP–D model, dividing the probabilities into serial steps is not useful. Instead, a rough estimate of the probability is obtained by counting the number of positive word associations that lead to probability-enhancement and the number of negative word associations that are probability-quenching.

For example, in the congruent case of the pattern-masked condition, the PDP–D model notes three enhancing associations $[P_{+++}]$: the "hand" meaning of PALM is associated with both the prime word HAND and the target word WRIST; in addition, the prime word HAND is also associated with the target word WRIST.

In the incongruent case for the pattern-masked condition, the association between the "tree" meaning of PALM and the prime word TREE is perceived and functions as a competing association $[P_{-}]$. But the "hand" meaning of PALM is not inhibited, allowing its association with WRIST, which is a positive association. Therefore, the predicted incongruent pattern-masked probability $[P_{-+}]$, appears to be significantly less (which means longer response time) than the pattern-masked congruent case $[P_{+++}]$. Thus, if our crude analysis holds, there seems to be a significant difference between the predicted response times for the congruent and incongruent cases in quantitative disagreement with the Marcel data.

Thus the PDP–D model, although expected to do better than the serial model for the pattern-masked Marcel data, quantitatively still predicts the response time for the congruent case to be significantly shorter than the incongruent case, whereas experimentally, there is virtually no difference in the response times.

Quantum Model

In the quantum model, events retain the unidirectionality of the serial model, but like the PDP–D model, multiple meanings are accessed when the polysemous word is perceived unconsciously so that its coherent superposition is not collapsed. Thus, multiple meanings are accessed without postulating back propagation.

We need to introduce a special notation for depicting and calculating the quantum probabilities. There is an initial state, there is a final state, and there is the probability amplitude that the system begins in the initial state I and ends up in the final state F. This is depicted as follows:

<system ends in final state F | system begins in initial state I>

Here the two brackets $<>$ signify "the amplitude that." Also, by convention the expression to the right of the vertical line in the middle is always the initial condition, and the one at the left is the final condition. Following Dirac (1947), we will shorten the notation and write the same amplitude as

$$<F|I>$$

An important implication of the Dirac notation is that a quantum mechanical state is represented as $|I>$ (called a ket) or $<F|$ (called a bra) depending on whether it is the state with which we start or with which we end. Finally, the probability of the event that begins with the state $|I>$ and ends with the state $<F|$ is given by the (absolute) square of the amplitude $|<F|I>|^2$.

If there is an intermediate state i, then the amplitude is a product of two amplitudes: the amplitude for starting with I and ending with i, and the amplitude for starting with i and ending with F. In Dirac's notation we write

$$<F|i><i|I>$$

For the unmasked congruent case, the prime word HAND projects out the "hand" meaning of the dichotomic word PALM (P_+); the wave function is collapsed because PALM is perceived consciously. The probability of the recognition of the target word is enhanced due to its association with the "hand" meaning of PALM [P_+]. In Dirac notation the relevant amplitude is

$$<\mathrm{WRIST}|\mathrm{HAND}><\mathrm{HAND}|\mathrm{HAND}>$$

and its square is equal to $P_+ P_+$.

Under the unconscious conditions, the word PALM is perceived as a coherent superposition of hand and tree (assuming that the two states come with the same phase)

$$(1/\sqrt{2})(|\mathrm{HAND}> + |\mathrm{TREE}>)$$

The factor $1/\sqrt{2}$ is necessary so that the overall probability is normalized to 1. The probability of the entire event HAND→PALM→WRIST is then given as

$$\begin{gathered}1/2(<\mathrm{WRIST}|\mathrm{HAND}><\mathrm{HAND}|\mathrm{HAND}> + \\ <\mathrm{WRIST}|\mathrm{HAND}><\mathrm{TREE}|\mathrm{HAND}> + \\ <\mathrm{WRIST}|\mathrm{TREE}><\mathrm{TREE}|\mathrm{HAND}> + \\ <\mathrm{WRIST}|\mathrm{TREE}><\mathrm{HAND}|\mathrm{HAND}>)^2\end{gathered}$$

Only the first term of the sum within the parenthesis is large and its square is $P_+ P_+$. Hence, to the extent that the rest of the terms above can be ignored, the probability is $1/2P_+ P_+$— of the same order as the unmasked case.

The incongruent case provides a more interesting prediction in the quantum model. First, note the unmasked condition. Here the probability of recognizing the "tree" meaning of PALM is enhanced (P_+), because the corresponding state is projected out by the prime word TREE. This occurs only because awareness is engaged, which collapses the coherent superposition. The subsequent amplitude of <WRIST | TREE> is, of course, small, P_-. The total probability is $P_+ P_-$, substantially less than the congruent case and in agreement with the Marcel data.

Now here lies the important predictive distinction of the quantum model over the cognitive. Let's look at the probabilities of the incongruent pattern-masked condition. In Dirac notation, the probability now is

$$\begin{aligned}&1/2[\langle \text{WRIST} | \text{HAND} \rangle \langle \text{TREE} | \text{TREE} \rangle + \\ &\langle \text{WRIST} | \text{HAND} \rangle \langle \text{HAND} | \text{TREE} \rangle + \\ &\langle \text{WRIST} | \text{TREE} \rangle \langle \text{HAND} | \text{TREE} \rangle + \\ &\langle \text{WRIST} | \text{TREE} \rangle \langle \text{TREE} | \text{TREE} \rangle]^2\end{aligned}$$

Again, the first term within the brackets is the large and relevant one; if we retain only this term, the probability is found to be $1/2P_+ P_+$. Surprise! The probability is the same as the congruent case of the pattern-masked condition. The reason is that, while the association between the prime word TREE and the "tree" meaning of PALM produces probability enhancement [P_+], the coherent superposition of PALM is not collapsed and the "hand" meaning of PALM is also perceived. The probability of recognizing WRIST is facilitated by its association with the "hand" meaning of PALM [P_+]. More interestingly, because PALM is perceived as a coherent superposition and not collapsed until the conscious perception of WRIST, the effect of the incongruent intermediate state, the "tree" meaning of PALM, is not perceived as a competing association.

This difference is quite striking when compared with that predicted by the PDP–D/Posner model. The primary feature distinguishing the quantum from the Posner model is the removal, in the quantum model, of any prior associative effect through the activation of the intermediate state which, under unconscious conditions, is a coherent superposition in the Marcel-type experiment.

A New Line of Proposed Experiments

The use of a pattern-masked polysemous word in a Marcel-type measurement is analogous to passing a photon beam through a double slit arrangement. We can accentuate quantum effects by using two consecutive double slits. The analog is the use of two pattern-masked polysemous words. The following experiment is proposed in an effort to accentuate the distinctions between the association effect hypothesized by the Posner model and the coherent superposition hypothesized by the quantum model.

The experiments proposed below are essentially an extended replication of the Marcel study in terms of procedures, apparati, and subjects. The four cases of the Marcel study are reconstructed using two polysemous words NOVEL and VOLUME along with congruent and incongruent priming words and comparing probabilities (and hence response times, which are reduced when probabilities are enhanced) for recognition of a target word in both unmasked and pattern-masked conditions. The primary distinguishing feature is the sequential presentation of two pattern-masked polysemous words, as opposed to one.

Comparative Predictions of the Posner and Quantum Models

Posner Model

For the unmasked case, no new insight is expected since the serial model and the quantum model give virtually the same predictions in that the probability for the congruent case is much enhanced whereas it is inhibited for the incongruent case. However, the distinction between the models is amplified for the pattern-masked condition.

Consider the pattern-masked, congruent case THESAURUS–NOVEL–VOLUME–DICTIONARY. According to the Posner model (PDP–D mode), the probability receives facilitation from six positive associations: (a) THESAURUS and the "book" meaning of NOVEL; (b) the "book" meanings of the first and second polysemous words, NOVEL and VOLUME; (c) the "book" meaning of VOLUME and the target word DICTIONARY; (d) THESAURUS and the "book" meaning of VOLUME; (e) THESAURUS and the target word DICTIONARY; and (f) the "book" meaning of the first polysemous word NOVEL and the target word DICTIONARY [P_{++++++}]. The response time for the target word DICTIONARY is reduced as a result of the multiple associations among THESAURUS, NOVEL, and VOLUME.

For the incongruent pattern-masked case INCH–SPACE–VOLUME–DICTIONARY, while there is one positive association (the book meaning of volume and dictionary), the probability for recognizing the target word DICTIONARY receives inhibition from three sources of competing association (inch, space, and the "dimension" meaning of volume); hence the probability is [P_{---+}], which requires additional processing time.

Quantum Model

Consider the congruent pattern-masked condition THESAURUS–NOVEL–VOLUME–DICTIONARY. Let's discuss only the major contributing term for the probability. Since the polysemous word NOVEL is perceived unconsciously, its coherent superposition state is not collapsed and both meanings of NOVEL, those of "new" and "book," are perceived. This results in an enhancement in probability due to the overlap between the "book" meaning of NOVEL and the prime word THESAURUS [P_+]. The second polysemous word VOLUME is also perceived as a coherent superposition and both the "dimension" and "book" meanings of VOLUME are perceived [P_+]. However, because each coherent superposition state removes any previous association, the recognition of the "book" meaning of VOLUME does not receive any facilitation from the association between the prime word THESAURUS and the "book" meaning of NOVEL. The probability of recognizing the target word DICTIONARY is enhanced due to its overlap in meaning with the "book" meaning of VOLUME [P_+]. The total probability is of the order of $P_+ P_+ P_+$.

The prediction for the pattern-masked incongruent case is the same as for the pattern-masked congruent case. Again, we will discuss only the major term contributing to the probability. Because the polysemous word SPACE is perceived unconsciously, the coherent superposition is not collapsed and both meanings of SPACE are perceived, resulting in an enhancement in probability [P_+]. The second coherent superposition is activated due to the overlap in meaning between the "dimension" meanings of SPACE and VOLUME [P_+]. However, as in the congruent pattern-masked condition, while the probability of recognizing the target word DICTIONARY is enhanced due to its associative overlap with the "book" meaning of the coherent superposition state of VOLUME [P+], the response time does not receive any inhibition from the associations between the "dimension" meanings of INCH, SPACE, and VOLUME because the activation of each coherent superposition removes any history effects. Again, the total probability is of the order of $P_+ P_+ P_+$.

To summarize, here lies the important distinction between the Posner and quantum models when we compare the pattern-masked congruent and incongruent recognition times of word strings containing single polysemous and two polysemous words. For the Posner model, the pattern-masked incongruent case probabilities seem to be even more inhibited (response time is significantly increased) relative to the congruent case, while the quantum model's relative probabilities remain the same.

Quantum Interference

Ambiguity implies a play of probabilities in the mind–brain; choice or selection is needed to end that play. Is the play of probabilities in the mind–brain classical or quantum? Can this question be answered with an objective experiment?

One difference between classical and quantum probabilities is still to be tested. In quantum mechanics, the probability amplitudes are added algebraically before squaring to find the net probability, and this produces, as in the passage of electrons through a double-slit arrangement, the interference phenomenon. However, in all the above cases, we have not had any occasion of true interference, which occurs only when there are two competing paths. The difference of quantum and classical probabilities, roughly speaking, is the difference of $(a \pm b)^2$ and $a^2 + b^2$; but the difference is enhanced only if a and b are of similar magnitude.

In the last section, we presented the cases of two pattern-masked ambiguous words of overlapping meaning for the congruent case but of no overlap in meaning for the incongruent case. And the probability predictions, as we saw, were roughly the same for both cases. If these words, instead of being presented consecutively, are presented simultaneously to the subjects, we have created a scenario of competing pathways. This is the true analog of the double slit experiment. And now the probabilities of the congruent and incongruent cases must be widely different because of interference.

Let's demonstrate this explicitly. Consider the string THESAURUS→(NOVEL AND VOLUME)→DICTIONARY. The quantum probability is given as

$$1/2[<\mathrm{DICTIONARY} \mid \mathrm{NOVEL}><\mathrm{NOVEL} \mid \mathrm{THESAURUS}> \pm \\ <\mathrm{DICTIONARY} \mid \mathrm{VOLUME}><\mathrm{VOLUME} \mid \mathrm{THESAURUS}>]^2$$

But now both of the contributing terms of the sum in the bracket are just about equal; therefore, the total probability will either be enhanced to be four times the original, or if the amplitudes perchance add with a minus sign, the two terms may cancel each other out. In contrast, for the incongruent word string INCH→(SPACE and VOLUME)→DICTIONARY, there is no such interference. The probability is

$$1/2\ [<\mathrm{DICTIONARY} \mid \mathrm{SPACE}><\mathrm{SPACE} \mid \mathrm{INCH}>\pm \\ <\mathrm{DICTIONARY} \mid \mathrm{VOLUME}><\mathrm{VOLUME} \mid \mathrm{INCH}>]^2$$

But the first term of the sum in the bracket is expected to be much smaller than the second and, therefore, there is no significant interference. It follows that in the case of simultaneous presentation the probabilities predicted by the quantum model are vastly different for the congruent and incongruent cases; in fact, if the terms add with a plus sign, the predictions are quite similar to those of the Posner model.

Notice that the Posner model looks upon this case of simultaneous unconscious showing of ambiguous words no differently than consecutive showing; the word associations are the same, and therefore the probabilities. In this way, we can see that perhaps the best way to discern between the Posner and the quantum models is to verify whether the reaction times change significantly between consecutive and simultaneous showings of two ambiguous pattern-masked words.

Conclusions

It has been shown through an analysis of word-sense disambiguation data that the quantum model provides an explanation of the difference between conscious and unconscious perception without the postulate of a central processing unit. The quantum model postulates that an ambiguous word gives rise to a state of coherent superposition in the mind–brain which is collapsed only in the case of conscious perception when awareness is present. The quantum model gives a better quantitative explanation of the Marcel data on word-sense disambiguation with pattern-masking than the cognitive model of Posner. An experiment with two polysemous words is proposed which provides even further quantitative distinction between the two models.

Specifically, the quantum model's prediction of recognition times is the same for pattern-masked congruent and incongruent word strings for both one and two polysemous intermediate words. In contrast, the predictions of the Posner model are different between the congruent and incongruent cases, and the difference is amplified from the case of one to the case of two polysemous words.

For simultaneous unconscious perception of two polysemous words, however, quantum interference leads to a model prediction that may be much the same as the Posner model, however. We conclude that the best way to discern between the two models would be to conduct both sequential and simultaneous unconscious perception experiments with two polysemous words and compare the data. According to the quantum model there may be a significant difference between sequential and simultaneous two polysemous word string experiments, but in the Posner model there is none. If the predictions of the quantum model prove accurate, a new understanding of consciousness will have been gained without the postulation of a central processing unit in the mind–brain. The success of the quantum interference experiment in the mind–brain will also help establish the mind–brain as a new and exciting arena for quantum processes.

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